

- [54] SELF COMPENSATING FLOW DIVIDER
FOR A GAS TURBINE STEAM INJECTION
SYSTEM

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 [58] **Field of Search**..... 60/39.55, 39.53,
 60/39.05, 39.3, 39.59; 110/60, 80; 431/190,
 4; 137/81.5

- [56]
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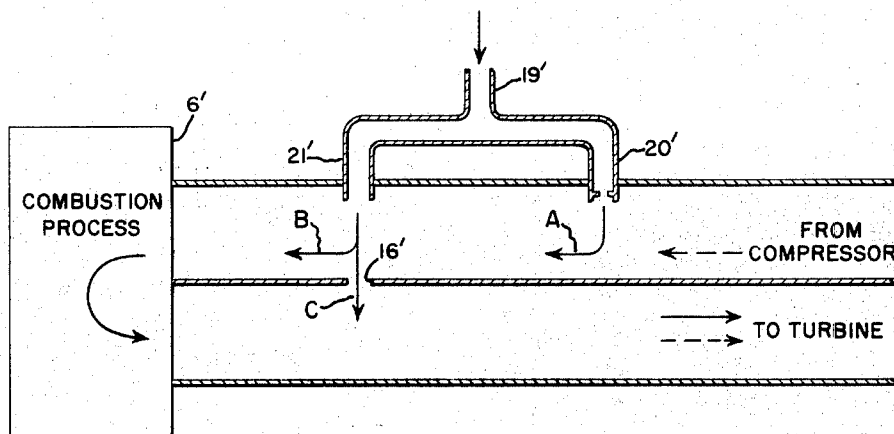
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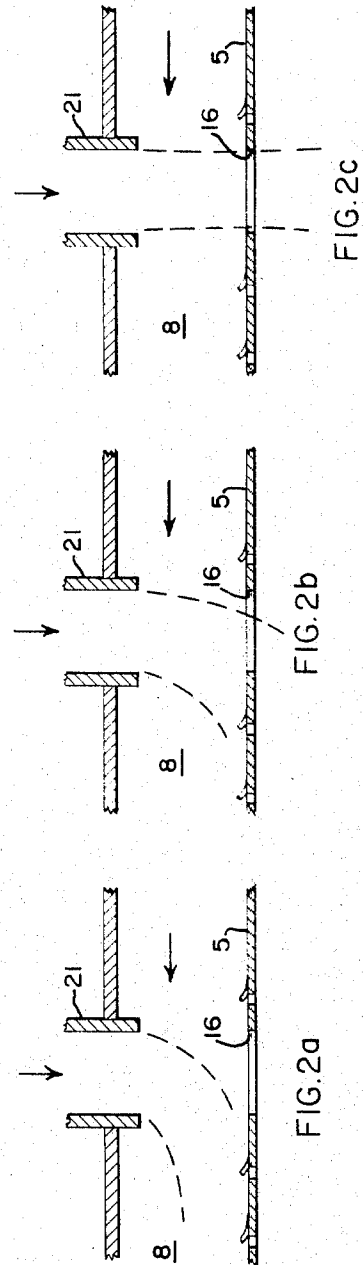
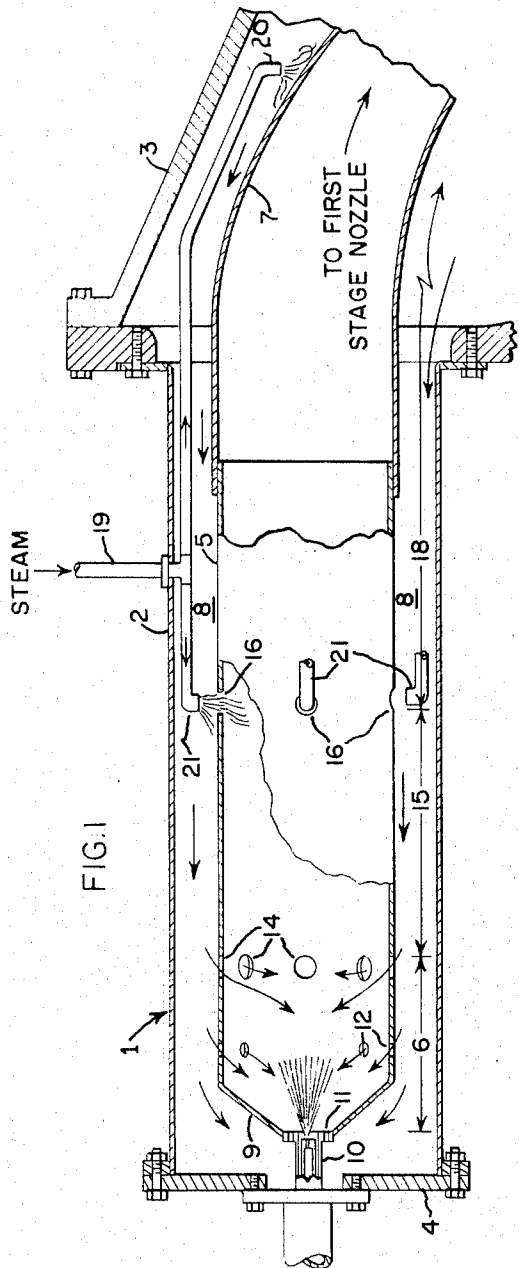
