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(54) GAS TURBINE COMBUSTOR.

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EP 0 335 978 B1

Description

The present invention relates to a gas turbine combustor according to the first portion of claim 1, in which a fuel and the air are mixed together prior to being burned.

Thermal NOx formed by the oxidation of nitrogen in the air for combustion in a high-temperature atmosphere occupy a majority proportion of nitrogen oxides (NOx) that generate when a gaseous fuel containing small amounts of nitrogen such as liquefied natural gas (LNG) burns. It has been known that formation of thermal NOx varies greatly depending upon the temperature; i.e., the amount of its formation increases with the increase in the flame temperature, and increases abruptly when the temperature exceeds 1500°C. The flame temperature changes depending upon the mixing ratio of the fuel and the air, and becomes the highest when the fuel is burned with the air of a quantity that is not too great or is not insufficient for completely burning the fuel, i.e., becomes the highest when the fuel is burned near a theoretical air requirement. To suppress the generation of NOx, the flame temperature must be lowered. The flame temperature can be lowered by a method according to which water or vapor is blown into the combustion chamber to forcibly lower the temperature, or by a method according to which the fuel is burned under the condition where the mixing ratio of the fuel and the air is extremely increased to be greater than the theoretical air requirement or, conversely, is decreased.

The method of blowing water or vapor involves a new problem, i.e., decrease in the turbine efficiency.

In an ordinary combustion apparatus, a so-called diffused flame takes place in which the fuel and the air are injected from separate nozzles, and are mixed together in the combustor and are burned, in order to stabilize the flame and to prevent backfire. In a step of mixing the fuel and the air together, however, there exists a region where the air ratio (ratio of the air flow rate to the theoretical air requirement) becomes close to 1 and where the flame temperature becomes locally high. That is, a region is formed where NOx are generated in large amounts; i.e., NOx are emitted in large amounts.

In contrast with the combustion apparatus which utilizes the diffused flame, there is a combustion apparatus which uses pre-mix flame in which the air in excess of the theoretical air requirement and the fuel are mixed together in advance and are injected into the combustor. In the pre-mix flame having a high air ratio, the region where the temperature becomes locally high is prevented from taking place and NOx are emitted in reduced amounts. The pre-mix flame remains most stable when the air ratio is close to 1, but tends to be blown out when the injection speed increases. When the injection speed is low, furthermore, flame enters into the nozzle to cause backfire. In the combustor of a gas turbine, the pre-mix gas consisting of the fuel and the air must be injected at a high speed of, usually, 40 m/s to 70 m/s, but the flame is not easily formed under such high injection speed conditions. In the JP-A-22127/1986 is described a combustor in which the fuel is supplied in a divided manner, part of it being used for forming diffused flame and the remainder being used for forming pre-mix flame, and relatively stable diffused flame or combustion gas of a high temperature formed by the diffused flame is used for igniting the pre-mix flame. The above combustor makes it possible to decrease the amount of NOx compared with the conventional combustor that utilizes the diffused flame. The amount of NOx can be decreased if the flow rate of the fuel used for the diffused flame is decreased and the fuel flow rate of pre-mixed flame is increased. However, the flame loses stability if the rate of pre-mixing increases, and limitation is imposed on decreasing the amount of NOx emission.

The amount of NOx generated from the gas turbine combustor can be decreased if unstable pre-mix flame is stabilized and if the gas turbine combustion system is of the type of completely pre-mixed combustion.

When the gas turbine combustion system is of the type of completely pre-mixed combustion, the air for combustion is supplied in large amounts compared with the fuel flow rate during the small-load operation conditions, whereby the fuel becomes lean and is difficultly ignited. During the high-load operation conditions, on the other hand, both the fuel supply and the air flow rate are increased, whereby the flow rate of the pre-mixed gas is further increased causing the pre-mix flame to be blown out.

The US-A-4 237 694 discloses a gas turbine combustor comprising a substantially cylindrical combustion chamber and a single main gas nozzle centrically disposed in the end wall of said combustion chamber. In front of the main gas nozzle is arranged a cylindrical mixing chamber, which is connected with a ring channel via a plurality of radial directed gas supply ports. An auxiliary gas nozzle concentrical surrounding the main nozzle is connected with a ring chamber for mixing air with an amount of fuel gas to a pre-mixed auxiliary gas flowing out from the single auxiliary nozzle. The end wall of the combustion chamber and the auxiliary nozzle are so formed that the auxiliary gas flow will generate a vortex ring around the main nozzle. The fuel gas supply to the main nozzle and to the auxiliary nozzle can be controlled in dependence with a parameter of the gas turbine, so that at low power a majority of the fuel gas is supplied to the auxiliary nozzle while at a higher power operation the majority of fuel gas will be injected through the centrally disposed main nozzle.

From the US-A-3 919 840 it is known a device for

mixing dissimilar swirling flow fluids in the combustion zone of an annular combustion chamber. To accelerate the combustion the mixing rate between the cool fuel air mixture and hot combustion products will be increased in the dilution zone of the annular combustion chamber. The hot vitiated gas flows with lower energy in the circumferential direction in an outer ring channel, while the cold combustible gas mixture flows with higher energy in an inner ring channel. Between the inner and outer both ring channels a dividing wall is provided.

In EP-A-0 095 788 there is disclosed a combustion chamber of a gas turbine in which a separate air distributing chamber is connected with the combustion room by a plurality of spaced pipe elements for pre-mixing the separately supplied fuel with compressed air. At the inner end of each of said pipe elements there is provided a whirling chamber, in which the fuel supplied by said pipe and an amount of air is mixed and immediately injected in the combustion chamber through a specially designed main nozzle of the diffusion type. Between the fuel pipe and the outer pipe element there is provided a ring-shaped mixing chamber in which an amount of air is mixed with a part of the fuel of the fuel pipe. This mixture is supplied to an annular auxiliary nozzle formed at the inner end of the pipe element around each of the main nozzles. During the load operation of the turbine about 90 to 95 % of the fuel amount should be injected as auxiliary gas mixture through the annular auxiliary nozzles and only 5 to 10 % as main gas mixture through the central main nozzles. The plurality of main and auxiliary nozzles are classified in several groups which are separately controlled in a predetermined order according to the turbine load.

The object of the present invention is to provide a gas turbine combustor which is capable of stably burning a lean pre-mixed gas having an air ratio of greater than 1 from low load through up to high load of the gas turbine, and a method of combustion.

This object will be solved according to the invention by the features of claim 1 (combustor) and claim 12 (method of combustion), respectively.

According to the present invention, stable auxiliary flame is formed at all times at the root of the combustion flame of a high air ratio in order to maintain the main flame that burns at high speeds. Therefore, the gas turbine combustion system is of the completely pre-mixed combustion type. Hence, if lean combustion is carried out while setting the air ratio of the fuel-air mixture gas for main flame to be greater than 1.0, it is allowed to decrease the amounts of NOx and CO that are polluting substances generated from the gas turbine combustor.

