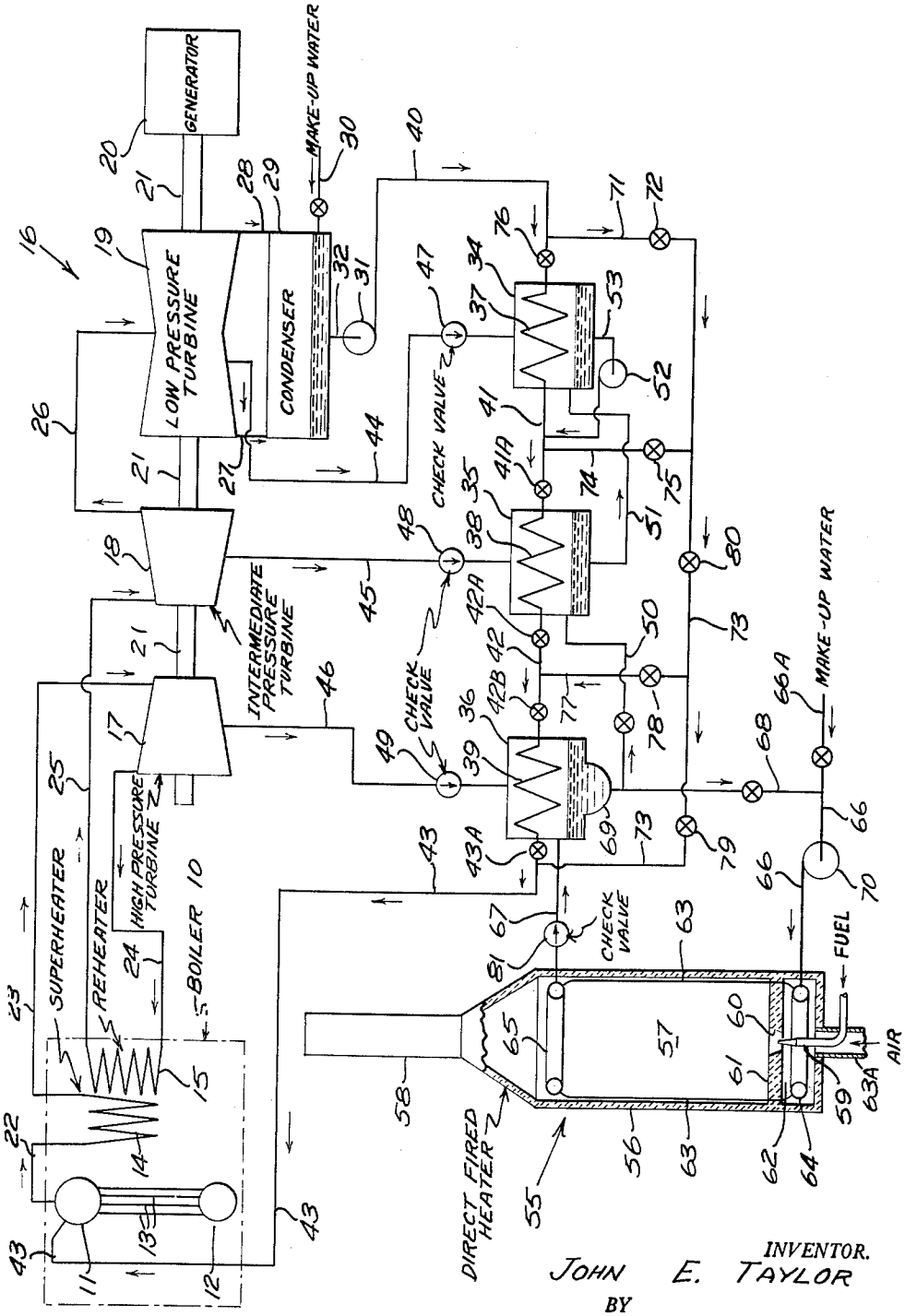
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METHOD AND APPARATUS FOR PREHEATING BOILER FEED WATER FOR STEAM POWER PLANTS

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METHOD AND APPARATUS FOR PREHEATING BOILER FEED WATER FOR STEAM POWER PLANTS

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This invention relates to steam power plants and, more particularly, pertains to apparatus for and method of heating feed water for the steam generating apparatus and increasing the output of the turbines of a steam power plant.

