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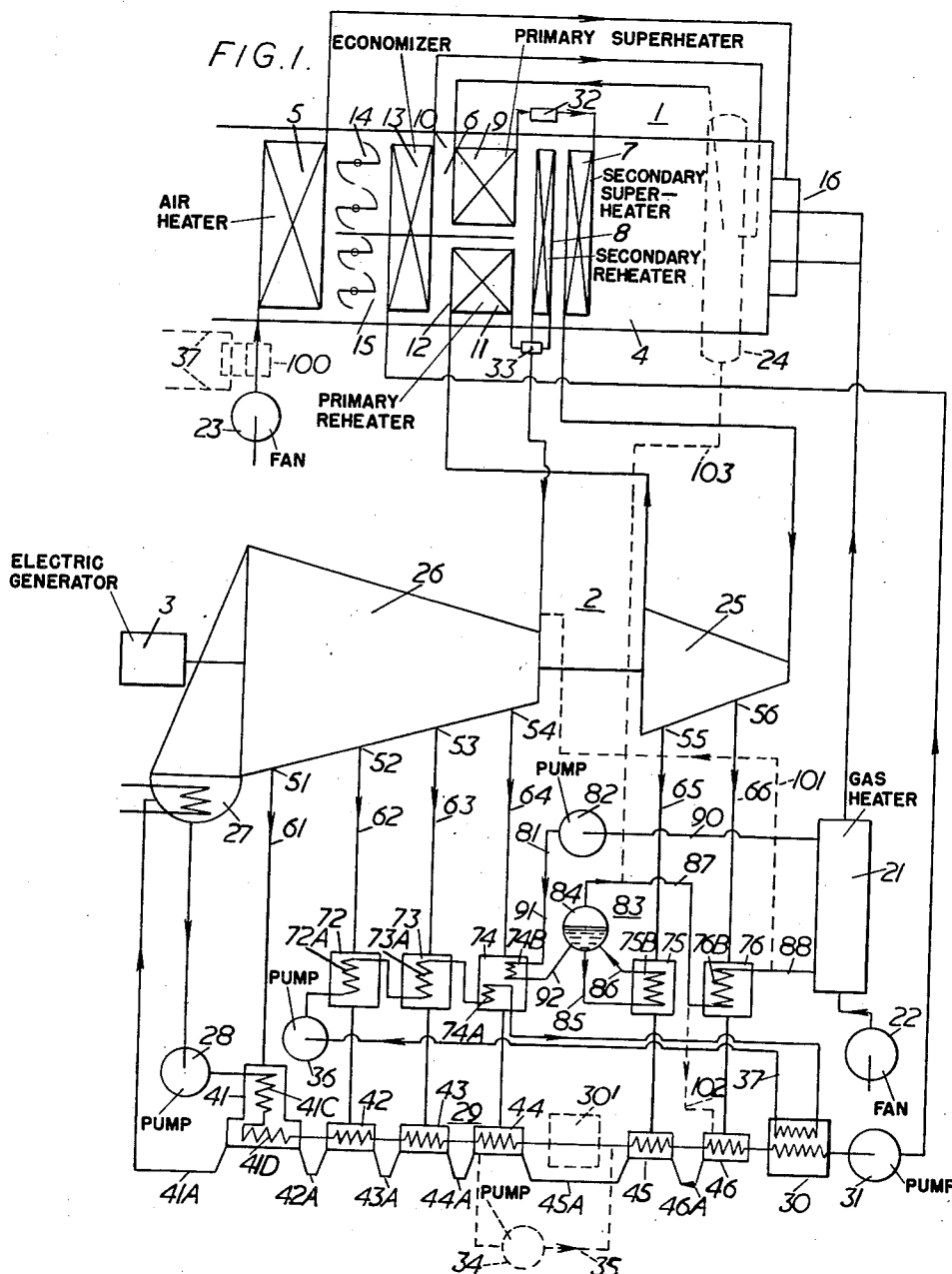
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STEAM TURBINE POWER PLANT