Brief Description of the Drawings:

Fig. 1 is a section view illustrating part of a gas turbine combustor embodying the present invention;

Fig. 2 is a section view along the line II-II of Fig. 1;

Fig. 3 is a section view illustrating in detail a nozzle portion of Fig. 1;

Fig. 4 is a graph illustrating a relationship between the turbine load and the opening degree of valves shown in Fig. 1;

Figs. 5(a) and 5(b) are graphs showing relationships between the amount of NOx generated and the amount of CO generated when the pre-mixed gas is burned while changing the air ratio;

Figs. 6(a) and 6(b) are graphs showing exhaust gas compositions from the combustor of the present invention up to a region of an air ratio of as high as 3.6;

Fig. 7 is a graph showing combustion exhaust gas composition of flame in the radial direction of the nozzle;

Fig. 8 is a section view illustrating part of the gas turbine combustor according to another embodiment of the present invention;

Fig. 9 is a section view along the line IX-IX of Fig. 8; and

Fig. 10 is a diagram of characteristics showing relationships between the change of load and the fuel supply system in the gas turbine combustor of Fig. 8.

Best Mode for Carrying Out the Invention

Fig. 1 is a section view of a gas turbine combustor embodying the present invention. An inner cylinder 20 is arranged concentrically in an outer cylinder 10, and annular space defined between the outer cylinder 10 and the inner cylinder 20 constitutes an air path 12 for guiding the air blown from the compressor to the head portion of the inner cylinder. Double end walls 11 and 12 are provided at the head of the inner cylinder 20, and in the inner end wall 11 are formed main nozzles 14 and surrounding auxiliary nozzles 15 over the entire surface thereof as shown in Fig. 2. The main nozzles 14 are formed at the right end of pre-mixing cylinders 16 that extend on the side of the outer end wall 12 penetrating therethrough. The pre-mixing cylinders 16 introduce the air from an air chamber 17 formed on the left side of the end wall 12. Fuel supply pipes 18 are inserted in the pre-mixing cylinders 16, and the fuel injected from the ends of the fuel supply pipes 18 is mixed with the air as it flows through the cylinders 16 thereby to form a pre-mixed gas. Auxiliary nozzles 15 are communicated with auxiliary pre-mixing chambers 30 formed between the end walls 11 and 12. The chambers 30 are served with a uniformly pre-mixed gas from a venturi-type mixer 31. The air of a high pressure is introduced into the mixer 31 by an introduction board 26 via an air adjusting valve 40,

and the fuel adjusted under the atmospheric pressure is sucked to form a uniformly pre-mixed gas. The fuel supply pipes 18 are communicated with a main fuel adjusting valve 60 via stop valves 50 provided for each of the pipes 18. The valves 50 and 60 are controlled according to instructions from a controller 70 which receive load of the gas turbine and rotational speed signals.

The stop valves 50 are fully opened upon receipt of an open signal from the controller 70 and are fully closed in other cases. Fig. 1 illustrates only four stop valves. The stop valves, however, are provided for all fuel supply pipes 18. In this embodiment, there are provided 19 stop valves. The number of stop valves that open increases with the increase in the load of the turbine as shown in Fig. 4. On the other hand, the opening degree of the adjusting valve 60 varies nearly in proportion to the turbine load. The adjusting valve 40 maintains nearly a constant opening degree (about 10%) irrespective of the turbine load. The pre-mixed air to be introduced into the auxiliary pre-mixing chambers 30 is uniformly pre-mixed in the mixer 31 so as to have an air ratio over a range of from 0.8 to 1.2. Further, the air adjusting valve 40 is so adjusted that the speed of injection from the auxiliary nozzles 15 will become nearly equal to the speed of combustion.

In operating the gas turbine, first, the air adjusting valve 40 for auxiliary flame is opened to form the auxiliary pre-mixed gas through the mixer 31. Next, the pre-mixed gas injected from the auxiliary nozzles 15 is ignited by ignition plugs that are not shown. The auxiliary pre-mixed gas has an air ratio which is close to 1, i.e., which lies from 0.8 to 1.2, and the speed of injection is nearly equal to the speed of combustion, i.e., 0.4 m/s. Therefore, the auxiliary pre-mixed gas is reliably ignited and stably sustains the combustion after it is ignited.

In this case, the stop valves 50 are mostly closed, and the air only is injected from the main nozzles 14. The opening degree of the adjusting valve 60 gradually increases in response to load signals of the turbine, and the stop valves 50 are opened according to a predetermined order. Then, a pre-mixed gas is formed in the pre-mixing cylinders 16 and is injected at high speeds from the main nozzles 14. The pre-mixed gas injected from the main nozzles 14 is ignited by auxiliary flame 80 (Fig. 3) formed around thereof thereby to establish a main flame 90.

As the stop valves 50 are opened successively, the number of flames formed by the main nozzles 14 increases gradually, and the flames are formed by all main nozzles 14 under the rated load condition. In a gas turbine for generating electricity, in general, the turbine rotates at a constant speed from 0% to 100%s of load, and the air supplied to the combustor flows nearly at a constant rate. Therefore, the air flows nearly at a constant rate from the air chamber 17 into the pre-mixing cylinders 16.

The amount of fuel that flows through the adjusting valve 60, on the other hand, varies nearly in proportion to the turbine load. However, since the number of stop valves 50 that open varies depending upon the amount of fuel, the amount of fuel supplied to the pre-mixing cylinders remains nearly the same per a stop valve that is open, and the air ratio of the mixture gas formed in the pre-mixing cylinders 16 does noit much change. In this embodiment, therefore, the air ratio is set to lie from 1.2 to 2.5.

In this embodiment in which the air ratio of the pre-mixed gas in the auxiliary nozzles 15 is set near to 1 to favorably maintain the flame, there is no likelihood that the flame is blown out even when the pre-mixed gas is injected from the main nozzles 14 at a speed greater than 20 m/s and, preferably, at a speed of 40 m/s to 70 m/s. Further, since the air is constantly injected from the main nozzles 14 at a speed of 20 m/s to 70 m/s, there takes place no backfire, either.

Moreover, even though the pre-mixed gas from the main nozzles 14 is so lean as to have an air ratio of 1.5 or more, the combustion is stably sustained owing to the auxiliary flame.

Figs. 5(a), 5(b) and 6(a), 6(b) illustrate relationships between the amount of NOx generated and the amounts of H_2 and CO generated when the pre-mixed gas is burned while changing its air ratio. Fig. 5 (a), (b) shows the analyzed results of exhaust gas from the combustion cylinder of when the pre-mix flame is formed in the combustion cylinder having an inner diameter of 90 mm and a height of 346 mm, and Fig. 6(a), (b) shows the analyzed results of exhaust gas from the combustion cylinder of when the pre-mix flame is formed in the combustion cylinder having an inner diameter of 208 mm and a height of 624 mm, both under the same combustion conditions.

Fig. 6(a), (b) shows the analysis of exhaust gas of up to the region of an air ratio of as high as 3.6. In Figs. 6(a) and 5(b) where the main flame is formed with the air ratio from 1.3 to 1.8, the amount of NOx is less than 100 ppm as indicated by a curve 221, and CO and H_2 are not almost formed as indicated by curves 231 and 241. Oxygen exhibits behaviour as represented by a curve 251, as a matter of course.