In conventional steam power plants, it is desirable to preheat the feed water to a predetermined temperature value before it enters the steam generating apparatus or boiler to provide for increased thermal efficiency of the power plant and the elimination of thermal shocks to the steam generating apparatus to which the latter would be subjected with the entry therein of relatively cold feed water. Feed water is usually preheated in steam power plants by serially flowing feed water through a plurality of heat exchangers, hereinafter referred to as feedwater heaters, and in indirect heat exchange relationship, in each of the feedwater heaters, with steam extracted from the steam turbines of the power plant. In the operation of many steam power plants at load conditions on the steam power plant above normal load conditions, one or more high pressure feedwater heaters are removed from service by bypassing feedwater around the feedwater heater or heaters or by closing off flow of extraction steam from the turbines to the feedwater heater or heaters. While this operating technique has the effect of increasing turbine capability by eliminating flow of extraction steam from the turbine so that more steam is utilized to drive the turbine, the feedwater is not heated to the desired predetermined temperature value. The failure to heat the feed water to the desired predetermined temperature value before the water flows into the boiler, results in decreased thermal efficiency and subjects the boiler to undesirable thermal shocks during load conditions on the power plant above normal load conditions. In view of the foregoing, the boilers of the power plants are sometimes designed to maintain a predetermined final steam temperature output when one or more high pressure feedwater heaters are removed from service. This is accomplished by incorporating in the boilers extra large fans, burners and steam temperature control apparatuses which increases the initial boiler cost.

Accordingly, it is an object of this invention to provide, in a steam power plant, apparatus for and method of increasing turbine output under above normal load conditions on the power plant and at the same time maintain feed water at the desired predetermined temperature value.

It is another object of the present invention to provide, in a steam power plant an apparatus for and method by which feed water is heated to a predetermined temperature value under all normal and above normal load conditions on the power plant while simultaneously providing for increased turbine output which apparatus for and method of preheating feed water eliminates the need for oversized fans, burners and/or steam temperature control apparatuses in the boiler of the power plant.

It is therefore contemplated by the present invention to provide, in a steam power plant, a novel method of and apparatus for preheating feed water which comprises a plurality of feedwater heaters arranged to receive feed water and steam from the steam turbines and pass the feed water and steam in indirect heat exchange relationship with each other to thereby heat the feed water to a predetermined temperature value under normal load conditions on the steam power plant, and steam generating means independent of the steam generating apparatus or boiler of the steam power plant, arranged to pass steam to at least one of the feedwater heaters, or to a heat exchanger disposed in the feed water line which is not connected to the turbines to receive extraction steam, to preheat the feed water to the predetermined temperature value only under above normal load conditions on the steam power plant. The invention also provides by-pass means for causing the feed water under above normal load conditions on the steam power plant to by-pass one or more feedwater heaters, except the feedwater heater or the heater exchanger which receives steam from said independent steam generating means so that little or no steam is bled from the turbines to the by-passed feedwater heaters and turbine output is increased.

The invention will be more fully understood from the following description when considered in connection with the accompanying drawing.

Referring to the drawing which diagrammatically illustrates a steam power plant having a feedwater heating system according to this invention, 10 designates a steam generating apparatus or boiler of the steam power plant. Boiler 10 may comprise, as schematically shown, a steam and water drum 11 and a water drum 12 which are interconnected by a bank of water tubes 13. The water tubes 13 receive water from the water space of drum 11 and conduct the water in indirect heat exchange relationship with products of combustion generated in the boiler by burners, not shown, to convert the water to saturated steam and conduct the saturated steam to the vapor space of the drum. The boiler 10 is also provided with a superheater unit 14 and a reheater unit 15, either of which units may be of the radiant, convection, or combination radiant and convection type. While superheater unit 14 and reheater unit 15 are shown as a part of boiler 10, they may be units separate and apart from the boiler without departing from the scope and spirit of this invention.

The steam power plant has a steam turbine-generator assembly 16 which comprises a high pressure turbine 17, an intermediate pressure turbine 18, a low pressure turbine 19, and an electric generator 20 which are suitably connected together by a drive shaft assembly 21 to drive electric generator 20. Although the turbines 17, 18 and 19 are shown and described as connected to a single drive shaft assembly 21, to drive a single electric generator, the turbines 17, 18 and 19 may each be connected to drive an electric generator without departing from the spirit and scope of the invention.