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2 Sheets-Sheet 1



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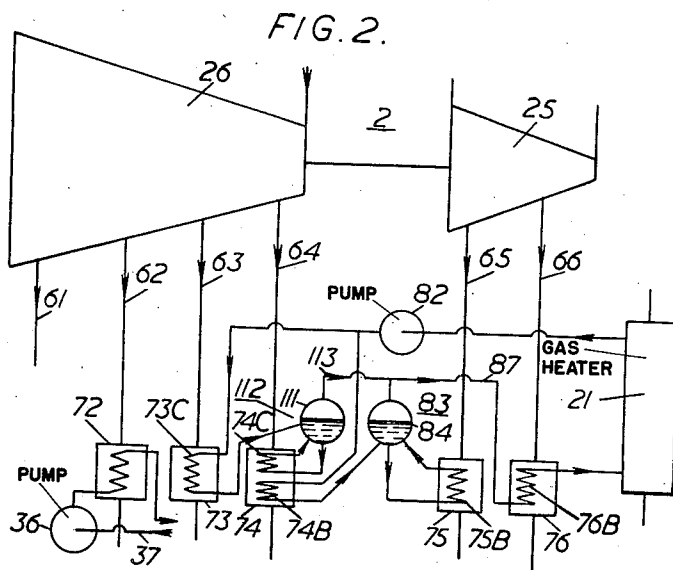
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1

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STEAM TURBINE POWER PLANT

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8 Claims. (Cl. 60-67)

This invention relates to steam turbine power plant. In steam turbine power plant having a turbine arranged to receive superheated steam, it is known to provide for the bleeding of steam at one or more stages in the turbine and for the passage of the bled steam to feed heating means in which the bled steam is condensed, in order thereby to secure, primarily by virtue of the fact that the latent heat of the bled steam is not rejected with the cooling water of the turbine condenser, an improvement in the thermodynamic efficiency of the Rankine cycle applicable to the system.

It has been observed that since the feed water to be heated in this expedient by a flow of bled steam must be at a temperature sufficiently low to condense the steam while the bled steam leaving the turbine has on the other hand a degree of superheat, which may be substantial, there is necessarily involved an element of irreversibility in the thermodynamic cycle, i.e., an element of degradation of heat which prima facie, represents an impairment of the efficiency of the conversion of heat to work. The object of the present invention is to provide means adapted for an improved exploitation of the heat in bled steam.

The present invention includes steam turbine power plant having a turbine arranged to receive superheated steam and to operate with the condensation of bled steam in feed heating means, wherein connected in a bleed line between the turbine and the feed heating means is a heat exchanger and means are provided for passing a heat transfer fluid therethrough and conveying to a point of use for relatively high grade heat withdrawn from superheated steam in the bleed line.

The invention will now be described by way of example with reference to the accompanying schematic drawings, in which

FIGURE 1 shows the interconnections of the constituents of an electric power generating installation including a steam turbine power plant, and

FIGURE 2 shows a modification of the steam turbine power plant shown in FIGURE 1.

Referring to FIGURE 1 of the drawings, an electric power generating installation comprises a steam generating superheating and reheating unit 1, a steam turbine power plant 2 arranged to receive steam from the unit 1 and an electric generator 3 driven by the power plant 2.

The unit 1 is a natural circulation boiler of known type comprising a water-cooled furnace 4 the combustion gases from which, before flowing through a combustion air heater 5, give up most of their heat in a working fluid convection section 6. In the convection section 6 the gases flow through a secondary superheater 7 and then through a secondary reheater 8. Subsequent to the secondary reheater 8 the convection section 6 is divided to form two parallel gas paths; a primary superheater 9 is disposed in one of the parallel gas paths, denoted by the reference numeral 10, while a primary reheater 11 is disposed in the other parallel gas path, denoted by the reference numeral 12. An economizer 13 extends across both the gas paths 10 and 12 at a location subsequent to the primary superheater 9 and the primary reheater 11. Dampers 14 and 15 are provided at the end of the convection section 6 for the control of the gases in the respective paths 10 and 12. The furnace 4 is arranged to be fired by the combustion of natural gas discharged by

2

burner apparatus 16; the natural gas is delivered to the burner apparatus 16 through a gas heater 21 by a fan 22 and combustion air is delivered to the burner apparatus 16 through the air heater 5 by a fan 23. The steam and water drum of the boiler unit 1 is denoted by the reference numeral 24.