Looking from these behaviours, it appears that NOx are generated in large amounts since the air ratio of the pre-mixed gas in the auxiliary nozzles is close to 1. As a whole, however, NOx are generated in small amounts since the fuel ratio of auxiliary flame is about 10% under the rated load condition.

In Fig. 7, the fuel gas is sampled and is analyzed at a point 5 mm away from the main nozzle (having an inner diameter of about 26 mm) in the direction of downstream by moving the sampling probe in the radial direction from the center of the nozzle, to examine the combustion condition in the main flame and near the auxiliary flame. As will be understood from

Fig. 7, CH_4 is not almost burned in the main flame but burns toward the auxiliary flame and burns by 100% over the auxiliary flame nozzle. This fact indicates that the flame is reliably transferred from the auxiliary flame of auxiliary nozzle to the pre-mixed gas of the main nozzle. The size of the burner used in this embodiment is as follows: i.e., the main nozzle has an inner diameter of 26 mm, the spacer surrounding the main nozzle has a thickness of 2 mm, and the auxiliary nozzle has a width of 2 mm.

Fig. 8 illustrates a gas turbine combustor in which a plurality of main nozzles provided in the end wall on the head side of the inner cylinder of the combustor are classified into three groups, and the amounts of fuel supplied to the nozzle groups are independently increased or decreased such that the air ratio of the fuel-air mixture injected from the main nozzles will lie from 1.2 to 2.5 when the turbine load is varied over a range of 20% to 100%, in order to suppress the amounts of NOx and CO generated from the combustor. Numerals on the main nozzles in the front view of the combustor of Fig. 9 represent classification numbers of the main nozzles grouped into three. Each nozzle group has four main nozzles. Reference numerals 61, 62 and 63 denote flow-rate adjust valves; i.e., 61 denotes the adjust valve for increasing or decreasing the amount of fuel supplied to the second nozzle group, 62 denotes the adjust valve for the first nozzle group and 63 denotes the adjust valve for the third nozzle group. Reference numeral 19 denotes a burner for diffused flame for igniting the pilot flame formed by the auxiliary nozzles. After the pilot flame is formed for the auxiliary nozzles, the fuel is no more supplied to the burner 19 and its flame is extinguished.

Fig. 10 shows changes in the amounts of fuel supplied to the nozzle groups when the load of the gas turbine combustor of Fig. 8 is changed. The fuel is supplied to the first nozzle group only over the turbine load of from 0% to 39%. At a moment when the air ratio of the fuel-air mixture injected from the main nozzles has reached 1.25, the supply of fuel is decreased such that the air ratio becomes 2.5. At the same time, the fuel is supplied to the second nozzle group so that the air ratio becomes 2.5, and the amount of fuel supplied to the first nozzle group is increased under the condition where the amount of fuel supplied to the second nozzle group is maintained constant, in order to increase the turbine load from 39% to 60%. Then, at a moment the air ratio of the fuel-air mixture of the first nozzle group has reached 1.25, the supply of fuel is decreased such that the air ratio of the first nozzle group becomes 2.5. At the same time, the fuel is supplied to the third nozzle group such that the air ratio becomes 2.5, and the amounts of fuel supplied to the first, second and third nozzle groups are increased proportionally from 60% to 100% of the turbine load. At 100% of the turbine load, the gas turbine combustor is so operated that the air ratio of the fuel-air mixture injected from the first, second and third nozzles will be 1.5.

Under the gas turbine operation conditions shown in Fig. 10, the air ratio of the fuel-air mixture injected from the first, second and third nozzle groups lies from 1.25 to 2.50 over the turbine load range of from 20% to 100%. As will be understood from Figs. 6(a) and 6(b), the amount of NOx generated is smaller than about 100 ppm over the air ratio range of from 1.25 to 2.50, and unburned components that include CO, H_2 and CH_4 are generated in very small amounts. It can therefore be said that the method of operating the gas turbine combustor can be effectively employed for the gas turbine combustion system that permits NOx to generate little.

According to the present invention as described above, the auxiliary flame injected at a low speed is used for igniting the pre-mixed flame (main flame) that is injected at high speeds and for maintaining the flame. Therefore, the pre-mixed gas for forming the pilot flame that works to maintain the flame is injected at a speed which is the same as the speed of combustion, i.e., injected at a speed of about 0.4 m/s. Furthermore, the air ratio is set to lie from 0.8 to 1.2 to suppress the generation of NOx and to prevent the blow out. The entire circumference of the pre-mixed gas injected at high speeds is surrounded by the auxiliary flame for maintaining the flame, so that the heat generated by the flame for maintaining the flame is efficiently transferred to the main flame. Moreover, a spacer is provided between the burner for main flame and the burner for auxiliary flame, so that vortex current is stably formed between the burner injecting the pre-mixed gas for main flame and the burner injecting the pre-mixed gas for auxiliary flame due to a difference in the speed of injection between them. This helps promote the mixing of the pre-mixed gas of a high air ratio for main flame and the combustion gas from the auxiliary flame of a high temperature, enabling the main flame to be ignited more easily. When the main flame is to be separated from the auxiliary flame using a thin partition wall such as a knife edge instead of providing the spacer, it has been clarified through experiments by the inventors that the auxiliary flame is blown out too under the condition where the flow of auxiliary flame is seriously affected by the ejection of the main flame and where the main flame is blown out. With the spacer being provided, however, the main flame and the auxiliary flame do not directly mix with each other near the burner outlet, but the two are only partly mixed with each other in the vortex current formed on the spacer portion. Accordingly, the auxiliary flame is stably formed at all times without being affected by the main flame, contributing to increasing the range of flow speed or air ratio in which the main flame can be stably formed.

Claims

1. A gas turbine combustor comprising
   - a cylindrical combustion chamber (20),
   - a plurality of spaced main nozzles (14) disposed in an end wall on the upstream side of said combustion chamber (20) for injecting a main gas mixture into the combustion chamber (20),
   - an annular auxiliary nozzle (15) formed around each of said main nozzles (14) for injecting an auxiliary gas mixture in the combustion chamber,
   - means (70) for controlling the operation time of the plurality of nozzles (14) in a predetermined order according to the turbine load,

   characterized in that
   - each of said main nozzles (14) is provided with first means (16, 17, 18) for premixing the separately supplied fuel with air to a main gas mixture having a first air ratio (λ_1) larger than the stoichiometric air ratio (λ) and for supplying said main gas mixture to said main nozzle (14) and
   - the auxiliary nozzles (15) are provided with second means (30, 31, 40) for premixing fuel with air to a uniform auxiliary gas mixture having a smaller air ratio (λ_2) than the first air ratio (λ_1) and for supplying said uniform gas mixture to all of said auxiliary nozzles (15).

2. Gas turbine combustor according to claim 1, wherein the second air ratio (λ_2) is 0.8 to 1.2 preferably close to 1.0 and the injection speed of the auxiliary gas mixture is almost equal to its flame propagation speed.

3. Gas turbine combustor according to claim 1 or 2, wherein the first air ratio is 1.25 to 2.5, preferably 1.5 or more and the injection speed of the main gas mixture is substantially greater than its flame propagation speed.