As shown, superheater unit 14, is connected by a line 22 to receive saturated steam from the vapor space of drum 11 and by a line 23 to high pressure turbine 17 to deliver superheated steam to the latter to drive the turbine. Reheater unit 15 is connected by a line 24 to high pressure turbine 17 to receive exhaust steam from the latter and is connected through a line 25 to intermediate pressure turbine 18 to deliver reheated steam to the latter to thereby drive turbine 18. A line 26 is connected at one end to intermediate pressure turbine 18 to receive exhaust steam from turbine 18 and at the opposite end to low pressure turbine 19 to deliver the steam to the latter whereby low pressure turbine 19 is driven. The exhaust steam from low pressure turbine 19 is conducted through lines 27 and 28 to a main condenser 29 wherein the steam is condensed. A valved line 30 is connected to deliver boiler make-up feed water to condenser 29 or some other suitable location. The con-

densate and make-up feed water, hereinafter referred to as feed water, is pumped from condenser 29 by way of a pump 31 and a line 32 and is heated and returned to drum 11 of boiler 10 by a feed water heating system of this invention, hereinafter fully described. In place of or in addition to pump 31, one or more pumps may be located between the feedwater heaters.

The feed water heating system comprises a plurality of feedwater heaters 34, 35 and 36 which are connected together to provide for series flow of feed water therethrough. Feedwater heaters 34, 35 and 36 may be of the shell and tube type feedwater heaters which are well known to those skilled in the art and in which feed water passes through a bank of tubes disposed in the shell. In feedwater heaters 34, 35 and 36 the bank of tubes through which the feedwater flows is shown, for illustration purposes only, as coils 37, 38 and 39, respectively. As shown, coil 37 of feedwater heater 34 is connected at one end to line 40 to receive feed water pumped by pump 31 from condenser 29, and at the opposite end is connected, through line 41, to coil 38 of feedwater heater 35 to conduct feed water to coil 38. A line 42 is connected at one end to coil 38 and at the opposite end to coil 39 of feedwater heater 36 to receive and conduct feed water from feedwater heater 35 to feedwater heater 36. A line 43 is connected at one end to coil 39 of feedwater heater 36 to receive heated feed water from the latter and at the opposite end is connected to drum 11 of boiler 10 to pass heated feed water into the water space of the drum.

Feedwater heaters 34, 35 and 36 are connected to the low pressure turbine 19, intermediate pressure turbine 18 and high pressure turbine 17, respectively, by bleed lines 44, 45 and 46, respectively. Bleed lines 44, 45 and 46 provide for flow of steam from the respective turbines to each of the feedwater heaters so that the feedwater flowing through coils 37, 38 and 39 is progressively heated by the steam in each of the feedwater heaters 34, 35 and 36. To insure against backflow of steam from feedwater heaters 34, 35 and 36 to turbines 19, 18 and 17, respectively, under certain operating conditions, bleed lines 44, 45 and 46 may be provided with check valves 47, 48 and 49, respectively, which only permit passage of steam into the feedwater heaters. The steam in each of the feedwater heaters 34, 35 and 36 passes around the respective coils 37, 38 and 39 and in indirect heat exchange relationship with the feed water flowing through each of the coils, whereby the feed water is heated and the steam condensed. Since feedwater heaters 34, 35 and 36 are connected respectively to low pressure turbine 19, intermediate pressure turbine 18, and high pressure turbine 17, the feedwater heaters are constructed to withstand the pressure of the steam delivered thereto by the respective bleed lines 44, 45 and 46. Accordingly, feedwater heaters 34, 35 and 36 will hereinafter be referred to respectively as low pressure, intermediate pressure, and high pressure feedwater heaters.

The condensed steam in high pressure feedwater heater 36 is removed therefrom and conducted to intermediate pressure feedwater heater 35 by way of a valved line 50 while the condensate in intermediate pressure feedwater heater 35 is conducted to low pressure feedwater heater 34 by way of a line 51. The steam condensate in low pressure feedwater heater 34 is pumped into admixture with the feed water by way of a pump 52 and a line 53 which is connected at one end to the low pressure feedwater heater and at the other end to line 41. Alternately, the steam condensate in low pressure feedwater heater 34 may be recirculated back into the feed water circuit by pumping the condensate into the reservoir of condenser 29.

