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Aguet

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[54] **GAS/STEAM TURBINE PLANT AND A METHOD OF OPERATING SAME**

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[51] **Int. Cl.** **F01k 23/06**

[58] **Field of Search** .... 60/39.05, 39.18 B, 60/39.55, 73; 122/479

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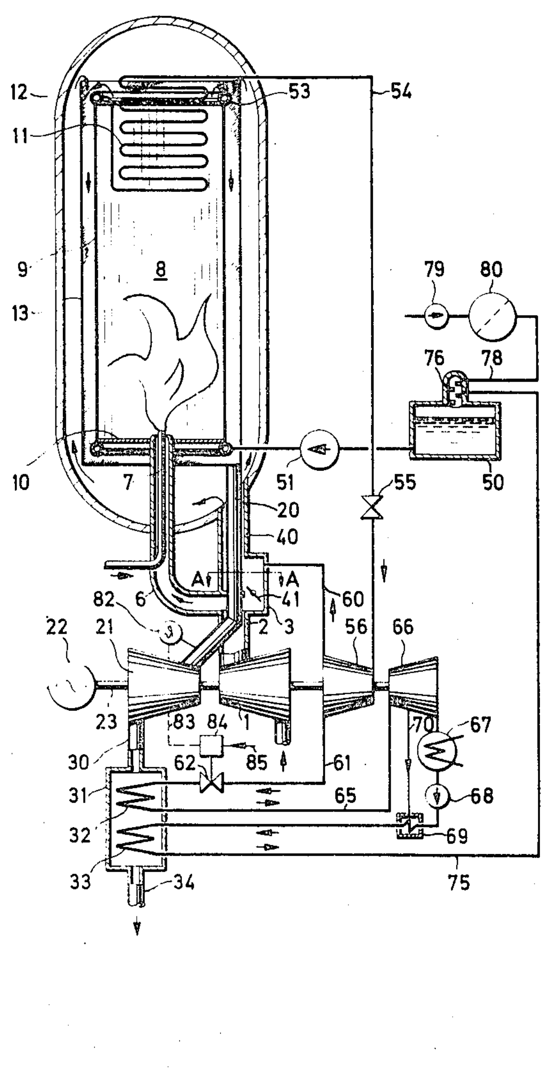
[57] **ABSTRACT**

A second steam turbine is connected to the existing steam turbine to be operated by the exhaust steam of the existing steam turbine. In addition, the exhaust steam from the existing steam turbine is heated by the waste gas of the plant before entering the second turbine.

The air supply is also connected over a throttle to the steam line into the pressure vessel to cool the outside of the combustion chamber walls.

