

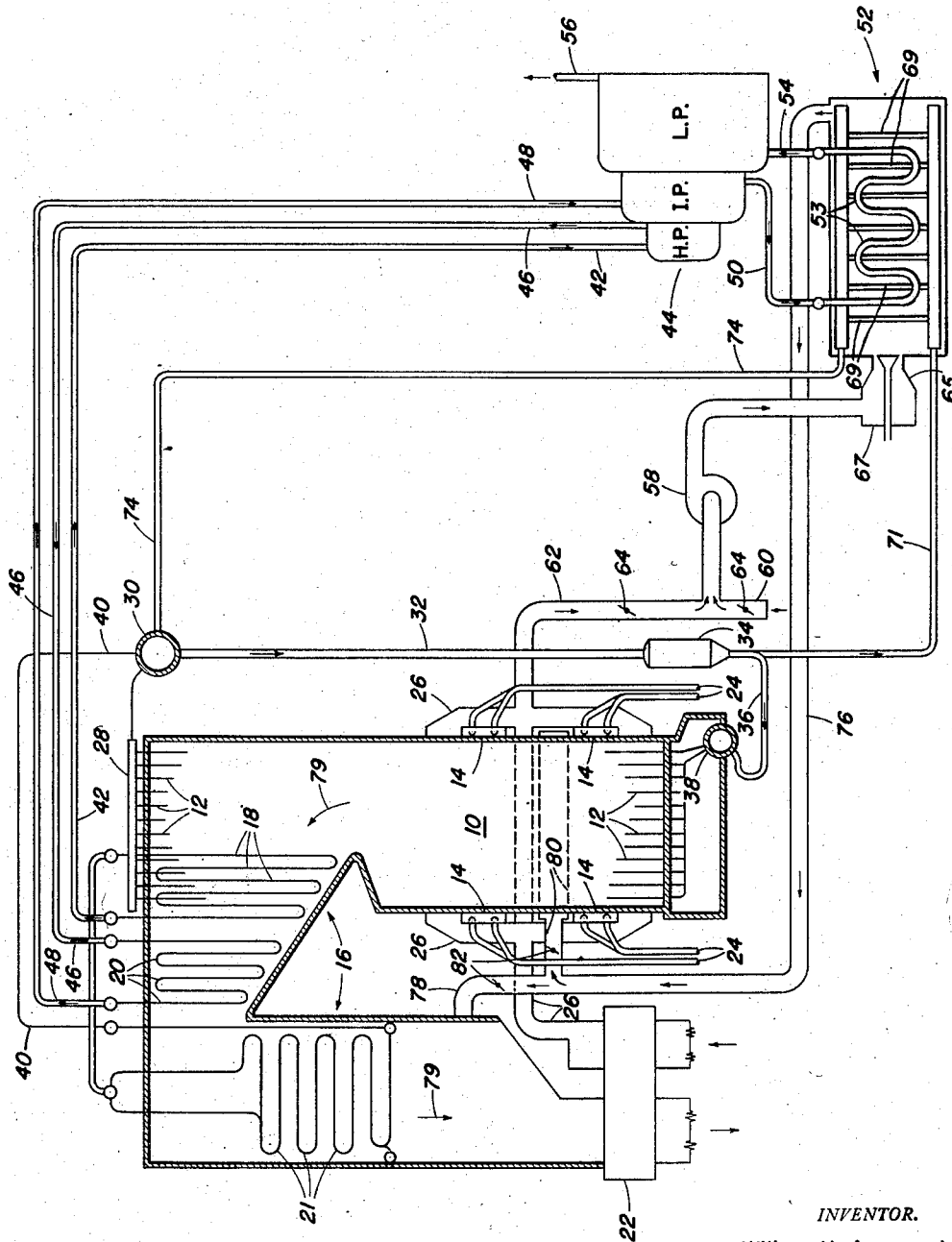
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POWER PLANT WITH SEPARATELY FIRED REHEATER

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1

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POWER PLANT WITH SEPARATELY FIRED REHEATER

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This invention relates to power plants operating on the reheat cycle and particularly to such a power plant wherein a separately fired reheater is employed and which is located adjacent the prime mover.