To provide for heating the feed water to the predetermined temperature value under above normal load conditions on the power plant and also provide for increased turbine output upon removal of one or more feedwater heaters from service, there is provided in the feedwater heating system and independent of boiler 10, a steam generating apparatus 55 which may, as shown, be of the direct fired heater type, as is well known by those skilled in the art, and will hereinafter be referred to as a direct fired heater.

For purpose of illustration, the direct fired heater 55 is shown as comprising a cylindrical setting 56 defining a combustion chamber 57 which communicates at the top with a flue 58. A fuel burner 59 is disposed to fire fuel upwardly in combustion chamber 57 through a burner port 60 in a floor 61. A plenum chamber 62 is defined between the bottom of setting 56 and floor 61. An air duct 63A communicates at one end with plenum chamber 62 and at the other end with a suitable source of air (not shown) to thereby supply combustion air to plenum chamber 62 and, from the plenum chamber, to combustion chamber 57 through burner port 60. A plurality of steam generating tubes 63 (only two of which are shown) are disposed adjacent and parallel to the inner surface of setting 56. Tubes 63 are in communication at their lower ends with a circular inlet header 64 which is disposed in plenum chamber 62 and at their upper ends with a circular outlet header 65. Water is supplied to inlet header 64 through a feed pipe 66. The water in flowing upwardly through tubes 63 passes in indirect heat exchange relationship with the products of combustion in chamber 57 and is converted to steam which is collected in outlet header 65. Outlet header 65 is connected to high pressure feedwater heater 36 by an outlet pipe 67 so that the steam generated in tubes 63 is delivered to the high pressure feedwater heater 36 and into indirect heat exchange relationship with the feed water flowing through coil 39 to heat the feed water. The steam generated by direct fired heater 55 and delivered to feedwater heater 36 is condensed and returned to the direct fired heater 55 by a valved line 68 which is connected at one end to a sump or condensate reservoir 69 of feedwater heater 36 and at the opposite end to feed pipe 66. A circulating pump 70 may be provided in pipe 66 if the hydrostatic head of condensate is not sufficient to cause flow of condensate into inlet header 64 of direct fired heater 55. Make-up feed water may be introduced into heater 55 by a valved line 66A or in place thereof, the direct fired heater 55 may be automatically controlled to maintain at all times a small flow of bleed steam through line 46 into high pressure feedwater heater 36 so that the condensed steam in feedwater heater 36 provides the necessary water for the operation of direct fired heater 55.

To provide for by-passing feed water around feedwater heaters 34, 35 and 36 under load conditions on the power plant above normal or to remove one or more feedwater heaters from service for purposes of repairs or inspection, a line 71 having a valve 72, is connected at one end to line 40 and at the other end to a main by-pass line 73 which is connected at its opposite end, to boiler feed water line 43. A line 74, having a valve 75, is connected at one end to main by-pass line 73 and at the opposite end to line 41. A valve 76 is disposed in line 40 between coil 37 of low pressure feed water 34 and the juncture of lines 40 and 41. A line 77, having a valve 78, is connected at one end to main by-pass line 73 and at the other end to line 42 to provide for by-passing feed water around intermediate pressure feedwater heater 35. A valve 79 and a valve 80 are disposed in main by-pass line 73, valve 79 being positioned on the downstream side of the juncture of line 77 and main by-pass line 73 and valve 80 being placed between the junctures of main by-pass line 73 and lines 74 and 77. A valve 42A is disposed in line 42 for controlling flow through that line from intermediate pressure feedwater heaters 35. To by-pass feed water around low pressure feedwater heater 34, valve 76 in line 40 is closed while valve 72 and valve 75 in lines 71 and 74, respectively, are opened so that feed water flows from line 40 through lines 71, 73 and 74, into line 41. By closing valve 75 in line 74 and opening valves 80

