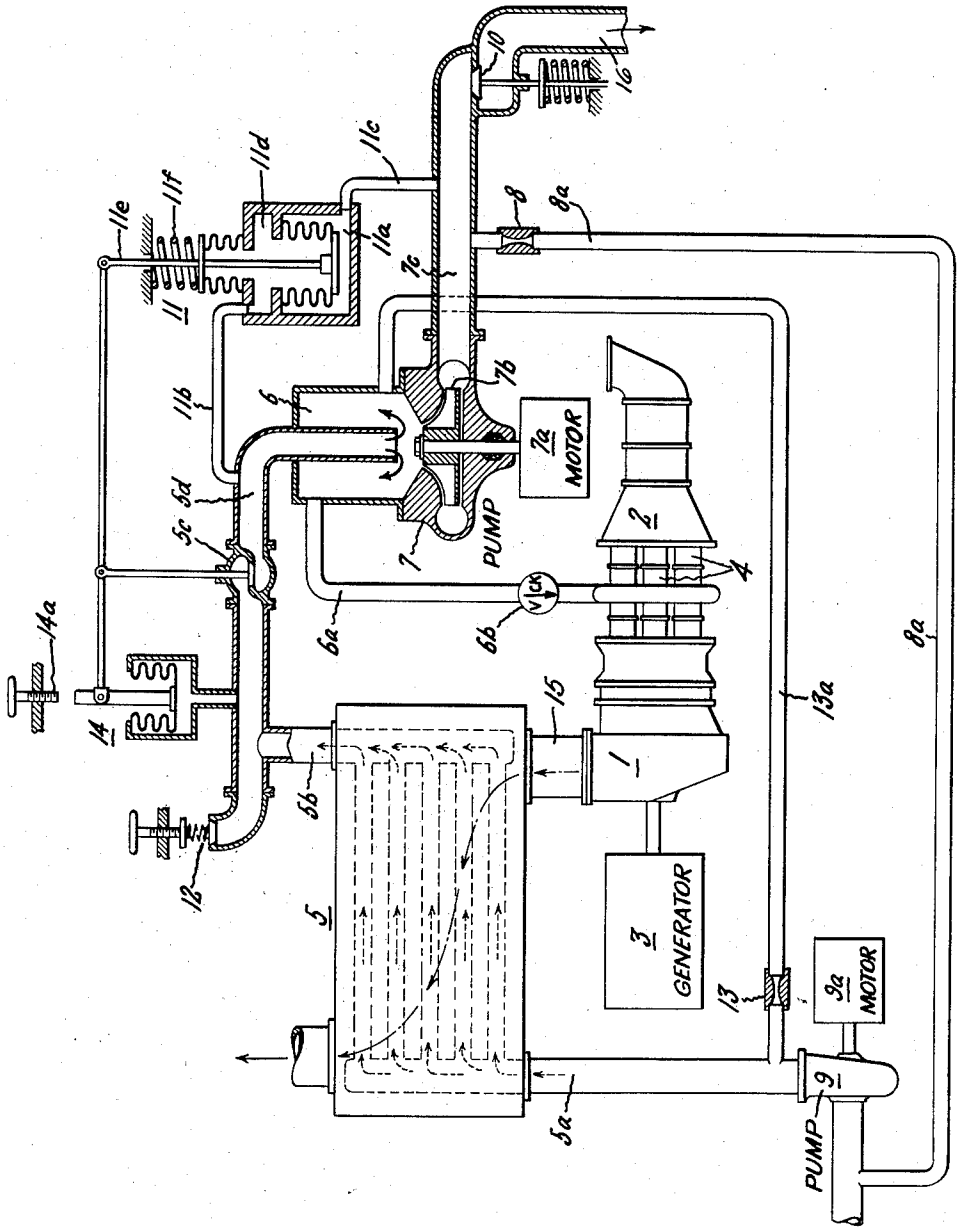
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GAS TURBINE POWER PLANT WITH STEAM INJECTION

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GAS TURBINE POWER PLANT WITH STEAM INJECTION

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My invention relates to means for removing large quantities of water from steam in a very rapid and reliable manner. Such an arrangement is useful in certain types of steam turbines and may be of great value in gas turbin powerplants operating on "steam injection" cycles.