4. Gas turbine combustor according to anyone of the claims 1 to 3, wherein the total flow rate of air in the auxiliary nozzles (15) is about 10 % of the total flow rate in the combustor at the rated load.

5. Gas turbine combustor according to anyone of claims 1 to 4, wherein each main nozzle (14) is formed on the inner end of a pre-mixing cylinder (16) into which the open end portion of a fuel supply pipe (18) is inserted.

6. Gas turbine combustor according to anyone of the claims 1 to 5, wherein the means (30, 31, 40) for premixing the auxiliary gas mixture includes a mixer (30) supplied with an air flow and the fuel, an adjusting valve (40) disposed in the air flow path and auxiliary pre-mixing chambers (30) communicated with the auxiliary nozzles (15) and served with the uniformly pre-mixed gas from the mixer (30).

7. Gas turbine combustor according to anyone of the claims 1 to 6, wherein the fuel supply means (18) of the main nozzles (14) are controlled by separate stop valves (50) and by a common adjusting valve (60).

8. Gas turbine combustor according to anyone of the claims 1 to 7, wherein the main nozzles (14) are classified into at least three groups each group being independently controlled by a separate flow-rate adjusting valve (61, 62, 63).

9. Gas turbine combustor according to claim 8, wherein, when the first air ratio (λ_1) of the main gas mixture supplied to the first group of the main nozzles (14) reaches about 1.25, the operation of the second group of the main nozzles (14) will be started.

10. Gas turbine combustor according to claim 8 or 9, wherein, when the first air ratio (λ_1) of the main gas mixture supplied to the second group of the main nozzles 14 reaches about 1.25, the operation of the third group of the main nozzles (14) will be started.

11. Gas turbine combustor according to claims 9, 10, wherein the first air ratio (λ_1) of the main gas mixture successively supplied to the first and second group of the main nozzles (14) is about 2.5 in the beginning.

12. Combustion method for a gas turbine combustor including a plurality of main nozzles (14) provided in an end wall of a combustion chamber and an annular auxiliary nozzle (15) formed around each of the main nozzles (14),
    comprising the steps of:
    - injecting a pre-mixed auxiliary fuel-air gas mixture having an air ratio (λ) of substantially 1 through the auxiliary nozzles (15) into the combustion chamber;
    - igniting the injected auxiliary gas mixture;
    - injecting a pre-mixed fuel-air gas mixture having an air ratio larger than 1 through a predetermined number of the main nozzles (14) into the combustion chamber, while only air is supplied to the remaining main nozzles (14);
    - igniting the injected gas mixture of the pre-

determined number of the main nozzles (14);
- injecting the pre-mixed fuel-air gas mixture having an air ratio larger than 1 through another predetermined number of the main nozzles (14), while only air is supplied to the remaining main nozzles (14), after the ignition of the first number of the main nozzles (14);
- igniting the injected pre-mixed gas of the second predetermined number of the main nozzles (14);
- injecting a pre-mixed fuel-air gas having an air ratio larger than 1 into a third predetermined number of the main nozzles (14) after the ignition of the second predetermined number of the main nozzles (14); and
- igniting the injected pre-mixed gas of the third predetermined number of the main nozzles (14).

13. Combustion method according to claim 12, wherein the air ratio (λ_1) of the main gas mixture injected into the main nozzles is 1.25 to 2.5, preferably 1.5 or more, and the injection speed of the main gas mixture is substantially greater than its flame propagation speed.

14. Combustion method according to claim 12 or 13, wherein the second air ratio (λ_2) is 0.8 to 1.2, preferably close to 1.0, and the injection speed of the auxiliary gas mixture is almost equal to its flame propagation speed.

15. Combustion method according to claims 12 to 14, wherein fuel and a controlled rate of air will be premixed to the uniform auxiliary gas mixture and supplied to all of the auxiliary nozzles (15).

16. Combustion method according to anyone of the claims 12 to 14, wherein the total flow rate of air in the auxiliary nozzles (15) is about 10 % of the total flow rate in the combustor at the rated load.

17. Combustion method according to anyone of the claims 12 to 16, wherein the main nozzles (14) are classified into at least three independently controlled groups and when the air ratio (λ_1) of the main gas mixture injected into the first group of the main nozzles (14) reaches about 1.25, the operation of the second group of the main nozzles (14) will be started.

18. Combustion method according to claim 17, wherein, when the air ratio (λ_1) of the main gas mixture injected into the second group of the main nozzles (14) reaches about 1.25, the operation of the third group of the main nozzles (14) will be started.

19. Combustion method according to claim 17, wherein the air ratio of the main gas mixture injected into the first group of the main nozzles (14) is about 2.5 in the beginning.

20. Combustion method according to claim 18, wherein the air ratio (λ_1) of the main gas mixture injected into the second group of the main nozzles (14) is about 2.5 in the beginning.

Patentansprüche

1. Gasturbinenbrenner mit
- einer zylindrischen Brennkammer (20),
- mehreren beabstandeten Hauptdüsen (14), die in einer Endwand an der stromauf gelegenen Seite der Brennkammer (20) zum Einspritzen eines Haupt-Gasgemisches in die Brennkammer (20) angeordnet sind,
- einer ringförmigen Zusatzdüse (15), die um jede der Hauptdüsen (14) zum Einspritzen eines Zusatz-Gasgemisches in die Brennkammer gebildet ist, und
- einer Einrichtung (70) zur Steuerung der Betriebsdauer der mehreren Düsen (14) in einer vorbestimmten Ordnung gemäß der Turbinenlast,

dadurch gekennzeichnet, daß
- jede der Hauptdüsen (14) eine erste Einrichtung (16, 17, 18) zum Vormischen des getrennt zugeführten Brennstoffs mit Luft zu einem Haupt-Gasgemisch mit einem ersten Luftverhältnis (λ_1) größer als das stoichometrische Luftverhältnis (λ) und zur Zufuhr des Haupt-Gasgemisches zu der Hauptdüse (14) aufweist und
- die Zusatzdüsen (15) eine zweite Einrichtung (30, 31, 40) zum Vormischen von Brennstoff mit Luft zu einem gleichmäßigen Zusatz-Gasgemisch mit einem kleineren Luftverhältnis (λ_2) als das erste Luftverhältnis (λ_1) und zur Zufuhr des gleichmäßigen Gasgemischs zu allen Zusatzdüsen (15) aufweisen.

2. Gasturbinenbrenner nach Anspruch 1, bei dem das zweite Luftverhältnis (λ_2) 0,8 bis 1,2, vorzugsweise in der Nähe von 1,0, und die Zufuhrgeschwindigkeit des Zusatz-Gasgemischs nahezu gleich seiner Flammenausbreitungsgeschwindigkeit ist.

3. Gasturbinenbrenner nach Anspruch 1 oder 2, bei dem das erste Luftverhältnis 1,25 bis 2,5, vorzugsweise 1,5 oder mehr, und die Zufuhrge-

schwindigkeit des Haupt-Gasgemischs wesentlich größer als seine Flammenausbreitungsgeschwindigkeit ist.

4. Gasturbinenbrenner nach einem der Ansprüche 1 bis 3, bei dem der gesamte Luftdurchsatz in den Zusatzdüsen (15) in etwa 10 % des gesamten Luftdurchsatzes in dem Brenner bei Nennlast ist.