and 78 in lines 73 and 77, respectively, the feed water is by-passed around intermediate pressure feedwater heater 35, as well as around low pressure heater 34. By closing valve 41A and 42A in lines 41 and 42, respectively, and with valves 75, 80 and 78 open, feed water flow is provided through feedwater heaters 34 and 36 but by-passing intermediate feedwater heater 35. By closing valves 76, 75 and 78 in lines 40, 74 and 77, respectively, and opening valves 72 and 79 in lines 71 and 73, respectively, the feed water is by-passed around all the feedwater heaters and is conducted through line 43 to drum 11 of boiler 10 without passing through any of the feedwater heaters. By closing valves 42B in line 42 and valves 43A in line 43 and opening valves 78 and 79 in lines 77 and 73, respectively, high pressure feedwater heater 36 may be taken out of service. As can be readily seen, by suitable adjustment of valves 41A, 42A, 42B, 43, 72, 75, 76, 78, 79 and 80 in their respective lines, feed water may be made to by-pass any one or all of the feedwater heaters 34, 35 and 36.

In the operation of the steam power plant under normal load conditions on the power plant, saturated steam is generated in boiler 10 and is passed from drum 11 through line 22 to superheater unit 14 where the steam is superheated. The superheated steam, at elevated temperature and pressure, is conducted by way of line 23 to the inlet end of high pressure turbine 17. The steam drives turbine 17 and is exhausted through line 24 to reheater unit 15. The steam is reheated in reheater unit 15 and is delivered at an intermediate temperature and pressure to intermediate pressure turbine 18 by line 25. The steam rotates turbine 18 and is exhausted therefrom through line 26 at relatively low temperature and pressure to low pressure turbine 19. Turbine 19 is rotated by the steam in flowing therethrough and the steam is exhausted from turbine 19 by way of lines 27 and 28 into condenser 29. In condenser 29, the steam is condensed and admixed with make-up feed water delivered to the condenser 29 through valved line 30. The feed water (condensate and make-up water) is drawn by pump 31 from condenser 29, through line 32, and pumped through line 40 into coil 37 of low pressure feedwater heater 34. Steam is induced to flow from low pressure turbine 19 through bleed line 44 to low pressure feedwater heater 34 and into indirect heat exchange relationship with the feed water in coil 37 whereby the feedwater is heated and the steam condensed. The partially heated feed water flows through line 41 into coil 38 of intermediate pressure feedwater heater 35 and in indirect heat exchange relationship with steam induced to flow from intermediate pressure turbine 18, through bleed line 45, whereby the feed water is further heated and the extracted steam in the feed water heater is condensed. The further heated feed water then flows into coil 39 of high pressure feedwater heater 36, through line 42. Steam is induced to flow from high pressure turbine 17, through bleed line 46, to high pressure feedwater heater 36 and in indirect heat exchange relationship with the feed water in coil 39 so that the feed water is heated to the desired predetermined temperature value and the steam condensed. Steam is prevented from flowing from high pressure feedwater heater 36 through line 67 by a check valve 81 disposed in line 67. The finally heated feed water is then conducted by line 43 to the water space of drum 11 of boiler 10 for conversion to steam and delivery to turbine-generator assembly 16, as previously described. Steam condensate in high pressure feedwater heater 36 is conducted therefrom through valved line 50 to intermediate feedwater heater 35 and steam condensate in the latter heater is conducted through line 51 into low pressure feedwater heater 34. The condensate in low pressure feedwater heater 34 is introduced into admixture with the feed water in line 41 by means of line 53 and pump 52. During this phase of operation of the steam power plant, valves 76, 41, 41A, 42A, 42B and 43A in the respective lines are open, while valves 72, 75, 78, 79 and 80 are closed.