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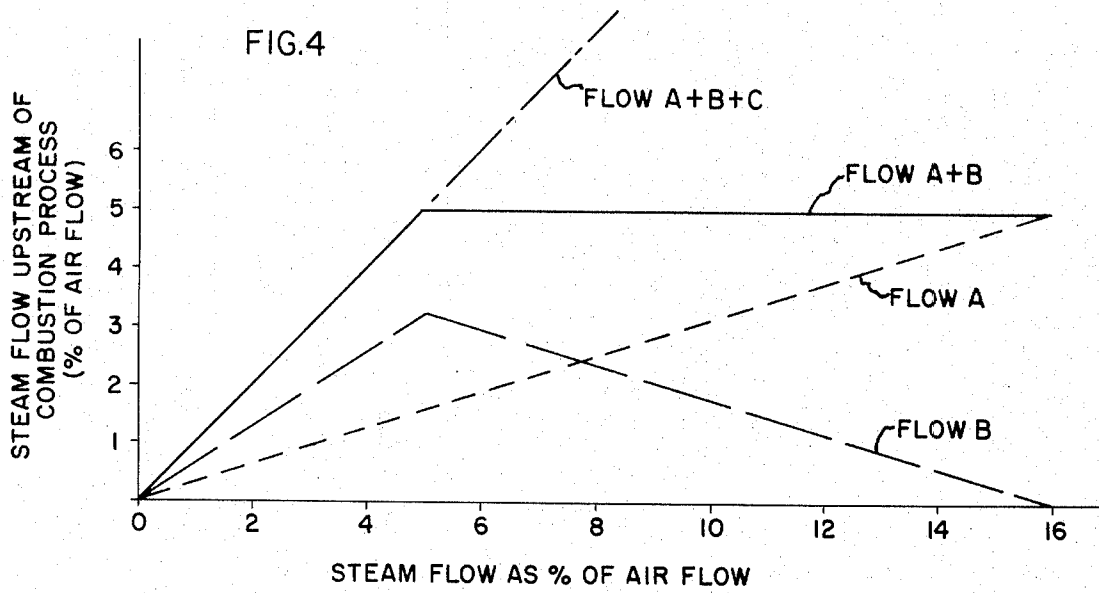
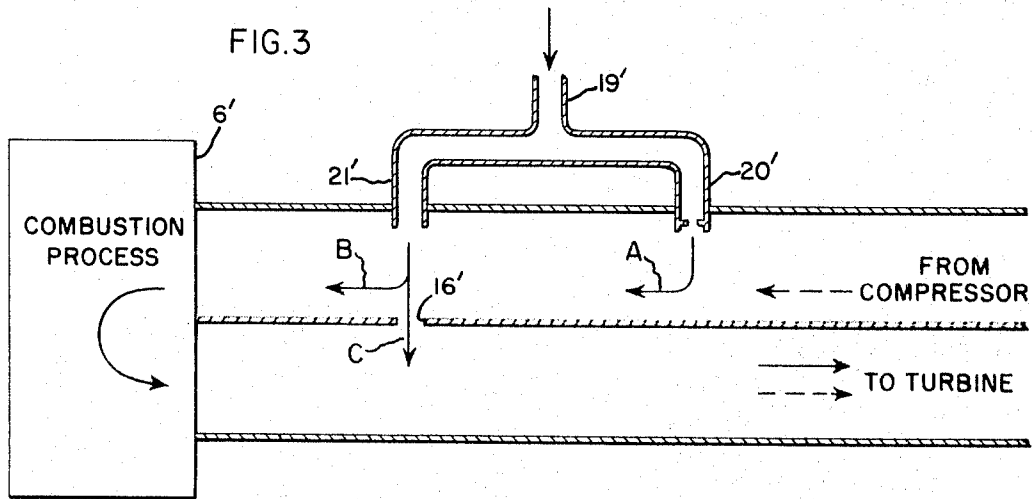
[57] **ABSTRACT**

In a gas turbine, steam is injected into the combustion chamber both upstream and downstream of the combustion reaction zone. A self-compensating feeding device divides the steam flows between the upstream and downstream injection points and supplies a constant percentage of steam to air to the combustion reaction zone regardless of the total rate of steam flow into the gas turbine cycle.

4 Claims, 6 Drawing Figures







SELF COMPENSATING FLOW DIVIDER FOR A GAS TURBINE STEAM INJECTION SYSTEM

BACKGROUND OF THE INVENTION

This invention relates generally to steam injection systems for gas turbines, and more particularly to a self-compensating flow divider for supplying steam to two different points in the gas turbine cycle.

It is well known in the prior art that water or steam may be injected into the motive fluid of a gas turbine in order to increase the mass flow and thus augment the power output. It is also known that limited amounts of steam injected upstream of the combustion reaction zone will reduce the amounts of oxides of nitrogen, such as nitrous oxide and nitric oxide generated in the combustion process, and referred to hereafter as NO_x . However, excess amounts of steam injected ahead of or into the combustion reaction zone may cause degradation of the combustion process and reduce the combustion efficiency of the gas turbine.

The flow rates of steam which may be beneficially added to the cycle for the purpose of power augmentation will vary and maybe in excess of the amounts needed to reduce NO_x in the gas turbine exhausts. The latter steam flow rate for NO_x reduction should remain fairly constant as a percent of air flow.

Accordingly, one object of the present invention is to provide an improved steam injection system for a gas turbine which adds varying amounts of total steam for the purpose of both NO_x abatement and power augmentation, but which limits the steam added for the former so as not to degrade the combustion process.

Another object of the invention, in its more general sense, is to provide an improved self-compensating flow divider which limits the amount of flow added upstream of a combustion process, but which permits variation of the flow added downstream of the process to a substantial degree.

Another object of the invention is to provide a steam injection system for a gas turbine which adds a limited constant percentage of steam flow rate to air flow rate for NO_x abatement and which adds a variable percentage of flow rate of steam for power augmentation.

SUMMARY OF THE INVENTION

Briefly stated, the invention comprises adding primary and secondary proportioned flows of injected steam to the gas turbine motive fluid. The secondary flow is subdivided into two portions by splitting the injected steam into two parts, one of which bypasses the combustion process. The greater the total rate of flow of injected steam, the greater the portion which bypasses the process.

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 simplified schematic view, partly in section, of a gas turbine combustion chamber,

FIG. 2a, 2b, and 2c are simplified schematic views of a steam injection nozzle under low, medium and high rate of flow conditions respectively,

FIG. 3 is a simplified diagram representing the mode of operation of the invention, and

FIG. 4 is a graph showing a typical steam injection schedule for a gas turbine.

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 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 or alternatively may be a nozzle 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, there 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 accordance with the present invention, a pipe 19 connected to a source of steam is led into the combustor casing 2 and branches to supply a first fixed nozzle 20 and a second fixed nozzle 21. Nozzle 20 is arranged to empty a "primary" flow of steam into the annular space 8 containing compressor discharge air and also upstream of the combustion reaction zone 6. Nozzles 20 in an actual turbine may be arranged to provide some cooling of the hot transition member 7.

A secondary nozzle 21 is positioned radially outward from a tempering airhole 16 and substantially coaxial therewith. Similar secondary nozzles 21 are positioned around the periphery of the liner, one for each of the tempering airholes 16.

It will be understood that the drawing shown is schematic in form and in actual practice, suitable supply manifolding is required for the multiplicity of primary nozzles 20 and secondary nozzles 21, since several combustion chambers are usually employed in a gas turbine. For example, in a typical large unit, there may be 10 primary nozzles and 40 secondary nozzles divided among the 10 combustion chambers similar to the single one shown in FIG. 1.

Secondary nozzle 21 performs a flow dividing function in conjunction with holes 16 in the spaced liner 5. Reference to FIGS. 2a, 2b, and 2c shows the flow dividing operation under low, medium and high steam flow rates respectively. In FIG. 2a, steam at a low flow rate is deflected completely into the annular air space 8 by the incoming air so that none flows through hole 16. In FIG. 2b, a moderate rate of steam flow is divided into two parts by the edge of hole 16, one part continuing in the annular air space 8 toward the combustion reaction zone and the other part entering the interior of liner 5, downstream of the reaction zone. In FIG. 2c, the high flow rate of steam causes almost all of the steam to flow through hole 16 into the liner 5, bypassing annular space 8.

It remains to note that the effective flow to nozzles 20 with respect to the effective flow to nozzles 21 is proportioned, either by adjusting the relative pipe sizes or by employing flow-restricting orifices.

OPERATION OF THE INVENTION

Operation of the invention will be better understood by reference to FIG. 3 showing a simplified version of the system. The combustion reaction zone is represented by a block 6' while the primary nozzle is symbolized at 20' and the secondary nozzle at 21'. Flow dividing hole is symbolized at 16'.

A primary flow of fluid A leaves primary nozzle 20' and flows toward combustion process 6' at a rate of flow proportional to that entering the inlet 19'. A secondary flow from nozzle 21' is divided by hole 16' into a flow B entering the combustion process and a flow C which bypasses the combustion process and enters the flow downstream of the combustion process to rejoin it.

In a particular example, which is not limiting but merely illustrative, the nozzles 20', 21' or the passages supplying them are proportioned so that they pass five-sixteenths and eleven-sixteenths respectively of the total flow entering at 19'. The graph of FIG. 4 illustrates the result of this proportioning. The horizontal axis measures total steam flow as a percent of air (motive fluid) flow. At any given rate of air flow, therefore, the horizontal axis also represents the total rate of steam flow. Flow A from nozzle 20' increases approximately linearly as a percent of total air flow, as the steam flow is increased into inlet 19'. Flow B also increases approximately linearly at low flow rates (See FIG. 2a) but in greater quantity as determined by the relative flow passages of nozzles 20', 21'.

As a moderate steam flow rate is achieved (see FIG. 2b), flow B commences to decrease and flow C is initiated into a region downstream of combustion process 6'. The spacing of the secondary nozzle 21', the sizing of hole 16' and the relative flows to nozzles 20', 21' are selected so that flow B decreases at the same rate (as measured against the total percent of steam added) that flow A increases. Closer spacing of the secondary nozzle 21' from hole 16', or proportionately reducing the sizes of nozzles 20' and 21' while maintaining the same ratio with respect to one another (thereby increasing the exit velocity of steam from nozzle 21' relative to velocity of motive fluid) will cause flow B to decrease at a greater rate. Enlargement of nozzle 20' relative to nozzle 21' will cause flow A to increase at a greater rate. The particular design geometry will cause greater or lesser influence of these individual factors. Thus after reaching the desired fixed percentage of flow, the sum of flows A and B into combustion process 6' is constant as indicated by the graph. This flow to the combustion reaction zone in the example shown is limited to 5 percent of the total air flow.

Flows A and B after passing through combustion process 6' rejoin the additional flow C downstream of the combustion process. The total flow A + B + C is thus available for power augmentation of the turbine as shown on the graph. If desired, this total flow may be limited to any desired percentage of air flow, such as 16 percent of air flow in accordance with other operating limitations of the gas turbine.

Thus, there has been described an improved self-compensating flow divider which limits the amount of steam flowing to the combustion reaction zone to a fixed percentage of total air flow, while varying the total amount of steam added to the cycle without regard to this limitation. Although the flow divider has

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been particularly shown as applied to a gas turbine combustion process, it will be apparent that the invention is equally applicable to any type of process where one injected fluid is added to another working process fluid, and where it is desired to limit the injected fluid flow upstream of the process while continuing to add injected fluid into the process fluid downstream of the process.

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

What is claimed is:

1. A self-compensating flow divider for adding steam to gas turbine motive fluid flowing first toward and then away from a combustion process, comprising:

first conduit means conducting the motive fluid toward said combustion process,

second conduit means conducting the motive fluid away from said combustion process,

third conduit means connected to a source of said steam,

a primary fixed nozzle connected to said third conduit means and emptying into the first conduit,

a secondary fixed nozzle also connected to the third conduit means, and

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means providing communication between said secondary nozzle and the first and second conduit means arranged and adapted to divide the steam flowing from the secondary nozzle between said first and second conduit means in proportions determined by the rate of flow from the secondary nozzle.

2. The combination according to claim 1, wherein an opening provides communication between the first and second conduit means and wherein said secondary nozzle is arranged to empty into said first conduit means and is spaced from and directed toward said opening.

3. The combination according to claim 2, wherein said primary nozzle, said secondary nozzle and said opening are proportioned such that the rate of decrease of flow of steam into said first conduit means from the secondary nozzle is equal to the rate of increase of flow of steam into the first conduit means from said primary nozzle, as the total percent of steam, added to the motive fluid increases.

4. The combination according to claim 1, wherein said first conduit means is an elongated casing surrounding a combustion liner, wherein said second conduit means is said liner, wherein said primary nozzle is a fixed steam nozzle emptying into said casing, and wherein said secondary nozzle is a fixed steam nozzle emptying toward a hole in said liner.

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