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COMBINED STEAM AND GAS TURBINE POWER PLANT

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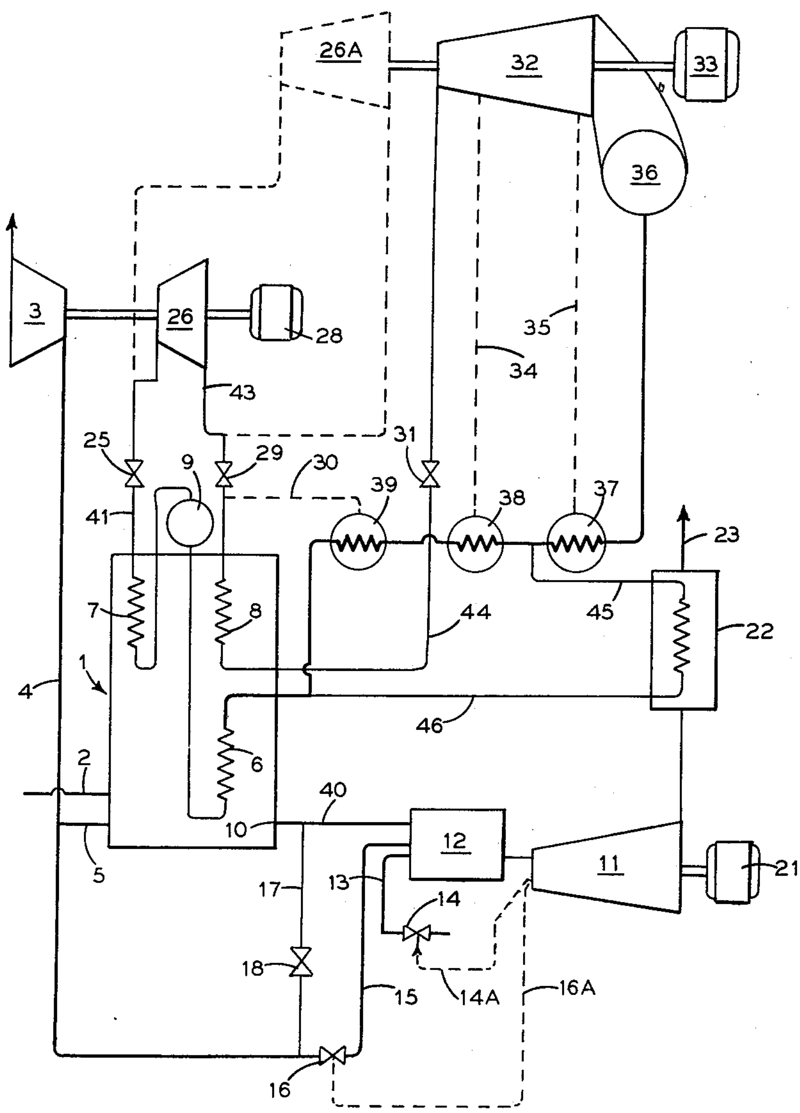

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COMBINED STEAM AND GAS TURBINE POWER PLANT

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This invention relates to binary elastic fluid power plants and more particularly to improvements in the construction and operation of supercharged or combined gas and steam turbine power plants.

The use of a gas turbine to supercharge a steam generator is well known in the art. The term "supercharged" as used herein means a combustion process wherein the pressure of the gases generated in the steam generator is of such a magnitude that useful work may be done by these gases after leaving the steam generator through expansion in a gas turbine to essentially atmospheric pressure. In this combination, a steam generator is constructed and arranged to deliver superheated steam to a steam turbine, while passing high temperature gases to a gas turbine, with the gas turbine driving a compressor which supplies the air required for maintaining high pressure combustion in the furnace of the steam generator. Experience has shown that one of the major drawbacks of a supercharged power plant of this character is its lack of flexibility in regulation, particularly at low loads, chiefly because of the limitations imposed in respect of the choice of output and pressure supplied by the air compressor.

In accordance with the invention, greatly improved flexibility in regulation of a power plant of the character described is provided by arranging the air compressor so that it is driven by a steam turbine using the first expansion of at least part of the superheated steam supplied by the steam generator. Various means of regulating this turbine permit a variation in the air output of the steam turbine-driven compressor in harmony with the requirements of the steam generator. Provisions are also made for regulating steam and gas temperatures to the steam and gas turbines.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of the invention.

The single figure is a diagrammatic illustration of a combined condensing steam power plant and a gas turbine power plant constructed and arranged in accordance with my invention.