As the load on the steam power plant increases above normal load, direct fired heater 55 is fired to generate combustion products in combustion chamber 57 to heat and convert the water in tubes 63 into steam. When the steam pressure exceeds the steam pressure in high pressure feedwater heater 46, steam flows from outlet header 65 through line 67, into high pressure feedwater heater 36 and into indirect heat exchange relationship with the feed water flowing through coil 39 so that the steam generated in direct fired heater 55 completely displaces extracted steam from high pressure turbine 17 in high pressure feedwater heater 36 and now heats the feed water to the final predetermined temperature value. Since the steam from direct fired heater 55 completely displaces extracted steam as a heating medium, all of the steam delivered to high pressure turbine 17 performs work thereby increasing the output of turbine 17. The steam condensed in high pressure feedwater heater 36 flows from condensate reservoir 69 through line 68 and is pumped into inlet header 64 by pump 70 and line 66. At this time the valve in line 50 is closed. With a further increase of load on the steam power plant above normal load conditions thereon, valve 42A in line 42 is closed while valves 75, 80 and 78 in lines 74, 73 and 77, respectively, are opened so that feed water by-passes intermediate pressure feedwater heater 35 by flowing from line 41 through lines 74, 73 and 77, and thence into line 42 where the feed water is then conducted into coil 39 of high pressure feedwater heater 36. Simultaneously, the firing rate of direct fired heater 55 is increased to maintain steam pressure in the direct fired heater sufficient to provide flow of steam through line 67 into high pressure feedwater heater 36 and the amount of steam required to heat the feed water to the final predetermined temperature value. With feed water by-passing intermediate pressure feedwater heater 35, no steam is induced to flow from intermediate pressure turbine 18 through bleed line 45 so that all of the steam delivered to the turbine is utilized for driving turbine 18, and thus its output is increased. Upon a still further increase of load on the steam power plant to a peak load condition, valves 75 and 76 in lines 74 and 40, respectively, are closed and valves 72 in line 71 is opened to cause the feed water to flow from line 40, through lines 71, main by-pass line 73 and line 77, and thence into line 42 so that the feed water by-passes low pressure feedwater heater 34 and intermediate pressure feedwater heater 35. Simultaneously, the firing rate of direct fired heater 55 is again increased to maintain steam pressure sufficient to provide flow of steam through line 67 into high pressure feedwater heater 36 and the amount of steam required to heat the feed water to the final predetermined temperature value. With no flow of feed water through coil 37 of low pressure feedwater heater 34, no flow of steam is induced to flow from low pressure turbine 19 through bleed line 44, so that all of the steam delivered to turbine 19 is employed for driving the turbine.

To restore the feed water heating system from a peak load operating condition to a normal load condition on the power plant while maintaining the heating of the feed water to the predetermined temperature value, flow of feedwater through low pressure feedwater heater 34 is restored by opening valve 76 in line 40 and closing valve 72 in line 71 and, simultaneously, reducing the firing rate of burner 59 of direct fired heater 55. Thereafter, opening valve 42A in line 42 and closing valves 75, 80 and 78 in lines 74, 73 and 77, respectively, to restore flow of feed water through intermediate pressure feedwater heater 35. Simultaneously, the firing of burner 59 of direct fired heater 55 is stopped and the valve in line 50 is opened. With flow of feed water through feedwater heaters 34 and 35 restored, steam is again induced to flow through bleed lines 44 and 45 to the feedwater heaters. With no steam delivered to high pressure feedwater heater 36

from direct fired heater 55, steam flow from high pressure turbine 17 is restored.

It is to be understood that it is contemplated by the present invention to permit a small amount of flow through the by-passed feedwater heaters 34, 35 and 36, to prevent thermal stresses thereon when full flow of feedwater is restored through the feedwater heaters. It is also contemplated without departing from the spirit and scope of the present invention to arrange the high, intermediate and low pressure feedwater heaters, in groups of high, intermediate and low pressure feedwater heaters rather than as single high, intermediate, and low pressure feedwater heaters as shown and described. Furthermore, it should be understood that the drawing is merely illustrative of the present invention and that pumps may be interposed in the feedwater lines to change the feed water pressure levels; that various methods of operation, pressure control, temperature control, and water feed and level controls may be employed. Still further the present invention contemplates a modification wherein in addition to the feedwater heaters, a separate heat exchanger is disposed in the preheating circuit between the feedwater heaters and the boiler 10, or at any other suitable point in the feed water preheating circuit, to receive feed water and connected to receive the steam generated in the direct fired heater 55 and to pass the steam in indirect heat exchange relationship with the feed water. In this modification, the direct fired heater 55 may be supplied with water for the generation of steam from the boiler feedwater supply or by condensing steam from a higher pressure source than that of direct fired heater.

It can now be readily understood from the foregoing description that a novel method of and apparatus for preheating feedwater in a steam power plant has been provided wherein feed water is heated to a predetermined temperature value for all load conditions on the steam power plant above normal loads on the steam power plant and wherein turbine capabilities are increased. It will also be apparent to those skilled in the art that in start-up operation of the steam power plant, direct fired heater 55 may be utilized to preheat the feed water to the desired predetermined temperature value until sufficient steam is generated by the boiler to provide the necessary amount of extraction steam for preheating the feed water.