5. Gasturbinenbrenner nach einem der Ansprüche 1 bis 4, bei dem jede Hauptdüse (14) an dem inneren Ende eines Vormischzylinders (16) ausgebildet ist, in den das offene Endteil einer Kraftstoffzufuhrleitung (18) eingesetzt ist.

6. Gasturbinenbrenner nach einem der Ansprüche 1 bis 5, bei dem die Einrichtung (30, 31, 40) zur Vormischung des Zusatz-Gasgemischs einen mit einem Luftstrom und Brennstoff versorgten Mischer (30), ein in dem Luftstromkanal angeordnetes Stellventil (40) und zusätzliche Vormischkammern (30) enthält, die mit den Zusatzdüsen (15) verbunden und mit dem gleichmäßig vorgemischten Gas von dem Mischer (30) versorgt werden.

7. Gasturbinenbrenner nach einem der Ansprüche 1 bis 6, bei dem die Brennstoffzufuhreinrichtung (18) der Hauptdüsen (14) durch getrennte Abschaltventile (50) und durch ein gemeinsames Stellventil (60) gesteuert wird.

8. Gasturbinenbrenner nach einem der Ansprüche 1 bis 7, bei dem die Hauptdüsen (14) in wenigstens drei Gruppen unterteilt sind, wobei jede Gruppe durch ein getrenntes Strömungsraten-Einstellventil (61, 62, 63) unabhängig gesteuert wird.

9. Gasturbinenbrenner nach Anspruch 8, bei dem der Betrieb der zweiten Gruppen von Hauptdüsen (14) gestartet wird, wenn das erste Luftverhältnis (λ_1) des der ersten Gruppe von Hauptdüsen (14) zugeführten Haupt-Gasgemischs etwa den Wert 1,25 erreicht.

10. Gasturbinenbrenner nach Anspruch 8 oder 9, bei dem der Betrieb der dritten Gruppe von Hauptdüsen (14) gestartet wird, wenn das erste Luftverhältnis (λ_1) des der zweiten Gruppe von Hauptdüsen (14) zugeführten Haupt-Gasgemischs etwa den Wert 1,25 erreicht.

11. Gasturbinenbrenner nach Anspruch 9, 10, bei dem das erste Luftverhältnis (λ_1) des der ersten und zweiten Gruppe von Hauptdüsen (14) nacheinander zugeführten Haupt-Gasgemischs am Anfang etwa 2,5 ist.

12. Brennverfahren für einen Gasturbinenbrenner mit mehreren Hauptdüsen (14) in einer Endwand einer Brennkammer und einer ringförmigen Zusatzdüse (15) die um jede der Hauptdüsen (14) gebildet ist, mit folgenden Schritten:
- Zuführen eines vorgemischten Zusatz-Kraftstoff-Luft-Gasgemischs mit einem Luftverhältnis (λ) von im wesentlichen 1 durch die Zusatzdüsen (15) in die Brennkammer;
- Zünden des zugeführten Zusatz-Gasgemischs;
- Zuführen eines vorgemischten Kraftstoff-Luft-Gasgemischs mit einem Luftverhältnis größer als 1 durch eine vorbestimmte Anzahl von Hauptdüsen (14) in die Brennkammer, während den verbleibenden Hauptdüsen (14) nur Luft zugeführt wird;
- Zünden des zugeführten Gasgemischs der vorbestimmten Anzahl von Hauptdüsen (14);
- Zuführen des vorgemischten Kraftstoff-Luft-Gemischs mit einem Luftverhältnis größer als 1 durch eine weitere vorbestimmte Anzahl von Hauptdüsen (14), während den verbleibenden Hauptdüsen (14) nach der Zündung der ersten Anzahl von Hauptdüsen (14) nur Luft zugeführt wird;
- Zünden des zugeführten Vorgemischs der zweiten vorbestimmten Anzahl von Hauptdüsen (14);
- Zuführen eines vorgemischten Kraftstoff-Luft-Gemischs mit einem Luftverhältnis größer als 1 in eine dritte vorbestimmte Anzahl von Hauptdüsen (14) nach der Zündung der zweiten vorbestimmten Anzahl von Hauptdüsen (14); und
- Zünden des zugeführten Vorgemischs der dritten vorbestimmten Anzahl von Hauptdüsen (14).

13. Brennverfahren nach Anspruch 12, bei dem das Luftverhältnis (λ_1) des den Hauptdüsen zugeführten Haupt-Gasgemischs 1,25 bis 2,5, vorzugsweise 1,5 oder mehr, und die Zufuhrgeschwindigkeit des Haupt-Gasgemischs wesentlich größer als dessen Flammenausbreitungsgeschwindigkeit ist.

14. Brennverfahren nach Anspruch 12 oder 13, bei dem das zweite Luftverhältnis (λ_2) 0,8 bis 1,2, vorzugsweise in der Nähe von 1,0, und die Zufuhrgeschwindigkeit des Zusatz-Gasgemischs nahezu gleich seiner Flammenausbreitungsgeschwindigkeit ist.

15. Brennverfahren nach den Ansprüchen 12 bis 14, bei dem der Brennstoff und eine gesteuerte Luftmenge zu dem gleichmäßigen Zusatz-Gasgemisch vorgemischt und sämtlichen Zusatzdüsen (15) zugeführt wird.

16. Brennverfahren nach einem der Ansprüche 12 bis 14, bei dem der gesamte Luftdurchsatz in den Zusatzdüsen (15) etwa 10 % des gesamten Luftdurchsatzes in dem Brenner bei Nennlast ist.

17. Brennverfahren nach einem der Ansprüche 12 bis 16, bei dem die Hauptdüsen (14) in wenigstens drei unabhängig gesteuerte Gruppen unterteilt sind und der Betrieb der zweiten Gruppe von Hauptdüsen (14) gestartet wird, wenn das Luftverhältnis (λ_1) des der ersten Gruppe von Hauptdüsen (14) zugeführten Haupt-Gasgemischs etwa den Wert 1,25 erreicht.

18. Brennverfahren nach Anspruch 17, bei dem der Betrieb der dritten Gruppe von Hauptdüsen (14) gestartet wird, wenn das Luftverhältnis (λ_1) des der zweiten Gruppe von Hauptdüsen (14) zugeführten Haupt-Gasgemischs etwa den Wert 1,25 erreicht.

19. Brennverfahren nach Anspruch 17, bei dem das Luftverhältnis des der ersten Gruppe von Hauptdüsen (14) zugeführten Haupt-Gasgemischs am Anfang etwa 2,5 ist.

20. Brennverfahren nach Anspruch 18, bei dem das Luftverhältnis (λ_1) des der zweiten Gruppe der Hauptdüsen (14) zugeführten Haupt-Gasgemischs am Anfang etwa 2,5 ist.