The steam turbine power plant 2 comprises a turbine consisting of a group of high pressure stages in a casing 25 and a group of low pressure stages in a casing 26. The high-pressure casing 25 is connected to receive steam from the secondary superheater 7 and to pass partly expanded steam to the primary reheater 11; the low-pressure casing 26 is connected to receive steam from the secondary reheater 8 and to pass fully expanded steam to the usual condenser 27. The condensate is withdrawn from the condenser 27 by an extraction pump 28 and passed through a feed train 29 of heat exchangers and through a heat exchanger 30 at the end of said feed train to a feed pump 31; the feed pump 31 returns the water to the economizer 13 of the boiler unit 1. The main flow circuit of the working fluid, for which the necessary connections are provided in the boiler unit, is from the steam space of the boiler drum 24 through the primary superheater 9, a spray-type atomizer 32, the secondary superheater 7, the high-pressure turbine stages in the casing 25, the primary reheater 11, a spray-type atomizer 33, the secondary reheater 8, the low-pressure turbine stages in the casing 26, the condenser 27, the extraction pump 28, the feed train 29, the heat exchanger 30, the feed pump 31, the economizer 13, and to the water space of the boiler drum 24 and includes flow under the influence of natural circulation through the furnace wall tubes which are associated with the drum.

The feed train 29 consists of first to sixth heat exchangers 41 to 46 through which the feed water passes in succession which heat exchangers receive heat from steam passing thereto in respective first to sixth bleed lines 61 to 66 from respective first to sixth bleed points 51 to 56 provided on the turbine casings. The lower pressure turbine casing 26 is provided with the first to fourth bleed points 51 to 54, and the steam flows entering the respective bleed lines 61 to 64 are at successively higher temperatures. The high pressure turbine casing 25 is provided with the fifth and sixth bleed points 55 and 56, and the steam flow entering the bleed line 66 is at a higher temperature than the steam flow entering the bleed line 65. It is assumed, moreover, that the steam flow entering the bleed line 65 is at a higher temperature than that entering the bleed line 64. The steam flows entering the bleed lines 61 to 66 are at successively higher pressures.

The steam flows which enter the heat exchangers 41 to 46 from the bleed lines 61 to 66 are condensed therein. A connection 46A is provided between the interiors of the sixth and fifth heat exchangers 46 and 45, through which condensate flows from the interior of the sixth heat exchanger 46 to the interior of the heat exchanger 45 under the influence of the pressure difference therebetween. A connection 45A is provided between the interiors of the fifth and fourth heat exchangers 45 and 44, through which the condensate of the fifth heat exchanger 45 together with the condensate of the sixth heat exchanger 46 received through the connection 46A flows to the interior of the fourth heat exchanger 44, similarly under the influence of pressure difference. Similarly, a connection 44A leads from heat exchanger 44 to heat exchanger 43, a connection 43 from heat exchanger 43 to heat exchanger 42, and a connection 42A from heat exchanger 42 to heat exchanger 41; a connection 41A is provided between the interior of the heat exchanger 41 and the condenser 27. By virtue of the connections 41A to 46A all the condensates of the heat exchangers 41 to 46 are added to the condenser water. In a modification,

3

while the other connections 41A, 42A, 43A, 45A and 46 remain the same, the connection 44A between the heat exchangers 43 and 44 is no longer provided, but instead, as indicated in dotted lines, the condensates of the heat exchangers 46, 45 and 44 are withdrawn from the interior of the heat exchanger 44 by a pump 34 in a line 35 and added to the feed water at a point in the feed water flow between the heat exchangers 44 and 45.