In the binary elastic fluid power plant illustrated, a compressor 3 discharges air at high pressure through a conduit 4 and branch conduit 5 to the furnace of a supercharged natural circulation steam generator 1 for mixing with fuel supplied to the furnace by way of a conduit 2. The steam generator comprises a steam and water drum 9 constructed and arranged to receive steam and water mixtures from a steam generating section 6 and to supply saturated steam to a superheating section 7, with subsequent reheating of the steam being provided by reheating section 8. Feedwater, after being preheated in feedwater heaters 22, 37, 38 and 39, enters the steam generating section 6 and passes therethrough to the steam-water drum 9 wherein the steam is separated from the water and passed through the steam superheating section 7 for superheating to the desired degree.

From the furnace the products of combustion pass over and in contact with the steam generating and heating sections 6, 7 and 8 to a gas outlet 10, then are directed to a gas turbine 11 by way of a conduit 40 and a secondary combustion chamber 12 wherein the temperature and quantity of gases supplied to the gas turbine 11 may be increased by the combustion of a fuel introduced into the chamber 12 by a conduit 13 under control of a valve 14, with the combustion air to the chamber 12 being supplied by the compressor 3 by way of the conduit 4, air control valve 16 and a conduit 15. Another portion of the air delivered by the compressor may by-pass the steam generator 1 by way of a branch conduit 17 leading from the conduit 4 to the conduit 40 and controlled by a valve 18. Control of air flow through the conduit 17 serves to regulate the superheat and reheat steam temperatures since air supply to the furnace of the steam generator is altered by such control. Regulation of the temperature of the gases entering the gas turbine 11 is provided by turbine gas inlet temperature transmitters 14A and 16A which respectively control the operation of the fuel supply valve 14 and the air regulating valve 16. The gases discharged from the secondary combustion chamber 12 go to the gas turbine 11, through which they expand to atmospheric pressure, producing mechanical energy to drive an electric generator 21 directly connected to the shaft of the gas turbine 11. Heat from the gas turbine exhaust is recovered before discharging to a stack 23 by passing the gases through a heat exchanger 22 in direct heat transfer relation with feedwater passing to the steam generator 1.

In accordance with the invention, steam separated in the drum 9 and superheated in the steam superheating section 7 is directed by way of a conduit 41 and a regulating valve 25 to a high pressure steam turbine 26, through which it expands, producing sufficient mechanical energy to drive the compressor 3 which is directly connected to the shaft of the steam turbine 26. Thus the power supplied by the expansion of the superheated steam by the turbine 26 is directly used in the compression of the combustion air of the plant. A starting motor 28 is provided to turn over the compressor 3 and the connected steam turbine 26 until such time as the pressure, temperature and flow conditions of the steam leaving the superheating section 7 are adequate to produce the required driving power by the steam turbine.

After expansion in the turbine 26, steam is directed through a conduit 43 and regulating valve 29 to the reheating section 8, with a small quantity of the steam being bled to a feedwater heater 39 by way of a valve-controlled conduit 30.

According to circumstances, the turbine 26 may receive all or a part of the steam flow from the superheating section 7. In the latter case, the turbine 26 is arranged, as shown by a dotted line in the drawing, in parallel with a second high pressure turbine 26A, the two turbines 26, 26A thus constituting the high pressure stage of the group of steam turbines of the power plant.

The steam reheated in the heating section 8 is discharged through a conduit 44 and a regulating valve 31 to a medium and/or low pressure turbine 32, through which the steam expands with a reduction in pressure to the vacuum of a condenser 36, while developing mechanical power which is transmitted to a directly connected electrical generator 33. When provided, the turbine 26A is directly coupled to the shaft of the turbine 32 and cooperates with the turbine 32 in driving the generator 33.

The condensate resulting from the turbine exhaust steam in the condenser 36 is withdrawn by a condensate pump, not shown, and is progressively heated as it flows to the steam generating section 6 in heaters 37 and 38 by steam bled from selected pressure stages of the turbine 32 through conduits 35 and 34, and in heater 39 by steam bled from the conduit 43 through conduit 30. At a point between the heaters 37 and 38 a part of the feedwater flow is directed through a conduit 45 to the heater 22 for indirect heating by the exhaust gases of the turbine 11, then passes through a conduit 46 to rejoin the main flow of feedwater to the steam generating section 6.