Revendications

1. Dispositif de combustion de turbine à gaz comprenant :
   - une chambre de combustion cylindrique (20),
   - une pluralité de buses principales espacées (14) disposées dans une paroi d'extrémité sur le côté, amont de ladite chambre de combustion (20) pour injecter un mélange gazeux principal dans la chambre de combustion (20),
   - une buse annulaire auxiliaire (15) formée autour de chacune desdites buses principales (14) pour injecter un mélange gazeux auxiliaire dans la chambre de combustion,
   - des moyens (70) pour commander la durée de fonctionnement de la pluralité de buses (14) dans un ordre prédéterminé en fonction de la charge de la turbine,

   caractérisé en ce que
   - chacune desdites buses principales (14) est équipée de premiers moyens (16,17,18) pour prémélanger le combustible envoyé séparément avec de l'air pour former un mélange de gaz principal possédant un premier rapport d'air ($\lambda 1$) supérieur au rapport d'air stoechiométrique (λ) et pour envoyer ledit mélange de gaz principal à ladite buse principale (14), et
   - les buses auxiliaires (15) sont équipées de seconds moyens (30,31,40) pour prémélanger du combustible à de l'air pour former un mélange de gaz auxiliaire uniforme possédant un rapport d'air ($\lambda 2$) inférieur au premier rapport d'air ($\lambda 1$) et envoyer ledit mélange de gaz uniforme à toutes lesdites buses auxiliaires (15).

2. Dispositif de combustion de turbine à gaz selon la revendication 1, dans lequel le second rapport d'air ($\lambda 2$) est compris entre 0,8 et 1,2 et de préférence est proche de 1,0 et la vitesse d'injection du mélange de gaz auxiliaire est presque égale à sa vitesse de propagation de sa flamme.

3. Dispositif de combustion de turbine à gaz selon la revendication 1 ou 2, dans lequel le premier rapport d'air est compris entre 1,25 et 2,5 et de préférence est égal à 1,5 ou plus et la vitesse d'injection du mélange de gaz principal est sensiblement supérieure à sa vitesse de propagation de flamme.

4. Dispositif de combustion de turbine à gaz selon l'une quelconque des revendications 1 à 3, dans lequel le débit total d'air dans les buses auxiliaires (15) est égal à environ 10 % du débit total dans la chambre de combustion, pour la charge nominale.

5. Dispositif de combustion de turbine à gaz selon l'une quelconque des revendications 1 à 4, dans lequel chaque buse principale (14) est formée sur l'extrémité intérieure d'un cylindre de prémélange (16), dans lequel est insérée la partie d'extrémité ouverte d'une canalisation d'alimentation en combustible (18).

6. Dispositif de combustion de turbine à gaz selon l'une quelconque des revendications 1 à 5, dans lequel les moyens (30,31,40) pour prémélanger le mélange de gaz auxiliaire incluent un mélangeur (30) alimenté par un écoulement d'air et par le combustible, une soupape de réglage (40) disposée dans le trajet d'écoulement d'air, et des chambres de prémélange auxiliaires (30) communiquant avec les buses auxiliaires (15) et

alimentées par le gaz uniformément prémélangé délivré par le mélangeur (30).

7. Dispositif de combustion de turbine à gaz selon l'une quelconque des revendications 1 à 6, dans lequel les moyens d'alimentation en combustible (18) des buses principales (14) sont commandé par des soupapes d'arrêt séparées (50) et par une soupape de réglage commune (60).

8. Dispositif de combustion de turbine à gaz selon l'une quelconque des revendications 1 à 7, dans lequel les buses principales (14) sont classées en au moins trois groupes, dont chacun est commandé de façon indépendante par une soupape séparée de réglage de débit (61,62,63).

9. Dispositif de combustion de turbine à gaz selon la revendication 8, dans lequel lorsque le premier rapport d'air (λ1) du mélange de gaz principal envoyé au premier groupe des buses principales (14) atteint environ 1,25, le fonctionnement du second groupe des buses principales (14) est déclenché.

10. Dispositif de combustion de turbine à gaz selon la revendication 8 ou 9, dans lequel, lorsque le premier rapport d'air (λ1) du mélange de gaz principal envoyé au second groupe des buses principales (14) atteint environ 1,25, le fonctionnement du troisième groupe des buses principales (14) est déclenché.

11. Dispositif de combustion de turbine à gaz selon les revendications 9, 10, dans lequel le premier rapport d'air (λ1) du mélange de gaz principal envoyé successivement aux premier et second groupes des buses principales (14) est égal, au début, à environ 2,5.

12. Procédé de combustion pour un dispositif de combustion de turbine à gaz comprenant une pluralité de buses principales (14) prévues dans une paroi d'une chambre de combustion et une buse auxiliaire (15) formée autour de chacune des buses principales (14),
comprenant les étapes consistant à :
- injecter un mélange de gaz auxiliaire combustible-air prémélangé présentant un rapport d'air (λ) égal sensiblement à 1 par l'intermédiaire des buses auxiliaires (15), dans la chambre de combustion;
- allumer le mélange de gaz auxiliaire injecté
- injecter le mélange de gaz combustible-air prémélangé, possédant un rapport d'air supérieur à 1 par l'intermédiaire d'un nombre prédéterminé des buses principales (14), dans la chambre de combustion, alors que seul de l'air est envoyé aux autres buses principales (14);
- allumer le mélange de gaz injecté du nombre prédéterminé des buses principales (14);
- injecter le mélange de gaz carburant-air prémélangé possédant un rapport d'air supérieur à 1 par l'intermédiaire d'un autre nombre prédéterminé des buses principales (14), alors que seul de l'air est envoyé aux autres buses principales (14), après l'allumage du premier nombre des buses principales (14);
- allumer le gaz prémélangé injecté du second nombre prédéterminé des buses principales (14);
- injecter un gaz combustible-air prémélangé possédant un rapport d'air supérieur à 1, dans un troisième nombre prédéterminé des buses principales (14) après l'allumage du second nombre prédéterminé des buses principales (14); et
- allumer le gaz prémélangé injecté du troisième nombre prédéterminé des buses principales (14).

13. Procédé de combustion selon la revendication 12, dans lequel le rapport d'air (λ1) du mélange de gaz principal injecté dans les buses principales est compris entre 1,25 et 2,5 et de préférence égal à 1,5 ou plus, et la vitesse d'injection du mélange de gaz principal est sensiblement supérieure à sa vitesse de propagation de flamme.

14. Procédé de combustion selon la revendication 12 ou 13, dans lequel le second rapport d'air (λ2) est compris entre 0,8 et 1,2 et de préférence est proche de 1,0, et la vitesse d'injection du mélange de gaz auxiliaire est presque égale à sa vitesse de propagation de flamme.

15. Procédé de combustion selon les revendications 12 à 14, dans lequel du combustible et un débit d'air commandé sont prémélangés au mélange de gaz auxiliaire uniforme et envoyés à toutes les buses auxiliaires (15).

16. Procédé de combustion selon l'une quelconque des revendications 12 à 14, dans lequel le débit total d'air dans les buses auxiliaires (15) est égal à environ 10 % du débit total dans le dispositif de combustion, pour la charge nominale.

17. Procédé de combustion selon l'une quelconque des revendications 12 à 16, dans lequel les buses principales (14) sont classées en trois groupes commandés de façon indépendante, et lorsque le rapport d'air (λ1) du mélange de gaz principal in-

jecté dans le premier groupe des buses principales (14) atteint environ 1,25, le fonctionnement du second groupe des buses principales (14) est déclenché.