It is well known that the efficiency and the power output of the conventional gas turbine cycle may be improved by the injection of steam into the combustion system. However, for such an arrangement to be successful, provision must be made so that large quantities of liquid water can never enter the gas turbine. Regardless of how carefully the boiler is designed and built, water carryover can result from two conditions. First, there is the possibility that the boiler feed pump may get out of control and actually flood the boiler to the point where water is forced over through the steam outlet; and the second condition may result from a very rapid drop in the steam pressure on the boiler which results in the entire mass of water boiling at such a rapid rate that large quantities of water are carried along with the steam.

It is an object of my invention to provide a means of removing entrained water in a very rapid and reliable manner and thus make possible a gas turbine powerplant with an improved steam injection system.

A further object is to provide improved means for assuring that large quantities of water can never pass beyond a certain point in the piping to a steam or gas turbine.

Another object is to provide means for removing water from the steam injected into a gas turbine powerplant operating on a steam injection cycle.

Other objects and advantages will become apparent as the following description proceeds, and the features of novelty which characterize the invention are pointed out with particularity in the claims annexed to this specification.

Briefly stated, in accordance with one aspect of the invention, in a steam injection gas turbine cycle I provide means for removing water from the steam injected into the gas turbine, comprising a centrifugal pump located in the bottom of a separating chamber. The pump is driven by a prime mover at all times. A small quantity of water is supplied to the bottom of the separator from a separate source through an orifice. This keeps the pump impeller in the bottom of the separator partially filled with water at all times. The discharge pressure of the pump builds up until the water it is receiving is discharged through an orifice back to the suction of the separate source. In the event that the separator receives additional water from the incoming steam conduit, the impeller will become more fully filled and the pump discharge pressure will rise. In the event that the rise in pressure cannot force the additional water through the discharge orifice the surplus will be discharged through a relief valve.

The nature of the invention will best be understood when described in connection with the accompanying

drawing, which illustrates diagrammatically a gas turbine powerplant incorporating the invention.

A gas turbine **1** is connected to drive a compressor **2** and a generator **3** or other suitable load device. Intake air enters the compressor **2** where it is compressed, passes into the combustion chambers **4** wherein heat is supplied thereto by burning suitable fuel, and then expanded through the gas turbine **1**. A heat recovery boiler **5** is shown connected to the exhaust of the gas turbine through conduit **15**, which boiler supplies steam to be injected into the gas turbine. However, the steam could as well be obtained from any other suitable source.

The water which will be evaporated into steam and injected into the gas turbine cycle enters the heat recovery boiler **5** through conduit **5***a*, passes in heat exchanging relation with the hot exhaust gases in the heat recovery boiler **5**, and is discharged from the heat recovery boiler **5** through conduit **5***b*. The steam from the boiler then passes through regulating valve **5***c*, conduit **5***d*, and into separating chamber **6**. The inertia of any liquid water particles entrained in the steam carries the liquid downward into the centrifugal pump **7**, while the dry steam proceeds through conduit **6***a*, check valve **6***b*, into the combustors **4**.

The centrifugal pump **7** located in the bottom of the separation chamber **6** is driven continuously by the motor **7***a*. A small quantity of water is supplied to the bottom of the separator from boiler feed pump **9** through conduit **13***a* and orifice **13**. Under such conditions, the pump **7** is running only partially filled and develops just enough pressure to remove the water through the orifice **8** and conduit **8***a* to return it to the suction side of the pump **9**. The centrifugal impeller **7***b* thus develops pressure at all times, which pressure is dependent upon the depth of the water in the pump impeller and on the construction of the impeller itself. The water furnished to the centrifugal pump **7** through orifice **13** and conduit **13***a* further acts to supply the impeller with a small quantity of water so that the impeller builds up a pressure in conduit **7***c* irrespective of whether any water is received by the centrifugal pump **7** through the steam conduit **5***d* and the separation chamber **6**. The feed water pump **9**, driven by the motor **9***a*, returns the water discharged through the orifice **8** to the heat recovery boiler through conduit **5***a*.

If substantial quantities of water came over with the steam, the impeller **7***b* will be more completely filled and will then develop sufficient pressure to open the relief valve **10** and discharge the additional water through a discharge conduit **16** to the atmosphere or to any suitable waste conduit (not shown).

So long as the centrifugal pump **7** has a greater capacity than the boiler feed water pump **9**, it can always remove from the system the maximum amount of water which could possibly enter through steam conduit **5***d*.

A pressure sensing device **14** serves to hold a predetermined pressure at the discharge side of the boiler, regardless of changes of pressure in the combustion system, and thus avoids the possibility of the boiler "priming," that is suddenly boiling so violently as to discharge large quantities of water with the steam.

