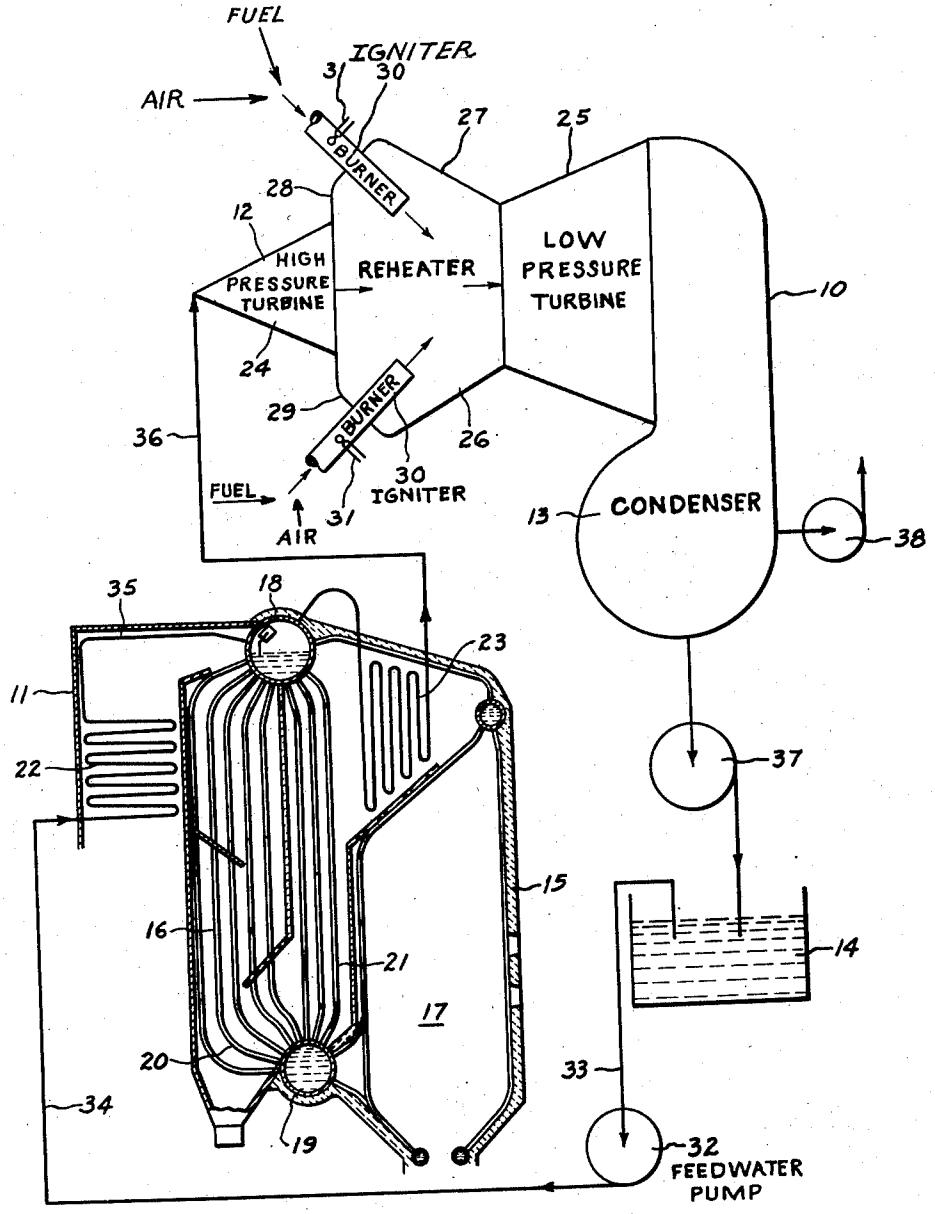
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MULTIPLE EXPANSION POWER PLANT USING STEAM AND MIXTURE OF STEAM AND COMBUSTION PRODUCTS

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MULTIPLE EXPANSION POWER PLANT USING STEAM AND MIXTURE OF STEAM AND COMBUSTION PRODUCTS

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1 Claim. (Cl. 60—39.17)

This invention relates generally to power plants and more particularly to prime mover apparatus including a steam-actuated turbine.