9 Claims, 2 Drawing Figures



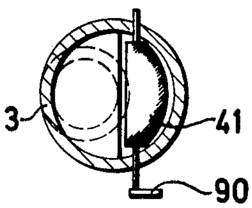


Fig. 2

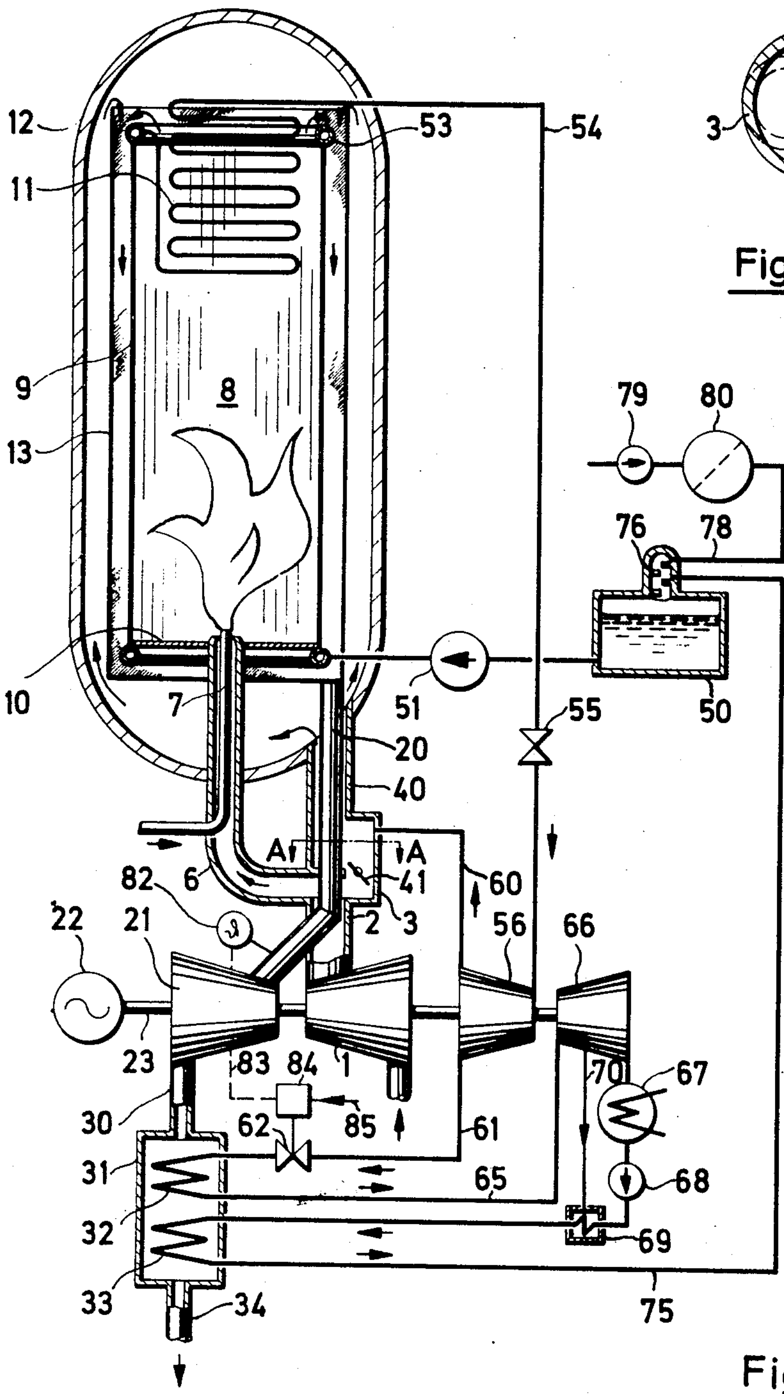


Fig.1 *Inventor:*

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GAS/STEAM TURBINE PLANT AND A METHOD OF OPERATING SAME

This invention relates to a gas/steam turbine plant and to a method of operating the same.

Heretofore, it has been known to operate a gas/steam turbine plant by feeding water to heating elements in a combustion chamber for evaporation and superheating at a pressure higher than the combustion chamber pressure. The superheated steam has thereafter been expanded in a steam turbine and, after expansion, a portion of the steam has been mixed with the combustion gases before entering into a gas turbine. These gas/-steam turbine plants have usually had a combustion chamber with heating elements to evaporate and superheat feed water and a steam turbine connected to the combustion chamber.

Plants of this type allow the building of a gas/steam turbine plant which is particularly suitable for producing peak current while combining high efficiency, approaching that of conventional steam power stations, with a much lower initial cost.

The present invention relates to a further development of the known plant and is intended to further increase the output and thermal efficiency of such a plant without enlarging the combustion chamber or the heating surfaces contained in this chamber. In particular, the invention is intended to be suitable where clean fuels (that is, fuels with a lower content of impurities such as, for example, sulphur or vanadium) are used.

The method by which this end is achieved is characterized in that a second portion of the expanded steam is reheated in heating elements and then, performing work, is expanded in a second steam turbine to a condenser pressure below atmospheric pressure.

The plant is characterized by a second steam turbine which is connected in series with the first steam turbine and which is connected by its inlet to the outlet of the first steam turbine by way of a reheater heating surface and by its outlet to a condenser. In addition, the plant includes a throttling means in one of the steam components in order to control the distribution of the steam volume between the combustion chamber and the second steam turbine.

To this end, the plant has a throttling member, e.g., a regulating valve in the line connecting the inlet of the second steam turbine to the outlet of the first steam turbine. The operation of this throttling member is made to depend on the temperature of the gas/steam mixture at the inlet of the gas turbine so that throttling is increased when the temperature rises and vice-versa. This provides low-loss control economically by simple means.