The first heat exchanger 41 is of a kind in which in a desuperheating zone therein the surface 41C first contacted by the steam led from the bleed point 51 in the bleed line 61 are adapted for receiving heat from the steam while it is cooled from its original temperature to a temperature equal to or only slightly greater than the saturation temperature corresponding to its pressure, while in a condensing zone therein the surfaces 41D subsequently contacted by the steam are adapted for the condensation of the steam. In the remaining heat exchangers 42 to 46 the surfaces are all adapted for the condensation of steam, and in the bleed lines 62 to 66 respective desuperheaters 72 to 76 are interposed between the bleed points 52 to 56 and the heat exchangers 42 to 46.

The desuperheater 72 contains heat exchange surfaces 72A, the desuperheater 73 heat exchange surfaces 73A and the desuperheater 74 heat exchange surfaces 74A which are connected in series; a pump 36 is arranged for the delivery of water at desired rate to the heat exchange surface 72A in a closed circuit 37 which leads from the pump 36 through the surfaces 72A, 73A and 74A, then through the heat exchanger 30 previously referred to, in which heat transferred in the desuperheaters 72, 73A and 74A to the water of the closed circuit 37 is transferred to the feed water, and then back to the pump 36.

The desuperheater 74 contains in addition to the heat exchange surfaces 74A heat exchange surfaces 74B which are connected in a further closed circuit 81 around which fluid is arranged to be circulated by a pump 82. The closed circuit 81 includes the elements of a natural circulation boiler 83, the heat exchange surfaces 74B providing the economizer element of the boiler. The surfaces 74B may provide a steaming economizer for the boiler 83. The desuperheater 75 contains heat exchange surfaces 75B which form the steam generating element of the boiler, and the surfaces 75B are arranged to receive water from the steam and water drum 84 through a connection 85 and to deliver steam and water mixture to the drum through a connection 86. The desuperheater 76 contains heat exchange surfaces 76B which form the superheater element of the boiler, and the surfaces 76B are arranged to receive steam from the boiler drum through a connection 87. The steam generated and superheated in the boiler 83 is led through a connection 88 to the gas heater 21 in which it is cooled and condensed in yielding heat to the natural gas to be burnt in the furnace 4; the condensate is withdrawn from the gas heater 21 through a connection 90 by the pump 82; the outlet of the pump 82 is joined by a connection 91 to the heat exchange surfaces 74B and a connection 92 leads from the heat exchange surfaces 74B to the boiler drum 84. The pump 82 will be operated at the rate necessary to maintain a constant water level in the drum 84. The rate of heat absorption in the boiler 83 is variable by adjusting by suitable means the pressure at which vapour is generated therein.

In the operation of the installation, steam is generated and superheated in the boiler unit 1, expanded in the high-pressure turbine casing 25, reheated in the boiler unit, expanded in the low-pressure turbine casing 26, and condensed in the condenser 27; the condensate is heated in the feed train 29, in the heat exchanger 30, and in the economizer 13 of the boiler unit. Fractional amounts of the steam generated in the boiler unit 1 flow only part of the way through the two turbine stages and leave the turbine casings at the various bleed points 51 to 56 to flow through the respective bleed lines 61

4

to 66; the latent heats of these amounts of steam are transferred to the feed water in the feed train 29. Therefore not all the steam entering the high-pressure turbine stage undergoes full turbine expansion to produce power at the turbine shaft. On the other hand, the latent heats of the bled amounts of steam are conserved in the system instead of being lost to the cooling water of the condenser and this fact is important for the thermodynamic efficiency of the system; moreover, the superheats in the steam in the bleed lines 62 to 66 are advantageously utilized.

Thus the initial and saturation temperatures of the steam in the bleed line 63 are higher respectively than the initial and saturation temperatures of the steam in the bleed line 62 and correspondingly the water in the closed circuit 37 enters the desuperheater 73 in the bleed line 63 at a higher temperature than that at which it enters the desuperheater 72 in the bleed line 62; similarly the initial and saturation temperatures of the steam in the bleed line 64 are higher respectively than the initial and saturation temperatures in the bleed line 63 and correspondingly the water in the closed circuit 37 enters the heat exchange surfaces 74A in the desuperheater 74 at a higher temperature than that at which it enters the desuperheater 73. The water in the closed circuit 37 leaving the desuperheater 74 at a relatively high temperature transfers heat in the heat exchanger 30 to feed water which has been raised considerably above the condenser temperature by the heat transferred thereto in the feed train 29.