18. Procédé de combustion selon la revendication 17, dans lequel lorsque le rapport d'air ($\lambda 1$) du mélange de gaz principal injecté dans le second groupe des buses principales (24) atteint environ 1,25, le fonctionnement du troisième groupe des buses principales (14) est déclenché.

19. Procédé de combustion selon la revendication 17, dans lequel le rapport d'air du mélange de gaz principal injecté dans le premier groupe des buses principales (14) est égal au départ à environ 2,5.

20. Procédé de combustion selon la revendication 18, dans lequel le rapport d'air ($\lambda 1$) du mélange de gaz principal injecté dans le second groupe des buses principales (14) est égal au départ à environ 2,5.

FIG. 1

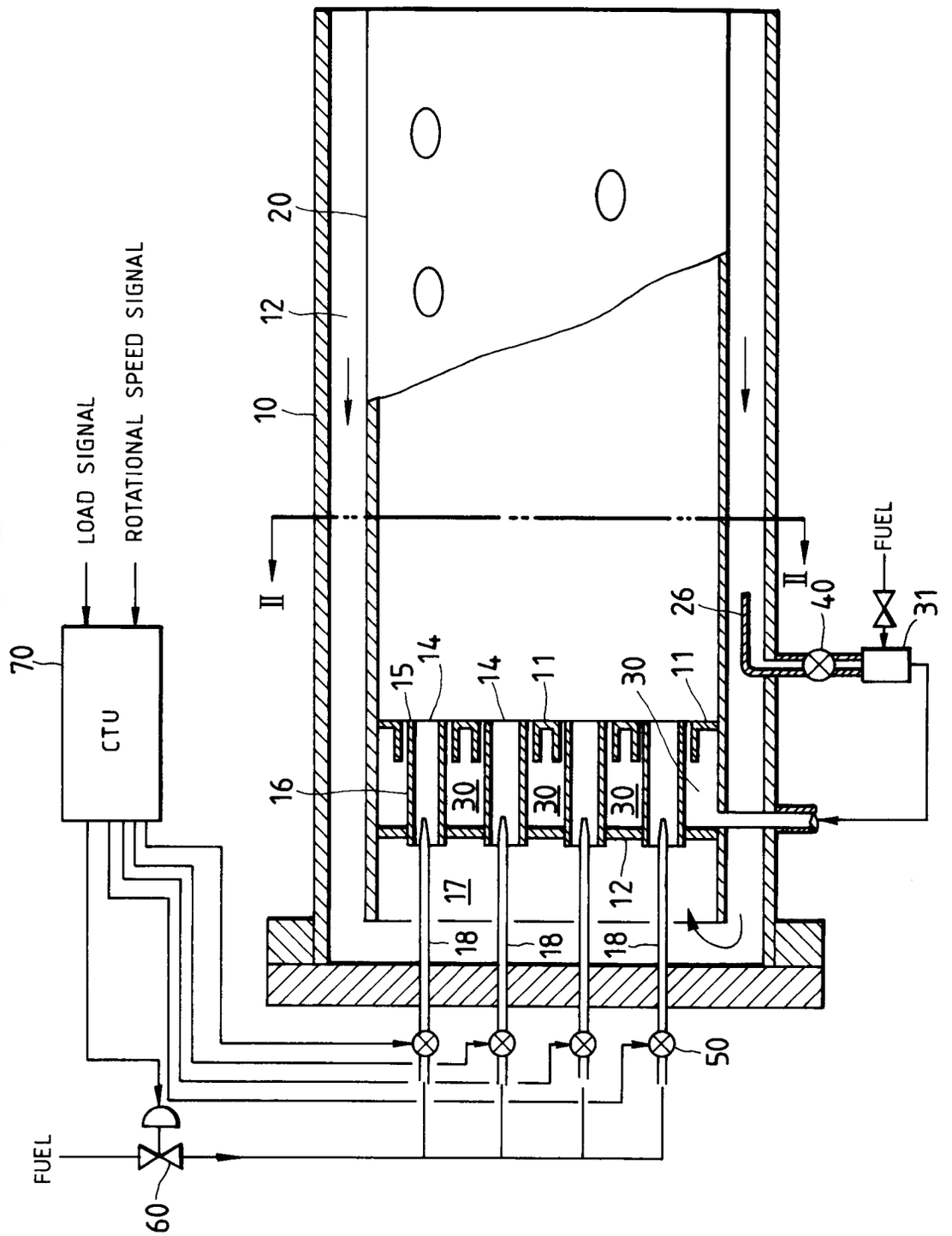

LOAD SIGNAL
ROTATIONAL SPEED SIGNAL
70
CTU
20
12
10
II
II
16
15
14
14
11
30
11
26
40
FUEL
31
30
30
17
18
18
18
12
50
FUEL
60