In addition, a delivery line of an air compressor which leads to a burner in the combustion chamber is provided with a branch line which contains a throttling member and leads into a space between the heating elements and an outer pressure shell of the combustion chamber. By this means, the air delivered by the compressor can be used to cool the combustion chamber shell in cases where a large proportion of the steam is fed to the second steam turbine and therefore is not available for mixing with the combustion gases.

These and other objects and advantages of the invention will become more apparent from the following detailed description and appended claims taken in conjunction with the accompanying drawings in which:

FIG. 1 diagrammatically illustrates an arrangement of a gas/steam turbine plant embodying the invention; and

FIG. 2 illustrates a cross-sectional view through the throttling member in the air compressor delivery line along line A—A in FIG. 1.

Referring to FIG. 1, the gas/steam turbine plant includes an air compressor **1** which delivers compressed air **2** to a distributor **3**, from which some of the air is fed along a line **6** to a burner **7**, e.g., having an adjustable air outlet cross-section, at the bottom of a cumbustion chamber **8**. The combustion chamber **8** has side walls **9**, consisting of tubes which are welded together in a fluid-tight manner, and an insulating floor **10**. The upper part of the combustion chamber **8** contains a superheater **11** in the path of the flue gases from the burner **7**. Also, the combustion chamber **8** is enclosed in a pressure vessel, such as a pressure shell **12**. A sheet metal jacket **13** which is open at the top is positioned between the combustion chamber walls **9** and floor **10** and the inner surface of the vessel **12** to partially enclose the combustion chamber **8**. A flue gas line **20** is connected to the bottom of the jacket **13** and leads to the inlet of a gas/steam turbine **21**, which shares a common shaft **23** with the compressor **1** and an electric generator **22**. The outlet of the gas/steam turbine **21** is connected by a line **30** to a heat exchanger **31** containing a reheater **32** and a feed water heater **33**. The heat exchanger **31** is connected by a line **34** to a stack (not shown) so that the cooled waste gas and the mixed-in steam can be exhausted. The line **20** is also enclosed by an air line **40** which connects the distributor **3** to the interior of the pressure vessel **12**.

Referring to FIGS. **1** and **2**, a throttle valve **41** is provided inside the distributor **3** and is adjustable by means of a lever for purposes as described below.

Referring to FIG. **1**, the tubes in the combustion chamber walls **9** form an economiser and evaporator heating surfaces or elements, as is known, to which feed water is fed from a feed water tank **50** by a feed pump **51**. At the upper end of the combustion chamber walls **9**, the tubes forming these walls lead into a header **53** which is connected to the tubes in the superheater **11**. A live steam line **54** containing a live steam valve **55** connects the superheater **11** to a first steam turbine **56**, which is a high pressure turbine.

The turbine **56** has two outlets. The first outlet is connected by a line **60** to the distributor **3**, which it enters downstream of the throttle valve **41**. The second steam outlet is connected to a line **61** with a regulating valve **62** leading to the reheater **32**. A line **65** extends to a second steam turbine **66** from the reheater **32** to direct the superheated steam thereto. This steam turbine **66** which is a low pressure turbine has an outlet which feeds the steam to a condenser **67**. The condenser **67**, in turn, connects over a condensate pump **68** which pumps the condensate through a bleeder steam economiser **69** to the feed water heater **33**, which is heated by the waste gases from the gas/steam turbine **21**. The bleeder steam economiser **69** is heated with superheated steam drawn from the low pressure turbine **66** along a bleeder line **70**.

A line **75** connects the heater **33** into a deaerator **76** on top of the feed water tank so as to conduct the condensate flow thereto. A pump **79** feeds make-up water to the deaerator **76** along a make-up water line **78**, by way of a desalting plant **80**. In addition, the flue gas line

20 is provided with a temperature sensor 82, the signal from which is fed along a signal line 83 to a controller 84. This controller also, by way of a line 85, receives a desired-value signal which may, for example, depend on the type of fuel used. The controller 84 serves to operate the regulating valve 62.