In modern high temperature and high pressure steam power plant operation it is now accepted practice to employ the reheat cycle wherein the steam that is exhausted from a first or high pressure stage of the prime mover is reconveyed to the boiler where it is reheated to a desired temperature and pressure and thereafter introduced into a lower pressure stage of the prime mover from which it is exhausted into a suitable condenser or the like. This method of operation is quite practicable and in fact highly efficient. The pressure of the steam returned to the boiler for a single stage of reheat is sufficiently high to permit its economical return to the boiler and reconveyance to the prime mover with an overall pressure drop not exceeding 10% of the pressure of this steam, which figure is acceptable for efficient operation. It has now become desirable, however, to reheat the steam a second time and while it is perfectly practicable in the large units used today to have a first stage of reheat in the main boiler it is exceedingly impracticable to provide the second stage of reheat in the main boiler. This is due to the fact that the pressure of the steam being heated a second time will necessarily be so low that in order to maintain a pressure drop that would be at all tolerable pipes of tremendous diameter would be required to convey the steam through the long reheat circuit, which would include the piping to and from the boiler and the prime mover and the necessary heat exchanger in the main boiler. Such piping would, of course, be totally unfeasible from an economic standpoint.

To overcome this difficulty the present invention provides a separately fired reheater positioned adjacent the prime mover and connected to the prime mover to provide a second stage of reheat therefor thereby eliminating any lengthy pipe runs. This separately fired reheater has a pressurized furnace lined with steam generating tubes which are effectively connected into the steam generating circuit of the main boiler. The combustion gases from the separately fired reheater are conveyed to the main boiler and there introduced at a first location adjacent the firing of this boiler and at a second location downstream of the superheater and immediately upstream of the air heater of this boiler with the combustion gases being proportioned between these two locations in a manner to effectively control the superheat temperature of the main boiler. The separately fired reheater is operated with an extremely high percentage of excess air with a substantial portion of the air introduced into the reheater being preheated by the air preheater of the main boiler. This excess air provides efficient burning of the fuel in the separately fired reheater and in the boiler and also desirably lowers the temperature in the separately fired reheater.

It is the object of the present invention to provide an

2

improved power plant organization operating on the reheat cycle and a novel method of operating such a power plant organization.

Other and further objects of the invention will become apparent to those skilled in the art as the description proceeds.

With the aforementioned objects in view, the invention comprises an arrangement, construction and combination of the elements of the power plant organization in such a manner as to attain the results desired as hereinafter more particularly set forth in the following detailed description of an illustrative embodiment, said embodiment being shown by the accompanying drawing wherein the single figure constitutes a diagrammatic representation of a steam power plant embodying the present invention.

Referring now to the drawing the controlled circulation main boiler illustratively disclosed therein includes a furnace 10 lined with steam generating tubes 12 and tangentially fired with a suitable fuel such as pulverized coal through the several burners 14. The gases created by the burning of this fuel within furnace 10 sweep upwardly through the furnace and then pass successively over high temperature section 18 of the superheater, generally designated 16, reheater 20, low temperature section 21 of the superheater and then through air heater 22 to a suitable stack, not shown. Pulverized coal or other suitable fuel is conveyed to burners 14 through conduits 24 and preheated combustion supporting air is conveyed from air heater 22 through ducts 26 to the location of burners 14 where it is introduced into the furnace to support the combustion of the fuel therewithin.

The steam generating circuit of the main boiler includes steam generating tubes 12 connected at their upper ends to headers 28 which in turn are connected to steam and water drum 30. Depending from steam and water drum 30 is downcomer 32 connected at its lower end to the inlet of pump 34 which in turn has its outlet connected by means of conduit 36 to orifice drum 38 into which the inlets or lower ends of steam generating tubes 12 are connected. Pump 34 is effective to circulate the boiler water from steam and water drum 30 downward through downcomer 32 and through conduit 36 into orifice drum 38 from which the water is distributed to and flows upward through steam generating tubes 12 where a portion of the water is converted into steam with the steam and water mixture being conveyed from these tubes back into drum 30. Suitable restrictors, not shown, are provided at the inlet of each of the steam generating tubes to meter the boiler water flowing therethrough as desired.