The conventional design of a reheat steam power plant requires a steam generating unit in which the high pressure steam is generated and superheated. This steam then passes through the high pressure section of the turbine, is returned to the boiler at lower pressure and lower temperature where it is then resuperheated to a higher temperature, returned to the intermediate stages of the turbine, and finally exhausted into a condenser. The heat added to the reheat steam must be liberated in the boiler furnace. The reheat temperature must be carefully controlled by either burner level control, combustion gas flow control, feed water spray control, heat exchanger control or a combination of several or all of these controls. The design of the boiler unit is complicated and is made costly by the steam reheater installation and by the fact that the furnace, fuel-burning equipment and mechanical draft equipment must be proportionally larger to provide for the added fuel to be burned for reheating. Costly steam piping and valving are required to transport the steam from the outlet of the high pressure turbine section to the boiler reheater and to return the reheated steam to the turbine. A certain amount of energy is lost by the pressure drop of the reheat steam in its path from the turbine through the boiler reheater and back to the turbine. This pressure drop is usually between 25 p. s. i. and 40 p. s. i., so that the pressure of the reheated steam entering the low pressure section of the turbine is usually between 25 p. s. i. and 40 p. s. i. lower than the pressure of the steam leaving the high pressure section of the turbine. In order to overcome some of the complications of the conventional reheat cycle steam power plant, designs have been proposed wherein the high pressure and high temperature steam is generated in a main boiler and the steam for reheating passes through a separately fired superheater place in the immediate vicinity of the turbine. This arrangement results in shorter steam piping and closer control over the reheat steam temperature, but it requires an entirely separate heat exchanger installation including a furnace, burners, controls, mechanical draft equipment and some type of heat recovery equipment or means to return the combustion gas after it has passed over the reheater surface to the heat recovery equipment of the main boiler. The saving in steam pressure drop and the convenience of close control over the reheat steam temperature are thus offset by the cost of equipment and operation of a separately fired superheater.

It is therefore an outstanding object of the present invention to provide for a steam power plant having an improved reheat cycle, simplified equipment, and little energy loss in the reheating operation.

It is another object of the invention to provide a steam power plant wherein there are no heat losses such as are experienced in ordinary plants in conduits returning steam

from the high pressure section of the turbine to the reheater section of the boiler and back again.

A further object of this invention is the provision of a power plant wherein pressure drop in reheat tubes is avoided.

A still further object of the present invention is a power plant whose cost is small because of the absence of insulated conduits for passing reheat steam to and from the boiler, because of the absence of a reheat section in the boiler, and because of the absence of apparatus associated with the boiler which are necessary in the conventional power plant.

The single figure shows a steam power plant embodying the present invention.

Generally speaking, the present invention involves placing a resuperheat or reheat chamber between the high pressure and the low pressure sections of the turbine. The steam exhausts from the high pressure section into the heater chamber at pressures below 500 p. s. i. g. The heater chamber is equipped with reaction-type burner tubes similar to the combustors used in jet engines and gaseous or liquid fuel is burned in the burner tubes so that the products of combustion will be in direct contact with steam. The burner tubes are arranged radially, so that they are cooled by the steam flowing through the reheater chamber. The reheater chamber is constructed for the pressure existing between the high temperature and the low temperature section of the turbine, i. e., approximately 500 p. s. i. g. The firing rate will be controlled either by increasing or decreasing the number of burner tubes in service, or by controlling the fuel-air ratio of the individual burners. Electric ignitors of the type used with jet engine combustors will provide ignition for the fuel within the burner tubes. The reheated steam mixed with the products of combustion then passes through the low pressure turbine section and is discharged into the condenser in the usual manner. The water space of the condenser is connected to a vacuum pump for the removal of non-condensable gas which is produced by combustion. Condensate returns to a hot well and in the usual manner is returned to the boiler as boiler feed.

Referring to the single figure of the drawing, the power plant, designated generally by the reference character **10**, is shown as comprising a steam generating unit **11**, a turbine **12**, a condenser **13**, and a hot well **14**. The steam generating unit **11** is of the usual type having a furnace **15** and a boiler **16**, the furnace having water walls forming a combustion chamber **17**. The boiler has a steam-and-water drum **18** and a mud drum **19** joined by downcomer tubes **20** and steam risers **21**. An economizer **22** resides in the outlet gas pass and a pendant superheater **23** resides in the horizontal gas pass joining the combustion chamber **17** with the boiler passes. The turbine **12** is provided with a high pressure section **24** and a low pressure section **25** arranged coaxially and with the outlet end of the high pressure section adjacent the inlet end of the low pressure section, the two ends being separated by a substantial space. In the space between the ends and joining the high pressure section to the low pressure section is a re-superheat or reheat chamber **26**. The chamber is formed in part by a wall portion **27** which is in the form of a truncated cone, the smaller end merging with the inlet end of the low pressure section of the turbine and the larger end flaring outwardly and facing the outlet end of the high pressure section. Another wall portion **28** joins the outlet end of the high pressure section to the larger end of the conical wall portion and this wall portion **28** is of conical form in a portion **29** adjacent the large end of the wall portion **27**, the larger ends of the two cones being joined. Fastened to and extending through the conical portion