Similarly, the initial and saturation temperatures of the steam in the bleed line 66 are higher respectively than those of the steam in the bleed line 65 which again are higher respectively than those of the steam in the bleed line 64; correspondingly, the average temperature of the steam undergoing heating in the heat exchange surfaces 76B acting as superheater is higher than the temperature of the steam and water mixture within the heat exchange surfaces 75B, which again is higher than the average temperature of the water within the heat exchange surfaces 74B acting as economizer.

If the amount of reheating and the positions of the bleed points 54 and 55 are such that the initial temperature of the steam entering the bleed line 64 is higher than the initial temperature of the steam entering the bleed line 65 it will be appropriate to change the connections of the boiler 83 so that steam is generated in natural circulation in the heat exchange surfaces 74B in the desuperheater 74 while the heat exchange surfaces 75B in the desuperheater 75 act as the economizer.

A number of modifications, additional to those already indicated, of the installation described and shown will now be mentioned.

Thus some of the superheated steam produced by the boiler 83 may be used for purposes other than combustion gas heating, for example, for sootblowing in the boiler unit 1. The loss of working fluid in the circuit 81 of the boiler 83 is made up by withdrawing water from the outlet of the pump 28, the pump 31 or the pump 34 or from an independent source.

All the superheated steam produced by the boiler 83 may be used for purposes other than combustion gas heating, for example, it may be expanded in the turbine, as indicated for instance by the connection 101 leading from the outlet of the heat exchange surfaces 76B to the inlet to the low-pressure turbine casing 26. The whole of the feed water for the boiler 83 is arranged in these cases to come from the pump 28, the pump 31 or the pump 34 or from an independent source. If the steam is used for a purpose in which it is retained in the main working fluid system, the feed water for the boiler 83 should come from one of the said pumps, preferably the pump 34, while if the steam is used for any purpose in which it is not recovered, the feed water should come

from an independent source if husbanding of the main working fluid is important.

The saturated steam led from the drum 84 of the boiler 83 through the connection 87 may, as indicated by the connection 102, be conveyed not to the desuperheater 76 but to the heat exchanger 46 in the feed train 29; alternatively, it may, as indicated by the connection 103, be led into the steam and water drum 24 of the boiler unit 1. If the furnace 4 is fired with steam-atomized oil burners instead of natural gas burners, some of the saturated steam may be used for the operation of such oil burners. As before, the feed water for the boiler 83 is arranged in these cases to come from the pump 23, the pump 31 or the pump 34 or from an independent source; the heat extracted from steam in the desuperheater 76 may be used for some appropriate purpose with the aid of an intermediate heat transfer fluid, for example, a mixture of diphenyl and diphenyl oxide, caused to circulate in a closed circuit.

If the described location along the feed water flow path of the heat exchanger 30 is unsuitable because the maximum temperature of the water in the closed circuit 37 is too low, the heat exchanger 30 may be inserted in the feed water flow path at a more appropriate location, for example, as indicated at 30', between the heat exchangers 44 and 45 in the feed train 29. The heat exchanger 30 may be of any suitable construction, for example, it may consist of tubes, through which flows one of the two fluids involved in heat exchange, positioned within a shell through which the other of the fluids flows.

The water of the closed circuit 37, instead of flowing through a heat exchanger 30 in the feed water flow path, may flow through an air heater 100, adapted to heat the combustion air for the furnace 4 between the fan 23 and the air heater 5.

In variants of the turbine power plant there may be more than one turbine bleed line handling steam at higher pressure and temperature than the steam in the bleed line 65, and in such cases the steam from the drum 84 of the boiler 83 may be passed in succession through desuperheaters in the respective bleed lines traversed by steam at successively increased pressure and temperature.