Although, but one embodiment of the invention has been illustrated and described in detail, it is to be expressly understood that the invention is not limited thereto. Various changes can be made in the arrangement of parts without departing from the spirit and scope of the invention, as the same will now be understood by those skilled in the art.

What is claimed is:

1. In a steam power plant having a boiler and turbines connected to receive and be driven by steam generated in said boiler, apparatus for preheating the feed water for said boiler comprising a plurality of feedwater heaters connected together in series and to a source of feed water so that feed water flows successively through each of the feedwater heaters, means for extracting steam from the turbines and for supplying the extracted steam to each of the feedwater heaters, each of the feedwater heaters having means for passing the feed water and extracted steam in indirect heat exchange relationship with each other to heat the feed water and to condense the steam, conduit means connected to the last feedwater heater and to the boiler for passing heated feed water from the last feedwater heater to the boiler, a steam generating apparatus connected to the last of the feedwater heaters with respect to the direction of flow of feed water through the feedwater heaters to pass steam generated in said steam generating apparatus to the last feed water heater and in indirect heat exchange relationship with the feed water to heat the latter and condense the steam, said steam generating apparatus being operative to generate steam and pass the steam to the last feedwater heater when the load on the steam power plant increases above normal load conditions so that the feed water is heated to a predetermined temperature value, and a conduit connected at one end to the last feedwater heater and at the opposite end to said steam generating apparatus to respectively receive and pass the condensate from the last feedwater heater to the steam generating apparatus for reconversion to steam in the latter.

2. The apparatus of claim 1 wherein a means is provided for by-passing feed water around each of the feedwater heaters not including the last feedwater heater as the load on the power plant increases above normal load conditions.

3. In a steam power plant having a boiler and a high pressure turbine, an intermediate pressure turbine and a low pressure turbine each of which is connected to receive steam generated in said boiler and to be driven thereby, apparatus for preheating feed water for said boiler comprising; a high pressure feedwater heater, an intermediate pressure feedwater heater, a low pressure feedwater heater; each of the feedwater heaters comprising a shell and a bank of tubular members within said shell; the bank of tubular members of the low pressure feedwater heater being connected to a source of feed water to be heated and to the bank of tubular members of the intermediate pressure feedwater heater to pass feed water to the latter; the bank of tubular members of the high pressure feedwater heater being connected to the bank of tubular members of the intermediate pressure feedwater heater to receive feed water from the latter; extraction means connected to each of the feedwater heaters and to the high pressure turbine, intermediate pressure turbine, and low pressure turbine for supplying steam from the high pressure, intermediate pressure, and low pressure turbines to the respective high, intermediate, and low pressure feedwater heaters so that the feed water in each of the banks of tubular members of each of the feedwater heaters passes in indirect heat exchange relationship with the extracted stream whereby the feed water is heated and the steam condensed; a conduit means communicating with the bank of tubular members of the high pressure feedwater heater and with the boiler to receive heated feed water from the high pressure feedwater heater and pass the same to the boiler, a direct fired heater having steam generating tubes therein and burner means for generating combustion gas therein; said steam generating tubes being in communication with a source of water to receive and conduct the water in heat exchange relationship with the combustion gas to convert the water to saturated steam and in communication with the interior of the shell of the high pressure feedwater heater to pass saturated steam to the latter and in indirect heat exchange relationship with the feed water; the burners of said direct fired heater being fired independently of the boiler of the steam power plant when the load on the steam power plant increase above normal load conditions to generate steam and pass the same to the high pressure feedwater heater to heat the feed water to a predetermined temperature value and condense the steam; and means communicating with the high pressure feedwater heater and the steam generating tubes of the direct fired heater to recirculate the condensate from the high pressure feedwater heater to the steam generating tubes of the direct fired heater.

4. The apparatus of claim 3 wherein a by-pass means is provided for the low pressure and intermediate pressure feedwater heaters for by-passing feed water around the low pressure and intermediate pressure feedwater heaters and conducting the feed water directly to the high pressure feedwater heater under loads on the steam power plant above normal load conditions.

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