With a power plant constructed and arranged as described, considerable flexibility in operation is provided, particularly at low loads. In this connection the superheat and reheat steam temperatures may be regulated by varying the quantity of air by-passing the steam generator by means of the valve 18. Varying the quantity of air passing through the conduit 17 will alter the supply of air to the furnace of the steam generator. Variation of the air supply to the furnace of the steam generator will effect a change in the furnace temperature, thereby altering the amount of heat absorbed radiantly by the steam generating section 6, while at the same time varying the quantity of products of combustion passing over the steam generating and heating sections 6, 7 and 8, so that superheat and reheat steam temperatures will be altered. In addition the valves 14, 16 provide a means of regulating the temperature of the gases admitted to the gas turbine 11 by their action on the operating conditions of the secondary combustion chamber 12. Consequently, there is provided considerable flexibility of operation in respect of the output and the pressure of the air supplied by the compressor 3.

While in accordance with the provisions of the statutes there is illustrated and described herein a specific embodiment of the invention, those skilled in the art will understand that changes may be made in the form of the invention covered by the claims, and that certain features of the invention may sometimes be used to advantage without a corresponding use of the other features.

What is claimed is:

1. In a binary elastic fluid power plant, a steam generator, fuel firing means for generating heating gases in said generator, a gas turbine receiving gases from said steam generator, a heat exchanger connected for flow of gases from said gas turbine for recovery of some of the residual heat thereof, a steam turbine receiving steam from said steam generator, and an air compressor driven by said steam turbine and operating independently of said gas turbine and supplying high pressure air for combustion to said fuel firing means, said air compressor having an output varying in direct proportion to increases and decreases in steam flow rate to said steam turbine to provide an air flow to said generator at a rate in proportion to the combustion air demands of the fuel being burned so that the rate of generation of heating gases in the generator increases and decreases in proportion to the air compressor output.

2. In a binary elastic fluid power plant, a steam generator, fuel firing means for generating heating gases in said generator, a gas turbine receiving gases from said steam generator, a heat exchanger connected for flow of gases from said gas turbine for recovery of some of the residual heat thereof, a first steam turbine receiving a part of the steam generated by said steam generator, a second steam turbine receiving the rest of the steam generated by said steam generator and connected in parallel flow relation with said first steam turbine, and an air compressor driven by said first steam turbine and operating independently of said gas turbine and supplying high pressure air for combustion to said fuel firing means, said air compressor having an output varying in direct proportion to increases and decreases in steam flow rate to said first steam turbine to provide an air flow to said generator at a rate in proportion to the combustion air demands of the fuel being burned so that the rate of generation of the heating gases in the generator increases and decreases in proportion to the air compressor output.

3. In a binary elastic fluid power plant, a steam generator including a superheater, fuel firing means for generating heating gases in said generator, a gas turbine, a secondary combustion chamber connected to receive gases from said steam generator and to discharge gases to said gas turbine, means for firing said secondary combustion chamber to regulate the temperature and supply of gases passing to said gas turbine, a heat exchanger connected for flow of gases from said gas turbine for recovery of some of the residual heat thereof, a first steam turbine receiving a part of the superheated steam leaving said superheater, a second steam turbine receiving the rest of the superheated steam leaving said superheater and connected in parallel flow relation with said first steam turbine, an air compressor driven by said first steam turbine and operating independently of said gas turbine, means supplying high pressure air for combustion from said compressor in parallel to said fuel firing means of said steam generator and of said secondary combustion chamber, and means for regulating the temperature of the steam leaving said superheater including a valve-controlled conduit for passing a part of the steam generator combustion air supply to the gas inlet of the secondary combustion chamber, said air compressor having an output varying in direct proportion to increases and decreases in steam flow rate to said first steam turbine to provide an air flow to said generator at a rate in proportion to the combustion air demands of the fuel being burned so that the rate of generation of heating gases in the generator increases and decreases in proportion to the air compressor output.

4. In a binary elastic fluid power plant, a steam generator, fuel firing means for generating heating gases in said generator, a gas turbine, a secondary combustion chamber connected for supply of gases to said gas turbine, said gas turbine being connected to said generator via said secondary combustion chamber, fuel firing means for generating heating gases in said secondary combustion chamber, a heat exchanger connected for flow of gases from said gas turbine for recovery of some of the residual heat thereof, a steam turbine receiving steam from said steam generator, and an air compressor driven by said steam turbine and operating independently of said gas turbine and supply high pressure air for combustion to the fuel firing means of said steam generator and of said secondary combustion chamber, said air compressor having an output varying in direct proportion to increases and decreases in steam flow rate to said steam turbine to provide an air flow to said generator at a rate in proportion to the combustion air demands of the fuel being burned in the generator so that the rate of generation of the heating gases in the generator increases and decreases in proportion to the air compressor output.

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SAMUEL LEVINE, *Primary Examiner.*

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,194,015 July 13, 196

Pierre Henri Pacault

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 32, for "direct" read -- indirect --.

Signed and sealed this 12th day of April 1966.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents