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Dibelius et al.

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[54] **STEAM INJECTION SYSTEM FOR A GAS TURBINE**

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[52] **U.S. Cl.** **60/39.55,** 60/39.3

[51] **Int. Cl.** **F02c 7/18**

[58] **Field of Search** 60/39.55, 39.05, 60/39.59, 39.53, 39.3; 110/60, 80; 431/190, 4

[56] **References Cited**

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[57] **ABSTRACT**

Steam injection nozzles for augmenting the power output of a gas turbine are arranged to selectively inject steam into the combustion liner downstream of the combustion reaction zone. The steam injection nozzles are spaced from but aligned with selected air holes in the liner, so that the injected steam restricts entry of air into the liner when the steam is on. Air is admitted through the holes into the liner when the steam is off, thus maintaining the proper pressure drop across the liner in either wet or dry operating mode.

4 Claims, 3 Drawing Figures

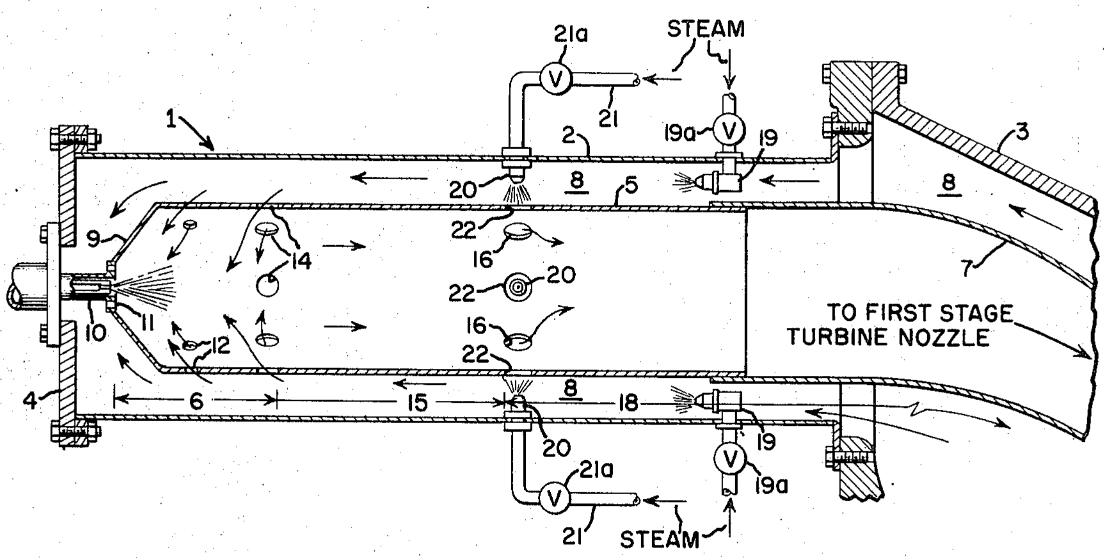


FIG.1

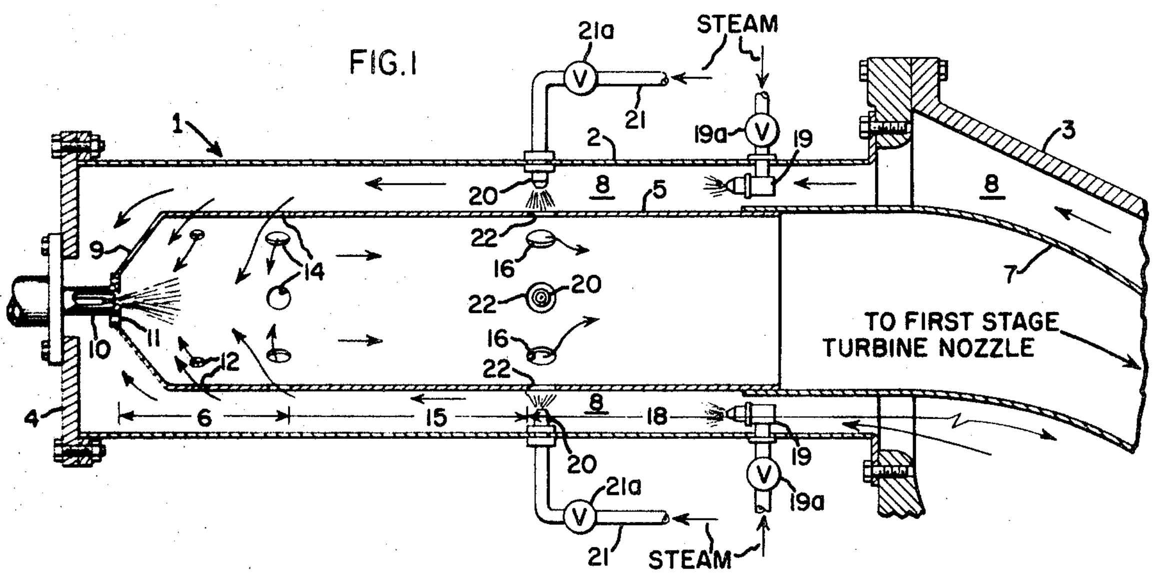


FIG.2

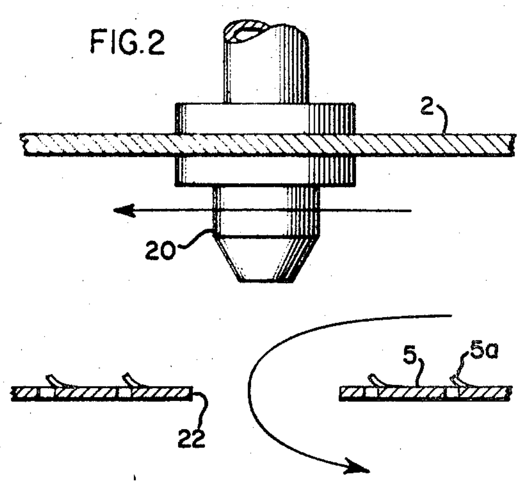
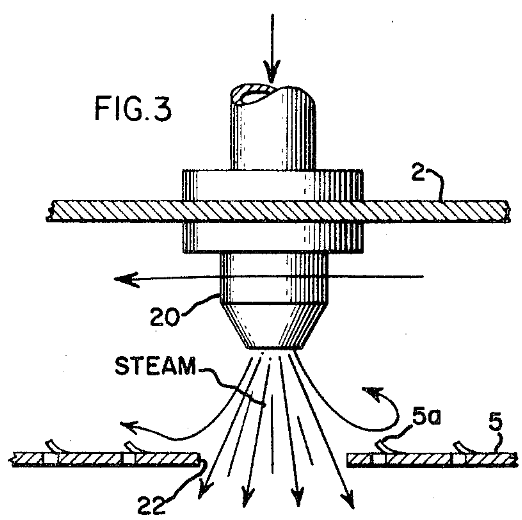


FIG.3



STEAM INJECTION SYSTEM FOR A GAS TURBINE

BACKGROUND OF THE INVENTION

This invention relates generally to steam injection systems for gas turbines and more particularly to steam injection systems for gas turbine combustors of the type which employ a perforated liner inside a casing supplied with combustion and dilution air.

It is known that water or steam may be injected into the gas turbine at various points within a cycle to increase the mass flow of motive fluid to augment gas turbine power, or to control the chemistry of the motive fluid such as reducing nitric oxide production. For example, the prior art shows provisions for injecting steam or water at many locations in a gas turbine cycle, such as the compressor inlet (U.S. Pat. No. 2,863,282 to Torell), at the compressor outlet (U.S. Pat. No. 3,280,555 to Charpentier), by aspiration within the fuel nozzle (U.S. Pat. No. 3,224,195 to Walsh), in the space between the combustion liner and its casing (U.S. Pat. No. 3,038,308 to Fuller), in a jacket around the combustion liner (U.S. Pat. No. 3,359,723 to Bohensky) and by spray nozzles inside the combustion liner (U.S. Pat. No. 2,669,091 to Schutte).

There is a limit to the amount of steam which may be added into the combustion reaction zone in the liner, because of degradation of the combustion process. On the other hand, if steam is added downstream of the combustion zone inside the liner, a back pressure is developed in the liner.

This is because the steam added is at a lower temperature and may contain some entrained moisture, leading to a volumetric expansion, both due to increase of temperature and evaporation of the moisture. Another reason for increased back pressure is that the steam flows through the critical flow turbine nozzle but not through the compressor.

Since the velocity of the air flow through the holes in the liner is dependent upon the pressure drop across the liner, and since sufficient air velocity is necessary in order to supply the air and provide mixing energy, this pressure drop must be maintained. If the liner is designed with the proper number of air holes to give the correct pressure drop without steam injection (dry), this pressure drop becomes inadequate when steam is added because of the increased back pressure, and the result is insufficient velocity of air to provide mixing.

Accordingly, one object of the present invention is to provide a gas turbine combustion system which maintains proper pressure drop across the combustion liner either with or without steam injection.

Another object of the invention is to provide an improved construction for selectively adding or not adding steam through the combustion liner downstream of the combustion reaction zone, which functions equally well in either mode.

Another objective is to add steam downstream of the combustion reaction zone while at the same time allow spillage of sufficient steam to flow into the reaction zone for nitric oxide abatement.

SUMMARY OF THE INVENTION

Briefly stated, the invention comprises a combustion liner disposed in a casing supplied with air, the liner having combustion air holes and downstream tempering air holes. Stream spray nozzles are disposed between the casing and the liner. The nozzles are aligned with and spaced from selected tempering holes. Steam injected through the nozzles restricts air flow through the holes when steam is on and admits flow of additional tempering air through the holes when the steam is off. Some steam spills to flow into the combustion reaction zone. This spillage steam also insures a seal so that no air enters the hole, thereby forcing air thru fewer liner holes. Accordingly, this causes a greater pressure drop to compensate for the increased back pressure when steam is flowing.

DRAWING

The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however, both as to organization and method of practice, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which:

FIG. 1 is a horizontal elevation, partly in section, of a single combustion chamber in a gas turbine, and

FIGS. 2 and 3 are enlarged cross-sections illustrating a steam injection nozzle under two modes of operation.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, a typical combustion chamber for use in a gas turbine is generally indicated at **1.** Combustion chamber **1** is of the type where the compressed air from the compressor (not shown) is directed in a reverse flow. The reverse flow of such a combustion chamber is well known in the art and provides the advantage of heating the compressed air before its use in the combustion processes.

Combustion chamber **1** is comprised of a generally cylindrical outer casing **2** to which is attached the casing **3.** Casing **3** in turn connects with the turbine section (not shown). The outer casing end cover **4** closes off the end of outer casing **2** opposite the casing **3** such that the volume within outer casing **2** is sealed from the atmosphere. Extending in a generally axial direction and generally coaxial with outer casing **2,** is the combustor liner **5.** As is well known in the art, it is within the liner **5** at the head end or combustion reaction zone **6** where the combustion process takes place in an operating combustor for gas turbines. As the hot combustion products proceed through the cylindrical liner **5,** they are tempered with diluting air. They then reach the transition liner **7** which directs the tempered combustion products to the first stage nozzle (not shown). An annular air space **8** surrounds the liners **5** and **7** in order to accommodate the flow of the compressed air.

Generally closing off the end of liner **5** toward the outer casing end cover **4** is the liner end cap **9** which accommodates the fuel nozzle generally indicated as **10.** The liner end cap **9** is generally in the shape of a truncated cone, the top of which is for the accommodation therein of the fuel nozzle assembly **10.** The air swirler assembly **11** is attached to the cap **9** but may also be attached to the fuel nozzle. The fuel nozzle assembly **10** may be any convenient type known to the art which can be accommodated in the head end of the liner **5** and particularly in the end cap **9.** Fuel nozzle **10** is of the variety which is capable of atomizing hydrocarbon fuels. The fuel nozzle **10** may be of the air atomizing type or pressure atomizing type. Alternatively it can be of the non-atomizing type adapted to inject gaseous fuel.

It is known in the art that the liners of combustion chambers are provided with spaced holes for the entry thereinto of the air which supports the combustion and also cools and dilutes the products of combustion.

As indicated on FIG. **1**, tehre are two rows of combustion air holes. A first row **12** is comprised of **8** holes circumferentially spaced about the liner **5**. A second row **14** is again comprised of **8** holes circumferentially spaced about liner **5**. Rows **12** and **14** are within combustion reaction zone **6**.

Following the row of holes **14** downstream (in relation to the flow of combustion products) in an axial direction, is the "thermal soaking" region of the liner **5**. This is indicated as **15** on FIG. **1**. The "thermal soaking" region **15** is closed in that there are no large circumferentially spaced holes along this axial length of liner; however, louvers or slits for metal cooling air are positioned throughout the length of liner **5**, but are not shown for clarity. The louvers are utilized for cooling the liner **5** and the air which enters the louvers does not contribute to the combustion process to an important degree.

Positioned at the end of the thermal soaking region **15** are a plurality of circumferentially spaced tempering air holes **16**. The actual size and number of tempering air holes **16** will depend upon the amount of tempering air to be added to the combustion products as they leave the soaking region **15**. The tempering region of the liner **5** is indicated on FIG. **1** as **18** and extends generally from the tempering air holes **16** to the first stage nozzle. The purpose of the tempering air holes **16** is to allow a portion of the compressed air which is relatively cool as compared to the hot combustion products to temper the combustion products before the overall air-combustion product mixture enters the first stage nozzle. Tempering holes **16** are large enough to allow sufficient penetration of the cooler tempering air into the combustion products so that the desired first stage turbine inlet temperature is achieved.

In order to inject steam into the cycle at the compressor discharge point or, in other words, upstream of the combustion reaction zone **6**, a first set of steam injection nozzles **19** may be disposed in the annular space between casing **2** and liner **5** and selectively supplied with a source of steam. Too much steam injected in nozzles **19** would tend to degrade the combustion reaction taking place in zone **6**, since the steam from nozzles **19** enters along with the air through combustion holes **12, 14** into the reaction zone.

In accordance with the present invention, a second set of steam injection nozzles **20** are circumferentially spaced around the liner and supplied with a source of steam through pipes **21**. This steam may be supplied from the same source as nozzles **19** and added through nozzles **19, 20** either at the same time or separately. Control of this steam is symbolically shown by valves **21***a* while control of nozzles **19** steam is symbolically shown by valves **19***a*.

Nozzles **10** are spaced from and aligned with the tempering air holes **22**. Nozzles **20** are of the type designed to give a wide angle solid-cone spray so as to substantially blanket the open area of holes **22**. A suitable nozzle for this purpose is known as solid-cone vortex nozzle and may be commercially obtained from the Monarch Nozzle Co.

The number of air tempering holes **22** which are provided with spray nozzles **20** and the number of tempering holes **16** which have no spray nozzles depend upon the particular design. The restriction of flow area when holes **16** only are admitting air should be such as to compensate for the volumetric expansion of the injected steam and back pressure due to choked turbine nozzle. In the embodiment shown, there are four open air tempering holes **16** and four holes **22** provided with spray nozzles, these being alternated and uniformly spaced around the liner circumference.

FIGS. **2** and **3** show enlarged views of one of the nozzles **20** and one of the holes **22**. Here the cooling louvers **5***a* in the liner wall are seen. When steam is not being injected, air flows toward the combustion reaction zone **6** and also flows through hole **22** to enter the tempering zone **18** downstream of the combustion zone.

In FIG. **3**, when the steam is one, hole **22** is substantially closed off from the entry of air. Some of the overflow steam may be blown toward the combustion zone permitting partial air admission depending upon the design. This overflow steam aids in nitric oxide abatement.

OPERATION OF THE INVENTION

Operation of the invention is as follows. When steam injection is not desired, tempering air flows into the liner both through holes **16** and **22**. The pressure drop across the liner is determined by the effective area of both sets of holes. When stream injection is desired, steam added into the liner tends to expand. Without the invention this would develop a back pressure and would normally reduce the pressure drop across the liner. With the invention, however, holes **22** are substantially blocked and air flow into the liner in the tempering zone takes place largely through holes **16**. Since these holes are only half in number in the embodiment shown, pressure drop across the liner is maintained. Thus proper air flow velocity through the combustion air holes **12, 14** and the remaining tempering air holes **16** and other air inlet holes in the liner is correct to provide the proper mixing energy for combustion stability and tempering of the cOmbustion products to the required turbine inlet temperature.

While there has been described what is considered to be the preferred embodiment of the invention, other modifications will occur to those skilled in the art and it is desired to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In a gas turbine having at least one combustion chamber comprising an elongated casing supplied with air and adapted to burn fuel in a liner spaced within said casing, the liner including combustion air holes supplying air to a combustion reaction zone and a plurality of tempering air holes supplying air to a tempering region in the liner and downstream from the combustion reaction zone, the improvement comprising:

conduit means supplied with a source of steam for injection into said tempering region,

a plurality of steam nozzles mounted on said casing and directed into the space between said casing and said liner, said nozzles being aligned with and spaced from selected tempering air holes, said nozzles being adapted to spray steam so as to substantially fill the open area of said selected tempering air holes.

2. The combination according to claim 1, wherein the total number of said tempering air holes in said liner are sized and arranged to provide a desired pressure drop across the liner when said nozzles are not supplied with injection steam, and wherein the selected tempering air holes which are fitted with steam injection nozzles are sized and arranged such that the remainder of liner air holes admit a reduced air flow such as to compensate for volumetric expansion of steam injected through the selected tempering air holes fitted with nozzles.

3. The combination according to claim 1, wherein additional steam nozzle means are disposed in the space between casing and liner and arranged to direct steam flow substantially toward the combustion reaction zone of the liner.

4. A steam injection system for a gas turbine comprising:

at least one elongated combustion casing with an open end and a closed end and supplied with air at the open end thereof from the gas turbine,

a combustion liner with a closed end and an open end coaxially disposed within said casing and arranged to direct combustion products from a combustion

reaction zone near its closed end toward the open end of said casing and liner,

fuel nozzle means injecting fuel into said liner closed end,

a plurality of combustion air admission holes near the closed end of the liner for supporting combustion of said fuel in said combustion reaction zone,

a plurality of tempering air holes axially spaced from said combustion air holes toward the open end of the liner,

a plurality of steam injection nozzles equal to or fewer in number than said tempering air holes, said nozzles being mounted on the casing and directed into the space between the liner and casing, each nozzle being directed toward a selected one of said tempering air holes and adapted to substantially fill said hole, with steam and

a conduit connected between a source of steam and said nozzles along with means to selectively supply steam through the conduit to said nozzles, whereby air is admitted through all of said air tempering holes when the steam is off, but primarily through a lesser number of the air tempering holes when steam is on.

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