More than one desuperheater may be placed in a bleed line, the arrangement being adapted to withdraw the superheat from the bleed steam in a plurality of successive stages and to transfer it at successively lower temperatures to intermediate fluid flows through the various desuperheaters. In one such arrangement the respective elements (economizer element, vapour generating element and superheater element) of a further boiler are housed in further desuperheaters in the respective bleed lines 64, 65 and 66, that boiler the elements of which are accommodated upstream (as regards the bleed steam flows) of the corresponding elements of the other boiler being arranged to deliver superheated steam at higher pressure and temperature than the said other boiler.

The elements of a boiler heated by bled steam may comprise heat exchange surfaces in a set of bleed lines different from the set of bleed lines in which lie the heat exchange surfaces constituting the elements of a further boiler heated by bled steam; the two sets may have a bleed line or some bleed lines in common, and the two boilers may operate at the same pressure. Referring for an example of such a modification to FIGURE 2, in which part only of the steam turbine power plant of FIGURE 1 is reproduced and which shows the addition of a further bled steam heated boiler, the boiler 83, as in FIGURE 1, includes heat exchange surfaces 74B in a desuperheater 74 in the bleed line 64, which surfaces form an economizer and are connected at their inlet to the pump 82 and at their outlet to the steam and water drum 84 of the boiler 83; the steam and water drum 84 is connected to the inlet and to the outlet of the natural circulation heat exchange surfaces 75B in the desuper-

heater 75 in the bleed line 65; steam from the steam and water drum 83 passes in connection 87 to the heat exchange surfaces 76B acting as superheater in the desuperheater 76 in the bleed line 66. The desuperheater 74 houses, upstream of the heat exchange surfaces 74B, heat exchange surfaces 74C which form natural circulation vapour generating surfaces, connected to a further steam and water drum 111, of a further boiler 112. The drum 111 is arranged to be supplied by the pump 82 through heat exchange surfaces 73C in the desuperheater 73 in the bleed line 63. Steam from the steam and water drum 111 of the boiler 112 passes in connection 113 to the connection 87 and in common with the steam from the drum 74 is superheated in the heat exchange surfaces 76B. The closed water circuit 37 in the modification of FIGURE 2 picks up heat only in the desuperheater 72.

Generally speaking, any of numerous constructions of indirect heat exchangers will be suitable for the desuperheaters 72 to 76 of FIGURES 1 and 2. It is specifically envisaged, however, that they may comprise more or less elongated pressure vessels as indicated in the drawings of patent application Serial No. 806,846, now Patent No. 2,945,309, containing helical coils where water is to be heated, as in the lower part of FIGURE 1 and the outer part of FIGURE 5 of those drawings and containing an assembly of vapour generating units where steam is to be formed, as in the upper part of FIGURE 1 and the inner part of FIGURE 5 of those drawings.

I claim:

1. In a steam turbine power plant of the kind in which superheated steam from a steam generator is expanded through a steam turbine and feed water for the steam generator is heated in a plurality of exchangers arranged for the condensation of steam led thereto in steam bleed lines from steam turbine bleed points, a boiler having steam generating surfaces and steam superheating surfaces arranged in the steam bleed lines and means for conducting to a stage of the turbine superheated steam generated in said boiler.

2. In a steam turbine power plant of the kind in which superheated steam from a steam generator is expanded through a steam turbine and feed water for the steam generator is heated in two steam condensing heat exchangers arranged for the condensation of steam led thereto in respective steam bleed lines from respective steam turbine bleed points of different temperatures, steam desuperheating heat exchangers connected in the respective steam bleed lines, means for supplying water to the steam desuperheating heat exchanger in the steam bleed line connected to the steam turbine bleed point of the lower temperature and thereby generating steam from said water, means for conducting said steam so generated to the steam desuperheating heat exchanger in the steam bleed line connected to the steam turbine bleed point of the higher temperature and thereby superheating the steam, and means for conducting said steam so superheated to a stage of the turbine.