Steam is taken from the upper portion of drum 30 and conveyed by a conduit 40 to low temperature section 21 of superheater 16. From low temperature section 21 the steam, after being partly superheated, is conveyed to high temperature section 18 where it is raised to the desired temperature and then conveyed by conduit 42 to the high pressure stage (H. P.) of prime mover 44. The exhaust from this high pressure stage is reconveyed to the main boiler through conduit 46 where it is introduced into reheater section 20 and reheated to a desired temperature and pressure after which it is conveyed to the intermediate pressure stage (I. P.) of the prime mover through conduit 48. The exhaust from this intermediate pressure stage is conveyed through conduit 50 to the separately fired reheater 52 located immediately adjacent prime mover 44. This exhaust steam is reheated to a desired temperature and pressure by conveying the same through heat exchange elements 53 forming a part of the separately fired reheater and is thereafter conveyed through conduit 54 to the low pressure stage (L. P.) of the prime

3

mover from which it is exhausted through conduit 56 to a suitable condenser or other apparatus.

While both the superheater and reheater of the main boiler are here shown as of the convection type, either or both of these elements may, if desired, be of the radiant type.

The separately fired reheater 52 is a pressurized unit into which combustion supporting air is introduced from fan or blower 58 at a pressure substantially in excess of the pressure within furnace 10 of the main boiler. In order that the air handled by the blower will be of sufficiently low temperature so that the blower will operate at a reasonable efficiency and in order that a portion of the air introduced into the separately fired reheater 52 will be preheated by air heater 22 of the main boiler the inlet of blower 58 is in communication with the atmosphere or some other relatively cold air supply through conduit 60 and with air duct 26 through conduit 62 with valves 64 being provided in each of these conduits to regulate the temperature of the air entering the blower. The tempered combustion supporting air passing through blower 58 is introduced into the separately fired reheater from wind box 65 centrally within which extends burner 67 for introducing a suitable fuel, such as gas or oil, into the separately fired reheater.

The walls of separately fired reheater 52 are lined with contiguous steam generating tubes 69 welded together to form a fluid tight pressure resistant structure. They are illustrated as spaced in the diagrammatic representation of the drawing only in order to simplify and clarify the illustration. These tubes 69 are connected into the steam generating circuit of the main boiler through conduits 71 and 74 in a manner so that boiler water is forced through conduit 71 from pump 34 and through these tubes where a portion of the water is converted into steam with the thus produced steam and water mixture being conveyed into steam and water drum 30 through conduit 74.

The combustion gases generated in separately fired reheater 52 are conveyed through duct 76 to the main boiler. From duct 76 these gases are introduced through branch duct 80 into the furnace of the main boiler and through branch duct 78 into the boiler at a location immediately upstream of air heater 22 and downstream of superheater 16 relative to the combustion gas flow through the main boiler indicated by arrows 79. The combustion gases flowing through duct 76 are proportioned between branch ducts 78 and 80 by means of valves 82 provided in these conduits with these valves being regulated to so control the introduction of combustion gases through branch duct 80 into the furnace to control the temperature of the steam leaving the superheater 16 in a well known manner.

In operation of the separately fired reheater 52 an extremely high percentage of excess air (such as 95%) is supplied through blower 58 and wind box 65. This high percentage of excess air together with steam generating tubes 69 which line the walls of separately fired reheater 52 have the effect of substantially reducing the temperature within the separately fired reheater thereby making it unnecessary to fabricate heat exchange elements 53 from as expensive alloy piping as would be needed to withstand the high temperature that would otherwise be encountered. Furthermore, by supplying this large percentage of excess air a very high fuel burning efficiency is obtained in the separately fired reheater and since the combustion gases from separately fired reheater 52 which are introduced into the furnace of the main boiler through conduit 80 will contain this large percentage of air the air thus introduced through conduit 80, which will have a high temperature, will constitute a portion of the combustion supporting air for the main boiler and will give a high burning efficiency of the fuel in the main boiler.

The combustion gases from separately fired reheater 52 that are in excess of those required to be introduced into the furnace of the main boiler through branch duct

4

80 in order to obtain the desired superheat temperature are introduced into the combustion gas stream of the main boiler through branch duct 78 immediately upstream of air heater 22 so that the air heater may extract sufficient heat from these gases to so reduce their temperature that they may be economically exhausted to a suitable stack. Since all of the combustion gases from both the main boiler and the separately fired reheater 52 are conveyed through air heater 22 it is necessary that this air heater heat more than just the combustion supporting air required by the main boiler in order to have an air-gas ratio at the air heater which will be sufficient to reduce the temperature of the gases leaving the boiler to an efficient one. This is taken care of by having the air heater supply a portion of the combustion supporting air for separately fired reheater 52, preheated air from air heater 22 being conveyed thereto via blower 58 and conduit 62 as hereinbefore explained.