29 of the wall portion 28 is a series of combustors or burner tubes 30 arranged with their exit ends at a position which is a substantial distance inside the chamber 26. The center lines or the lines of action of the burner tubes meet on the axis of the turbine 12 at a position somewhat removed from the inlet end of the low pressure section of the turbine. Each burner tube is provided with an electrical ignitor 31 and with a source of fuel and air under high pressure, the said source not being shown but being of the well-known type used with jet engines and the like, so that the exit pressure of the burner is greater than that in the chamber 26. The low pressure section 25 of the turbine, while formed efficiently to obtain mechanical energy from the steam passing therethrough, is also provided with components of stainless steel or the like which will resist the corrosive action of products of combustion passing therethrough. In this sense it resembles the well-known gas turbine.

The arrangement of the power plant constructed according to the philosophy of the invention will now be described. The hot well 14 is connected to the inlet of a feedwater pump 32 by a conduit 33. The outlet of the feedwater pump is connected to the downstream end of the economizer 22 by means of a conduit 34. The upper end of the economizer is connected to the steam-and-water drum 18 by a tube means 35. The steam space of the drum 18 is connected to the inlet or downstream end of the superheater 23. The outlet end of the superheater is connected to the inlet end of the high pressure section 24 of the turbine 12 by means of an insulated conduit 36. The outlet end of the low pressure section 25 of the turbine is directly attached to the inlet of the condenser 13, the normal discharge of which is connected to the inlet of a condensate pump 37 which discharges into the hot well 14. A vacuum pump 38 is also connected to the condenser for the removal of non-condensable gases, this pump discharging to the atmosphere.

The operation of the apparatus will be understood in view of the above description taken in conjunction with the drawings. Water from the hot well 14 is pumped by the feedwater pump 32 through the economizer into the steam-and-water drum 18. The water passes downwardly through the downcomer tubes 20 into the mud drum 19 and then upwardly through the risers 21, wherein steam is formed. The steam is released into the drum 18 and passes upwardly and into the superheater 23. After it has passed through the superheater, wherein it is raised to the desired superheat, it enters the high

pressure section 24 of the turbine. Passing through the section 24, it expands in the vanes and performs the work of rotating the turbine shaft. The expanded steam leaves the high pressure section and enters the chamber 26 in a more or less axial direction. The fuel entering the burner tubes 30 is ignited by the ignitors 31 and the products of combustion are projected under pressure into the chamber 26. The products of combustion and the steam are thoroughly mixed and the steam receives heat from the gases, whereupon the steam is reheated. The number of burner tubes, the type of fuel, and the rate of combustion are selected so that the products of combustion will be sufficient in volume and high enough in temperature to reheat the desired amount. The mixed steam and products of combustion pass through the low pressure section of the turbine together and the work of expansion serves to rotate the rotor of the turbine. The mixture then enters the condenser, where the steam is condensed and pumped back to the hot well by the condensate pump 37. The non-condensable gases resulting from the combustion are removed by the vacuum pump 38 and exhausted to the atmosphere.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

A power plant comprising a steam generating unit, a high pressure steam turbine section into which the said unit discharges steam at high pressure and temperature, a low pressure turbine section which is capable of operation with mixed steam and gas at relatively low pressure, the two sections being arranged coaxially with the outlet side of the high pressure section located adjacent to and spaced from the inlet side of the low pressure section, a generally truncated conical reheat chamber interposed between and connecting the said adjacent outlet and inlet sides, burners of the type having a high exit pressure mounted in the reheat chamber for discharging hot products of combustion under pressure into the flow of steam passing through the chamber, a condenser to which the outlet side of the low pressure turbine is connected and means for removing non-condensable gases from the condenser.

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