3. In a steam turbine power plant of the kind in which superheated steam from a steam generator is expanded through a steam turbine and feed water for the steam generator is heated in two steam condensing heat exchangers arranged for the condensation of steam led thereto in respective steam bleed lines from respective steam turbine bleed points of different temperatures, steam desuperheating heat exchangers connected in the respective steam bleed lines, a boiler drum, steam and water mixture connecting means to the drum from the steam desuperheating heat exchanger in the steam bleed line connected to the steam bleed point of the lower temperature, water connecting means from the liquid space of the drum to the steam desuperheating heat exchanger in the steam bleed line connected to the steam bleed point of the lower temperature, means for supplying water to the drum, means for conducting steam from the vapour space of the drum to the steam desuperheating heat ex-

changer in the steam bleed line connected to the steam bleed point of the higher temperature and means for conducting to a stage of the turbine superheated steam from the steam desuperheating exchanger in the steam bleed line connected to the steam bleed point of the higher temperature.

4. In a steam turbine power plant as claimed in claim 3 and in which the feed water is also heated in a third steam condensing heat exchanger arranged for the condensation of steam led thereto in a steam bleed line from a third steam turbine bleed point of lower temperature than either of the mentioned steam turbine bleed point, a steam desuperheating heat exchanger in the steam bleed line from the third steam turbine bleed point and means for supplying water to the drum through said last-mentioned steam desuperheating heat exchanger.

5. In a steam turbine power plant of the kind in which superheated steam from a steam generator heated by the combustion of fuel gas is expanded through a steam turbine and feed water for the steam generator is heated in a steam condensing heat exchanger arranged for the condensation of steam led thereto in a steam bleed line from a steam turbine bleed point, a steam desuperheating heat exchanger connected in the steam bleed line, a gas heater for the fuel gas for the steam generator and means for circulating heat transfer fluid in a closed circuit which includes the steam desuperheating heat exchanger and the said gas heater.

6. In a steam turbine power plant of the kind in which superheated steam from a steam generator heated by the combustion of fuel gas is expanded through a steam turbine and feed water for the steam generator is heated in two steam condensing heat exchangers arranged for the condensation of steam led thereto in respective steam bleed lines from respective steam turbine bleed points, of different temperatures, steam desuperheating heat exchangers connected in the respective steam bleed lines, a gas heater for the fuel gas for the steam generator and a closed circuit for aqueous fluid including means for supplying water to the steam desuperheating heat exchanger in the steam bleed line connected to the steam turbine bleed point of the lower temperature and thereby generating steam from said water, means for conducting said steam so generated to the steam desuperheating heat exchanger in the steam bleed line connected to the steam bleed point of the higher temperature and thereby superheating the steam, means for conducting said steam

so superheated to the gas heater for heating the fuel gas for the steam generator and means for withdrawing condensed water from the said gas heater.

7. In a steam turbine power plant of the kind in which superheated steam from a steam generator heated by the combustion of fuel gas is expanded through a steam turbine and feed water for the steam generator is heated in two steam condensing heat exchangers arranged for the condensation of steam led thereto in respective steam bleed lines from respective steam turbine points of different temperatures, steam desuperheating heat exchangers connected in the respective steam bleed lines, a gas heater for the fuel gas for the steam generator, a boiler drum, steam and water mixture connecting means to the drum from the steam desuperheating heat exchanger in the steam bleed line connected to the steam bleed point of the lower temperature, water connecting means from the liquid space of the drum to the steam desuperheating heat exchanger in the steam bleed connected to the steam bleed point of the lower temperature and a closed circuit for aqueous fluid including means for supplying water to the drum, means for conducting steam from the vapour space of the drum to the steam desuperheating heat exchanger in the steam bleed line connected to the steam bleed point of the higher temperature and thereby superheating the steam, means for conducting said steam so superheated to the gas heater for heating the fuel gas for the steam generator and means for withdrawing condensed water from the said gas heater.

8. In a steam turbine power plant as claimed in claim 7 and in which the feed water is also heated in a third steam condensing heat exchanger arranged for the condensation of steam led thereto in a steam bleed line from a third steam turbine bleed point of lower temperature than either of the mentioned steam turbine bleed points, a steam desuperheating heat exchanger in the steam bleed line from the correct steam turbine bleed point and arranged in the aqueous fluid circuit between the gas heater for the fuel gas and boiler drum.

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