The plant illustrated in FIGS. 1 and 2 operates as follows:

The shaft 23 runs at a constant speed, so that the compressor 1 delivers a substantially constant volume of air regardless of the load on the plant. Some of the air is fed along the line 6 to the burner 7, approximately in proportion to the load, whereas the remainder flows through the throttle valve 41 and line 40 into the pressure vessel 12 exteriorly of the heating elements, together with that portion of the steam expanded in the first turbine 56 which is fed along the line 60. The volume rate of flow of this steam drops as the load decreases. The steam/air mixture formed in the distributor 3 cools the surface of the pressure vessel 12 and then, at the upper end of this vessel 12, mixes with the combustion gases leaving the combustion chamber 8. The mixture then flows down through the space left between the combustion chamber wall 9 and the jacket 13 and flows through the pipe 20 to the gas/steam turbine 21. The mixture then performs work in the turbine 21 before passing on into the heat exchanger 31 and finally through the line 34 in the stack.

The temperature of the flue gases at the upper end of the combustion chamber 8 depends on the type of fuel. Fuels which burn with a roaring flame, for example, light oil and gas, radiate less heat so that less heat is transferred to the combustion chamber walls 9, less steam is produced and the discharge temperature of the flue gases is higher than if heavy oil is used. However, the plant is able to adapt to these conditions so as to burn light oil and gas as well as heavy oils which contain sulphur and vanadium.

When "clean" fuels, for example, light oil and gas, are used, the temperature at the inlet of the gas/steam turbine 21 may be relatively high, for example, 850° C. In such a case, the desired value 85 for the controller 84 is set at 850° C, with the result that the valve 62 allows a large quantity of steam to flow down, reducing the back pressure in the distributor 3. The compressor 1, in accordance with its characteristic curve, supplies somewhat more air permitting more fuel to be burned in the combustion chamber 8. The output of the plant is therefore increased.

When at full load, the throttle valve 41 is nearly or completely closed and the pressure vessel 12 and the combustion gases from the combustion chamber 8 are cooled almost entirely by steam from the line 60.

As the valve 41 is opened progressively as the load decreases, the proportion of air from the compressor 1 which is fed to the pressure vessel 12 progressively increases. To this end, the lever 90 is adjusted by means of the plant load transmitter (not shown). At the same time, the volume of steam arriving through the line 60 decreases due to the temperature-maintaining effect of the controller 84. The controller 84 is designed to reduce the flow cross-section at the valve 62 when the temperature-measuring device 82 detects a temperature rise at the inlet of the turbine 21, and vice-versa. As a result, the proportion of steam used for cooling purposes changes so that the temperature at the inlet of the gas/steam turbine 21 is kept constant. The remainder of the steam is processed in the second steam turbine 66, i.e., the low pressure turbine.

Because the temperature at the inlet of the gas/steam turbine 21 is kept constant as the load decreases, a drop in the efficiency of this turbine at partial load is prevented. Since, at the same time as the load decreases, the volume of steam required for gas cooling drops not only absolutely but also relative to the load, the proportion of the steam fed to the low pressure turbine 66 rises. As a result, the efficiency of the low pressure turbine 66, also, drops only slightly as the load decreases. The overall efficiency of the plant at partial load is therefore exceptionally high.

When heavy oils are burned, the steam production in the combustion chamber walls 9 increases and the discharge temperature of the flue gases leaving the combustion chamber 8 drops. Because of the impurities in the heavy oil, the temperature at the gas turbine inlet must be lower than in the preceding case, for example, 600° to 650° C. To this end, by means of a suitable throttling action at the valve 62, the volume of steam fed along the line 60 to the pressure vessel 12 is increased. This is done by suitably reducing the desired-value signal fed along the signal line 85 to the controller 84 when heavy oil is used.

In order to facilitate starting of the plant, there may be provision for disconnection of the steam turbine 66 and/or 56 from the common shaft 23 of the gas turbine set 1, 21, 22. Alternatively, however, the steam turbines 56, 66 may be completely separate from the gas turbine set and have their own electric generator.

A gas/steam turbine plant embodying the invention has the advantage of permitting, in return for a relatively small rise in initial cost, greater efficiency, particularly at partial load. Also, if clean fuel is used, the plant can have an output increase of up to 20% while still being equally suitable for poorer fuel. The apparatus required in addition to the known installation includes the low pressure turbine 66 with the reheater 32, the condenser 67 and the condensate pump 68. The desalting plant 80, however, can be smaller since some of the steam formed in the combustion chamber walls is recovered by the condenser 67.