A differential pressure sensing device **11** is arranged so that chamber **11***a* communicates through conduit **11***c* with the centrifugal pump discharge **7***c*; while a second chamber **11***d* in the pressure differential sensing device **11** communicates with the conduit **5***d* through conduit **11***b* so as to maintain the same pressure as the steam entering the separation chamber **6**. In the event the centrifugal pump **7** is stopped for any reason, the pressure in the centrifugal pump discharge conduit **7***c* drops and the differential pressure sensing device **11** causes rod **11***e* to move downward-

ly, which causes the stem of the regulating valve 5c to move downwardly and close valve 5c. The steam generated by the boiler would then be blown to the atmosphere through the boiler relief valve 12, until the centrifugal pump is placed back in service. The gas turbine powerplant continues to operate under these conditions, except that steam would not be injected into the combustion system of the gas turbine powerplant.

So long as the centrifugal pump is operating, the pressure differential in conduits 5d and 7c will act on the differential pressure sensing device 11 to position lever 11e and permit the pressure sensing device 14 to regulate the position of valve 5c and hold a predetermined discharge pressure on the boiler. In the event that the centrifugal pump should fail the pressure in conduit 7c would drop to zero and the spring 11f and the difference in pressure between conduits 5d and 7c would act on the differential pressure sensing device 11 to close the steam regulating valve 5c. A stop 14a is provided to prevent the pressure sensing device 14 from overriding the differential pressure sensing device 11 in the event that the centrifugal pump 7 fails.

In the event that the load on the turbine should drop off, the pressure in the combustion system 4, and therefore on the injected steam in conduit 6a, chamber 6 and conduit 5d, drops off; and the pressure sensing device 14 moves the steam regulating valve 5c in the closing direction to prevent the boiler pressure from falling too rapidly and causing the boiler 5 to "prime."

Thus, it will be seen that the invention provides improved protective means for a steam consuming device which automatically removes either small or large quantities of entrained water from the steam, and automatically shuts off the supply of steam in the event boiler pressure drops so rapidly as to cause a danger of "priming." Auxiliary protective means are provided for discontinuing the supply of steam in the event the water-removal means becomes inoperative. While the invention has other applications, it is particularly valuable in connection with gas turbine power-plants having waste heat boilers generating steam which is injected into the combustion system of the gas turbine plant.

While I have described only certain preferred embodiments of my invention by way of illustration, many modifications will occur to those skilled in the art. Specifically, the water separating components may be used in a steam turbine powerplant, as well as in the gas turbine powerplant disclosed herein. Also, various components of the system described herein may take alternate forms. For instance, the pressure responsive device 11 could be replaced by any suitable means for closing valve 5c when pump 7 stops, possibly an electrical solenoid energized by a relay responsive to flow of current to the electric motor 7a. I, of course, intend to cover in the appended claims all such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a gas turbine powerplant operating on a steam injection cycle and comprising an expansion turbine, a compressor driven by the expansion turbine and supplying motive fluid for the expansion turbine cycle, a combustion chamber for heating the motive fluid discharged from the compressor, said heated motive fluid being expanded in the expansion turbine to produce mechanical energy, and means for producing steam for injection into the combustion system, the combination of a water separator connected to remove entrained water from the steam whereby only dry steam can reach the combustion chamber, and a centrifugal purging pump continuously driven and connected to pump a small quantity of liquid supplied to keep the pump primed at all times, said pump being connected to remove any water separated from the steam by the separator, a restricted first discharge conduit whereby a small quantity of water may be discharged by the pump, a second pump discharge conduit of larger capacity than said first discharge conduit, and pressure relief valve means connected in communication with the pump and said first discharge conduit and arranged to admit water to said second discharge conduit when the rate of delivery of water from the pump exceeds the capacity of said first discharge conduit.

2. A gas turbine powerplant according to claim 1 and including automatic valve means for stopping the flow of steam to the combustion chamber when the purging pump ceases operation.