The present invention thus provides a power plant organization wherein a separately fired reheater is positioned adjacent the prime mover thereby permitting economical double reheat and wherein the separately fired reheater is associated with the main boiler so as to obtain a highly efficient power plant with a minimum amount of equipment and so as to provide an accurate and efficient control for the superheat temperature of the main boiler. Moreover, the invention provides a novel method of operating the power plant permitting a more economical installation and resulting in a highly efficient operation.

While I have illustrated and described a preferred embodiment of my novel power plant organization it is to be understood that such is merely illustrative and not restrictive and that variations and modifications may be made therein without departing from the spirit and scope of the invention. I therefore do not wish to be limited to the precise details set forth but desire to avail myself of such changes as fall within the purview of my invention.

What I claim is:

1. In a power plant installation the combination of a controlled circulation boiler fired by suitable burners and including a furnace, a steam generating circuit at least portions of which line the furnace walls, pump means operative to force water through the steam generating circuit, a superheater and an air heater downstream of said superheater relative to the flow of combustion gases through said boiler and remote from the furnace, a separately fired reheater operative to reheat the steam generated in the boiler after a portion of its energy has been utilized, said separately fired reheater including steam generating tubes connected into said steam generating circuit in a manner to have water forced therethrough by said pump means and returned to said circuit, blower means having its inlet communicating with said air preheater and with a source of cold air with means to control the amount of air received from each of these sources and having its outlet communicating with said separately fired reheater to introduce combustion supporting air thereinto at a pressure substantially greater than that within the boiler, means interconnecting the separately fired reheater and the boiler in a manner to convey the combustion gases generated in the separately fired reheater to said boiler and introduce the same into the furnace of said boiler and into said boiler at a location remote from the furnace and intermediate the superheater and the air heater, and means operative to adjustably control the proportioning of these combustion gases between said two locations.

2. In an organization of the type described a boiler having a convection superheater and a water walled furnace fired with a suitable fuel, a separately fired reheater operative to receive superheated steam produced by said boiler after a portion of its energy has been utilized,

5.

conduit means conveying combustion gases from the separately fired reheater and introducing the same into said furnace, and adjustable regulating means operatively associated with the conduit means and independent of the firing of the separately fired reheater to control the quantity of gases thus introduced into the furnace to regulate the superheat temperature of the boiler.

3. In a power plant installation the combination of a controlled circulation boiler fired by suitable burners and including a furnace, a steam generating circuit at least portions of which line the furnace walls, pump means operative to force water through the steam generating circuit, a superheater and an air heater downstream of said superheater relative to the flow of combustion gases through said boiler and remote from the furnace, a separately fired reheater operative to reheat the steam generated in the boiler after a portion of its energy has been utilized, said separately fired reheater including steam generating tubes connected into said steam generating circuit in a manner to have water forced therethrough by said pump means and returned to said circuit, means interconnecting the separately fired reheater and the boiler in a manner to convey the combustion gases generated in the separately fired reheater to said boiler and introduce the same into the furnace of said boiler and into said boiler at a location remote from the furnace and intermediate the superheater and the air heater, and means operative to adjustably control the proportioning of these combustion gases between said two locations.

4. In a power plant installation the combination of a steam turbine means having high, intermediate and low pressure steam utilizing portions, a main boiler including a water walled furnace fired with a suitable fuel, a superheater and a reheater, said superheater being interconnected with said high pressure portion to supply the same with high pressure steam and said reheater being interconnected with said intermediate pressure portion and the exhaust of said high pressure portion to reheat the steam from said exhaust and supply the same to said intermediate pressure portion, a separately fired reheater juxtaposed to said steam turbine means, said last named reheater being interconnected with said low pressure portion and the exhaust of said intermediate portion to reheat the steam from said exhaust and supply the same to said low pressure portion, means conveying the hot combustion gases leaving said separately fired reheater to said main boiler and introducing the same into the furnace of said main boiler upstream of said superheater relative to the combustion gas flow and into said boiler at a location downstream of said superheater relative to the direction of gas flow through said main boiler and means effective to regulate the introduction of said gases into said furnace.