What is claimed is:

1. A gas/steam turbine plant comprising

a combustion chamber;

a gas turbine connected to said combustion chamber to receive combustion gases therefrom and exhaust waste gas;

heating elements within said combustion chamber for evaporating and superheating feed water to steam;

a first steam turbine connected to said heating elements to receive steam therefrom and to expand the received steam;

a second steam turbine connected to said first steam turbine to receive and expand a portion of the expanded steam therein while performing work;

a first means between said steam turbines for heating the expanded steam from said first turbine prior to delivery to said second turbine;

a second means between said first steam turbine and said combustion chamber for delivering a portion of the expanded steam from said first steam turbine into said combustion chamber exteriorly of said heating elements upstream of said gas turbine, said second means including a regulating valve between said steam turbines for controlling the flow of steam to said second steam turbine; and

a temperature sensing means for sensing the temperature of the combustion gases delivered to said gas turbine said sensing means being connected to said regulating valve for adjusting said regulating valve to decrease the flow of steam therethrough in response to an increase in sensed temperature and vice versa.

2. A gas/steam plant as set forth in claim 1 wherein said first means is connected downstream of said gas turbine to pass the expanded steam from said first steam turbine in heat exchange relation to the waste gas from said gas turbine.

3. A gas/steam plant as set forth in claim 1 further comprising a pressure shell enclosing said combustion chamber, a compressor, a burner in said combustion chamber, a delivery line between said compressor and burner for delivering compressed air into said burner, a branch line between said delivery line and said shell for delivering air between said shell and said combustion chamber, and a throttling member in said branch line for controlling the flow of air therethrough and wherein said second means is a line between said first steam turbine and said branch line for delivering steam into said branch line for entry into said shell.

4. A gas/steam turbine plant comprising

a pressure vessel;

a combustion chamber within said pressure vessel;

a compressor connected with said combustion chamber for delivering air thereto and selectively connected to said pressure vessel for delivering air therein;

a gas turbine connected with said combustion chamber to receive combustion gases therefrom;

heating elements within said combustion chamber for evaporating and superheating feedwater to steam;

a first steam turbine connected to said heating elements to receive steam therefrom and to expand the received steam;

first means connecting said first steam turbine with said pressure vessel for delivering steam therein exteriorly of said heating elements;

a second steam turbine connected to said first steam turbine to receive and expand a portion of the expanded steam therein while performing work; and

second means between said steam turbines for controlling the portion of the expanded steam delivered to said second steam turbine in response to the temperature of the combustion gases received in said gas turbine whereby the portion of expanded steam delivered to said second steam turbine decreases in response to an increase in said temperature while the portion of expanded steam delivered to said pressure vessel increans and vice versa.

5. A gas/steam turbine plant as set forth in claim 4 wherein said second means includes a line means between said steam turbines for passing steam therebetween, a regulating valve in said line means, and a temperature sensor connected between said regulating valve and said gas turbine for sensing said combustion gas temperature and for feeding a signal to said valve in response thereto.

6. A gas/steam turbine plant as set forth in claim 4 which further comprises a reheater between said steam turbines for receiving the expanded steam and a heat exchanger enclosing said reheater and connected to said gas turbine for receiving waste gas therefrom to heat the steam in said reheater.

7. A gas steam turbine plant comprising

a pressure vessel having an inner surface;

a combustion chamber within said pressure vessel;

a jacket having an open end positioned between said combustion chamber and said pressure vessel inner surface to partially enclose said combustion chamber;

a compressor connected with said combustion chamber for delivering air thereto and selectively connected to said pressure vessel for delivering air therein between said jacket and said pressure vessel inner surface to cool said surface;

a gas turbine connected with said combustion chamber to receive combustion gases therefrom;

heating elements within said combustion chamber for evaporating and superheating feed water to steam;

a steam turbine connected to said heating elements to receive steam therefrom for expansion; and

means connecting said steam turbine with said pressure vessel for delivering expanded steam therein exteriorly of said heating elements.

8. A gas/steam turbine plant as set forth in claim 7 further comprising a branch line between said compressor and said pressure vessel for delivering air to said pressure vessel and a throttle valve in said branch line for controlling the amount of air delivered to said pressure vessel.

9. A gas/steam turbine plant as set forth in claim 8 wherein said branch line leads into a space between said pressure vessel and said jacket.

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