3. In a combined steam and gas turbine powerplant having a compressor, a combustion system, and a gas turbine supplying exhaust gases to a waste heat boiler, first boiler feed pump means supplying feed water to the boiler and a first steam conduit supplying steam from the boiler to the motive fluid flow path of the gas turbine powerplant, the combination of water separating means associated with said steam supply conduit and including continuously driven second pump means having an inlet chamber and a second discharge conduit, the first steam conduit including a portion discharging into said pump inlet chamber at a location immediately adjacent the inlet side of the second pump, the first steam conduit including also a portion communicating with the second pump inlet chamber at a point remote from the inlet side of said second pump, third conduit means connected to supply water at a restricted rate from the boiler feed pump means to said second pump inlet chamber, fourth conduit means connected to return water discharged by said second pump means to the inlet side of the first boiler feed pump, pressure relief valve means connected to pass quantities of water discharged from said second pump in excess of the capacity of said fourth conduit means, pressure regulating valve means in said first steam conduit and including means responsive to the pressure of the steam discharged by the boiler, boiler pressure relief valve means adapted to vent the boiler upon closing of said steam regulating valve, and means to close said steam regulating valve in the event said second pump ceases operation.

4. A water separating system in accordance with claim 3, in which the steam pressure regulating and shutoff means comprises a lever member connected to position the steam regulating valve, means responsive to the pressure of steam discharged from the boiler and having a member connected to said lever, and means responsive to the pressure differential across the water separating pump and having a member connected to a spaced portion of said lever, whereby said first pressure responsive means positions the regulating valve to control the pressure of the steam discharged from the boiler and said second pressure responsive means closes the steam regulating valve in the event operation of the water separating pump ceases.

5. In a steam generating plant including a boiler and first steam discharge conduit for supplying steam from the boiler to a consumer, the combination of means for furnishing substantially dry steam comprising first pump means having an intake chamber communicating with said steam discharge conduit, means for continuously supplying water at a limited rate to said intake chamber to prime the pump, second conduit means for disposing of the water discharged by said first pump means, whereby entrained water in the steam discharge conduit is discharged by the first pump means through said second conduit, a regulating valve in the steam discharge conduit, and pressure-responsive servo means to position said regulating valve to maintain substantially constant pressure at the discharge side of the boiler and to close said valve in the event of rapid drop in boiler discharge pressure, whereby priming of the boiler is prevented in the event of excessive decrease of pressure in the steam discharge conduit.

6. In a steam generating plant including a boiler and

a first steam discharge conduit for supplying steam from the boiler to a consumer, the combination of means for furnishing substantially dry steam comprising first pump means having an intake chamber communicating with said steam discharge conduit, means for continuously supplying water at a limited rate to said intake chamber to prime the pump, second conduit means for disposing of the water discharged by said first pump means, whereby entrained water in the steam discharge conduit is discharged by the first pump means through said second conduit, a valve for shutting off the flow of steam through said steam discharge conduit, and servo means for automatically closing said valve in the event the first pump means stops.

7. In a steam generating plant including a boiler and first steam discharge conduit for supplying steam to a consumer, the combination of means for separating entrained water from the steam comprising a first pump having an intake chamber communicating with said first steam discharge conduit, a second pump connected to supply water at a restricted rate to the intake chamber of said first pump to prime the pump, return condit means for conducting water from the discharge side of the first pump to the inlet side of said second pump, and a relief valve connected in communication with the discharge side of the first pump and said return conduit, said relief valve being arranged to open and discharge water from the discharge side of the first pump when the discharge rate of said first pump exceeds the capacity of the return conduit.

8. In a steam generating plant including a boiler and first steam discharge conduit for supplying steam from

the boiler to a consumer, the combination of means for furnishing substantially dry steam comprising first pump means having an intake chamber communicating with said steam discharge conduit, means for continuously supplying water at a limited rate to said intake chamber to prime the pump, second conduit means for disposing of the water discharged by said first pump means whereby entrained water in the steam conduit is discharged by the pump means through said second conduit, a regulating valve in the first steam discharge conduit, first pressure-responsive servo means for actuating said regulating valve, and second pressure-responsive servo means for actuating said regulating valve, said first and second servo means acting in concert on the regulating valve whereby the first servo means urges the regulating valve to maintain substantially constant boiler discharge pressure and to close in the event of rapid drop in boiler discharge pressure and the second servo means urges the regulating valve to close in the event there is a substantial drop in pressure on the discharge side of the first pump means.

References Cited in the file of this patent

UNITED STATES PATENTS

943,840	Noyes	Dec. 21, 1909
1,889,938	Thomas	Dec. 6, 1932
2,405,573	Frisch	Aug. 13, 1950
2,784,674	Carver et al.	Mar. 12, 1957

FOREIGN PATENTS

642,118	Great Britain	Aug. 30, 1950