5. A power plant installation operating on the reheat cycle and including a main boiler having a furnace with fluid circulation tubes on its walls and fired with a suitable fuel, a gas pass through which the combustion gases thus generated are conveyed, an air heater positioned at the discharge end of said gas pass for reception of the combustion gases therefrom, a superheater at least a substantial portion of which is disposed in said gas pass, a separately fired reheater operative to reheat superheated steam produced in said superheater after a portion of its energy has been utilized, a passageway leading from the combustion gas outlet of said separately fired reheater into said main boiler at a location downstream of said superheater but upstream of said air heater relative to the direction of gas flow through said main boiler and at a location in said furnace remote from where the combustion gases leave the furnace and where the gases from the separately fired reheater are contacted by the burning fuel in said furnace, means effective to regulate the percentage of the combustion gases flowing through said passageway that

6.

are introduced into said boiler at said first named location, said air heater being interconnected with both the boiler and the separately fired reheater in a manner to supply preheated combustion supporting air to each of these units.

6. In a reheat boiler the combination of a furnace with heat exchange tubes on its walls and fired by suitable burners and also including a superheater and an air heater downstream of the superheater relative to the direction of combustion gas flow through the boiler and remote from the furnace, said air heater being connected to preheat the combustion supporting air of the boiler, a prime mover having a high, an intermediate and a low pressure portion, said high and intermediate pressure portion being interconnected with said boiler to receive superheated and reheated steam therefrom, a separately fired reheater positioned adjacent the prime mover and connected thereto in a manner to supply reheated steam to said low pressure portion, air pump means effective to supply combustion supporting air to said separately fired reheater at a pressure substantially greater than the pressure within said boiler, passageway, means connecting the combustion gas outlet of said separately fired reheater to said boiler at a location in the vicinity of the introduction of fuel into the boiler and at a location intermediate the superheater and the air heater and remote from the furnace, and means operative to adjustably control the proportioning of the combustion gases between said two locations.

7. A method of operating a reheat power plant installation wherein a main boiler having a furnace lined with fluid circulating tubes and fired by suitable burners and having a superheater and an air heater, respectively, serially arranged with respect to combustion gas flow with the air heater being remote from the furnace supplies superheated steam to a multiple expansion prime mover and a separately fired reheater juxtaposed to said prime mover supplies reheat steam to said prime mover comprising the steps of supplying a substantial quantity of excess air to said separately fired reheater during firing thereof, introducing the combustion gases of said separately fired reheater containing said excess air into said furnace at a location well upstream of the superheater relative to combustion gas flow through the boiler and where they will contact the burning fuel in said furnace and at a location intermediate the superheater and the air heater and remote from the furnace, and controlling the proportioning of said combustion gases between these two locations so as to maintain the outlet steam temperature of the superheater substantially constant.

8. In a steam power plant installation that operates on the reheat cycle and includes a boiler that supplies superheated steam to a prime mover and has a furnace fired with a suitable fuel and lined with steam generating tubes, a gas pass leading from said furnace through which the combustion gases generated therein are directed, and a superheater and an air heater associated with said gas pass to absorb heat from said combustion gases flowing therethrough and respectively serially arranged with respect to the gas flow, and also includes a separately fired reheater for reheating the steam generated by said boiler after utilization of a portion of the energy thereof in the prime mover and thereafter returning the same to the prime mover the method of controlling, within limits, the temperature of the superheated steam leaving the boiler and of obtaining efficient operation of the power plant comprising introducing combustion gases generated in the separately fired reheater into the furnace of the boiler and into the gas pass of the boiler at a location downstream of the superheater and upstream of the air heater, and controlling the proportioning of these combustion gases between these two locations so as to maintain said superheated

steam temperature substantially constant over varying load conditions.

9. The method of operating a reheat power plant installation wherein a main boiler having a furnace lined with fluid circulating tubes and fired by suitable burners and having a superheater and an air heater, respectively, serially arranged with respect to combustion gas flow supplies superheated steam to a prime mover and a separately fired reheater juxtaposed to said prime mover supplies reheat steam to said prime mover comprising the steps of supplying the separately fired reheater with combustion supporting air in a quantity greatly in excess of that required for complete combustion of the fuel supplied to and burned in the reheater and conveying at least a portion of the combustion gases leaving the reheater and which will contain a substantial quantity of air to the furnace of the boiler and introducing the same thereinto generally at a location such that they will come into contact with the burning fuel in the furnace of the main boiler.

10. In a power plant installation operating on the reheat cycle the combination of a steam boiler fired by suitable burners and including a furnace with fluid circulating tubes on its wall, a superheater operatively connected to receive the steam generated by the boiler and superheat the same to a desired temperature and an air heater downstream of said superheater relative to the flow of combustion gases through the boiler and operating to heat combustion supporting air, said air heater being connected with said furnace to supply heated combustion supporting air thereto, a separately fired reheater for reheating the superheated steam generated by said boiler after a portion of its energy has been utilized, means conveying the combustion gases generated in the reheater to said boiler and introducing the same into the furnace thereof and into the boiler at a location intermediate the superheater and air heater, and means operative to adjustably control the proportioning of these combustion gases between these two locations.

11. In a power plant installation operating on the reheat cycle the combination of a boiler including a furnace fired by suitable burners, a steam generating circuit at least portions of which line the furnace walls, a gas pass extending from the furnace so that combustion gases generated in said furnace are conveyed there-through, superheater means disposed in said gas pass and interconnected to receive the steam generated by said boiler and superheat the same, an air heater downstream of said superheater relative to combustion gas flow and being operative to heat combustion supporting air and interconnected with the furnace to supply hot air thereto to support combustion of the fuel there-within, a separately fired reheater for reheating the superheated steam generated by said boiler after a portion of its energy has been utilized, means conveying the combustion gases generated in the reheater to said boiler and introducing the same into the furnace thereof and into said gas pass intermediate the superheater and air heater, and means operative to adjustably control the proportioning of these combustion gases between these two locations.

12. In a power plant installation operating on the reheat cycle, the combination of a controlled circulation boiler including a furnace fired by suitable burners, a steam generating circuit at least portions of which line the inner surface of the furnace walls, pump means operative to force boiler water through said steam generating circuit, a superheater operatively connected to receive steam generated by the boiler and superheat the same to a desired temperature and an air heater down-

stream of said superheater relative to combustion gas flow and operative to heat combustion supporting air, said air heater being connected with said furnace to supply heated combustion supporting air thereto, a separately fired reheater for reheating the superheated steam generated by said boiler after a portion of its energy has been utilized, said separately fired reheater including steam generating tubes connected into said steam generating circuit in a manner to form a portion thereof and have boiler water forced therethrough, means interconnecting the separately fired reheater and the boiler in a manner to convey the combustion gases generated in the separately fired reheater to said boiler and introduce the same into the furnace of said boiler and into said boiler at a location intermediate the superheater and the air heater, and means operative to adjustably control the proportioning of these combustion gases between said two locations.

13. In a power plant installation the combination of a steam turbine means having high, intermediate and low pressure steam utilizing portions, a main boiler including a furnace fired with a suitable fuel, a superheater and a reheater disposed so that the combustion gases generated by burning fuel in said furnace flow thereover and impart heat thereto, said furnace having an upright portion with an exit for combustion gases at its upper end and having heat exchange tubes disposed on its walls, pump means operative to force water to be converted to steam through said tubes, said superheater being interconnected with said high pressure portion to supply the same with high pressure steam and said reheater being interconnected with said intermediate pressure portion and the exhaust of said high pressure portion to reheat the steam from said exhaust of said high pressure portion and supply the same to said intermediate pressure portion, a separately fired reheater juxtaposed to said steam turbine means and interconnected with said low pressure portion and the exhaust of said intermediate portion to reheat the steam from said exhaust and supply the same to said low pressure portion, said separately fired reheater having tubes disposed on its walls and interconnected with the main boiler so that said pump means is effective to force water therethrough and back to the main boiler, means conveying the combustion gases leaving said separately fired reheater to said main boiler well upstream of the superheater relative to combustion gas flow through the boiler and into said boiler at a location downstream of said superheater relative to the direction of gas flow through said main boiler and means effective to regulate the introduction of said gases into said furnace.

References Cited in the file of this patent

UNITED STATES PATENTS

55	255,271	Fish	Mar. 21, 1882
	333,001	Foreman	Dec. 22, 1885
	960,357	Loewenstein	June 7, 1910
	1,089,115	Curtis	Mar. 3, 1914
60	1,635,410	Harter	July 12, 1927
	1,889,307	Baumann	Nov. 29, 1932
	2,614,541	Armocost et al.	Oct. 21, 1952
	2,673,553	Rowand et al.	Mar. 30, 1954
	2,781,746	Armocost et al.	Feb. 19, 1957

FOREIGN PATENTS

55	220,960	Great Britain	Nov. 6, 1924
	258,589	Great Britain	Mar. 3, 1927
	523,871	Great Britain	July 24, 1940
70	955,787	France	July 4, 1949