FIG. 2

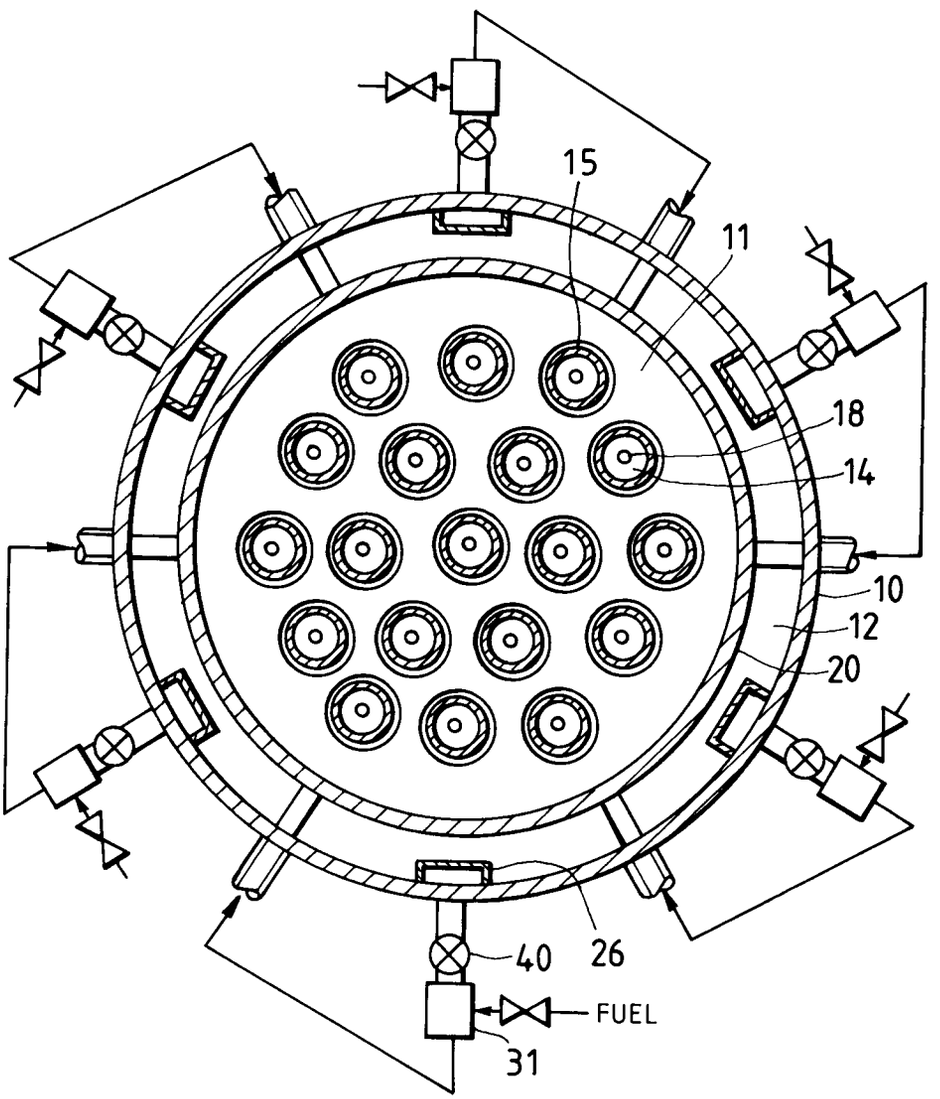


FIG. 3

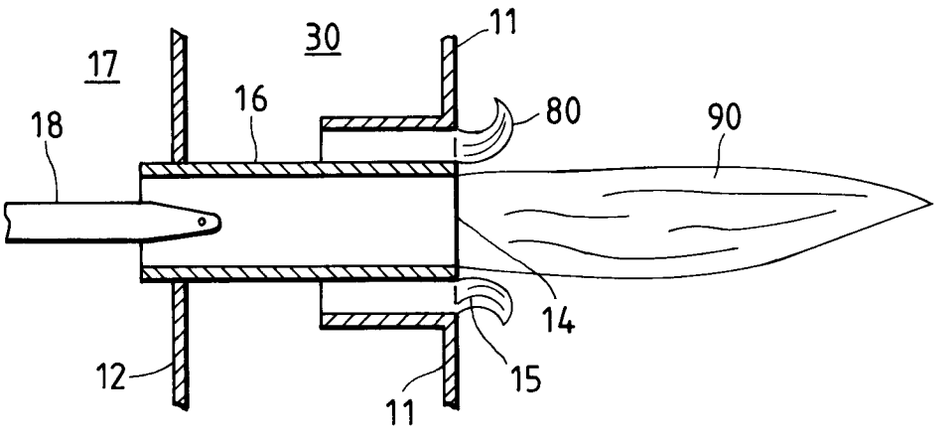

17
30
11
16
80
90
18
14
12
15
11

FIG. 4

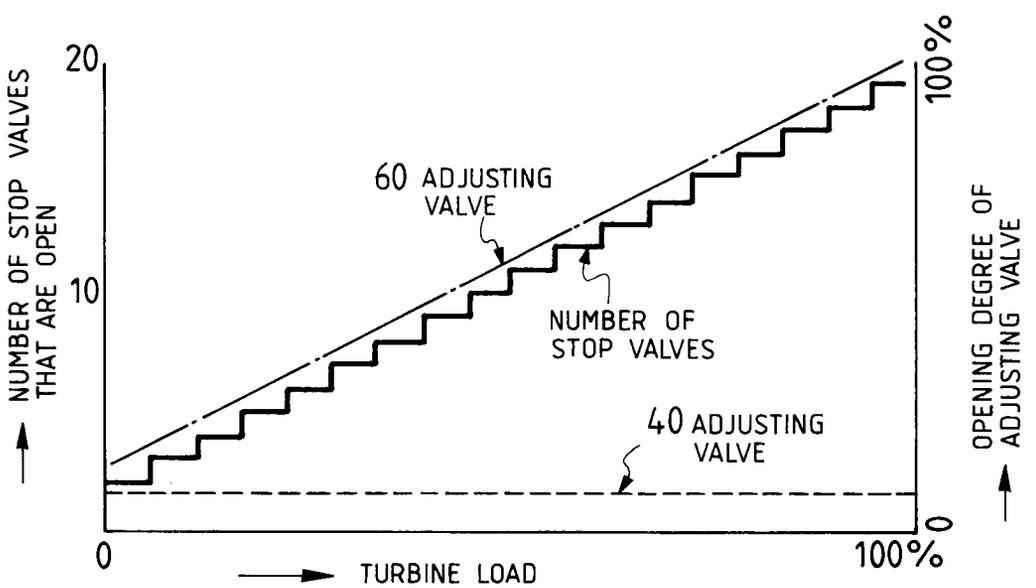

20
10
0
100%
100%
0
NUMBER OF STOP VALVES THAT ARE OPEN
OPENING DEGREE OF ADJUSTING VALVE
60 ADJUSTING VALVE
NUMBER OF STOP VALVES
40 ADJUSTING VALVE
TURBINE LOAD

FIG. 5(a)

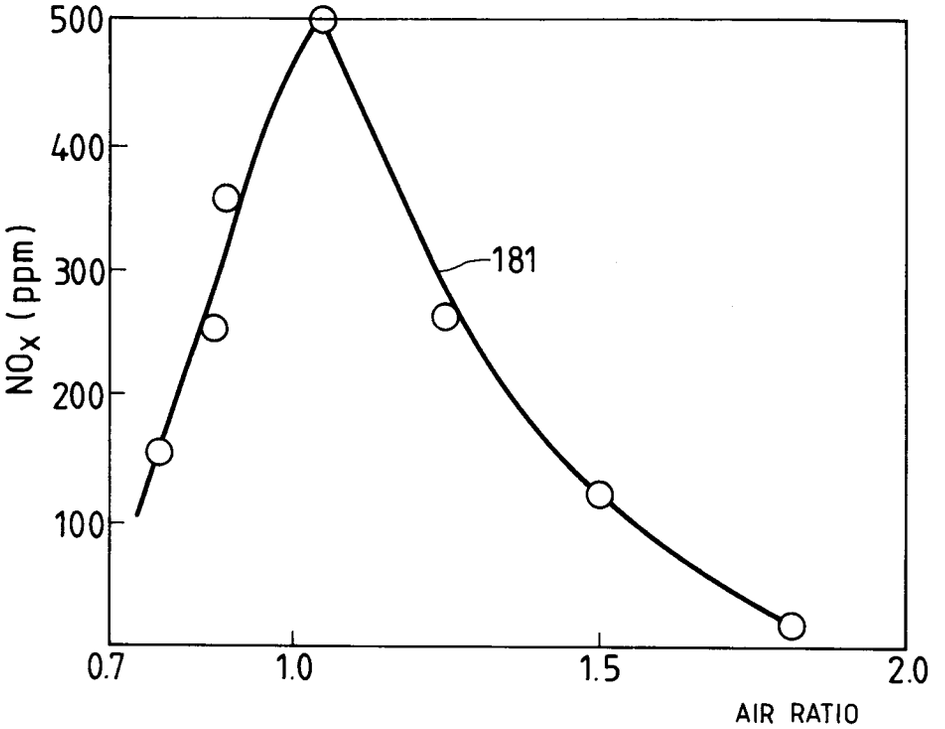

500
400
300
200
100
NO_X (ppm)
181
0.7
1.0
1.5
2.0
AIR RATIO

FIG. 5(b)

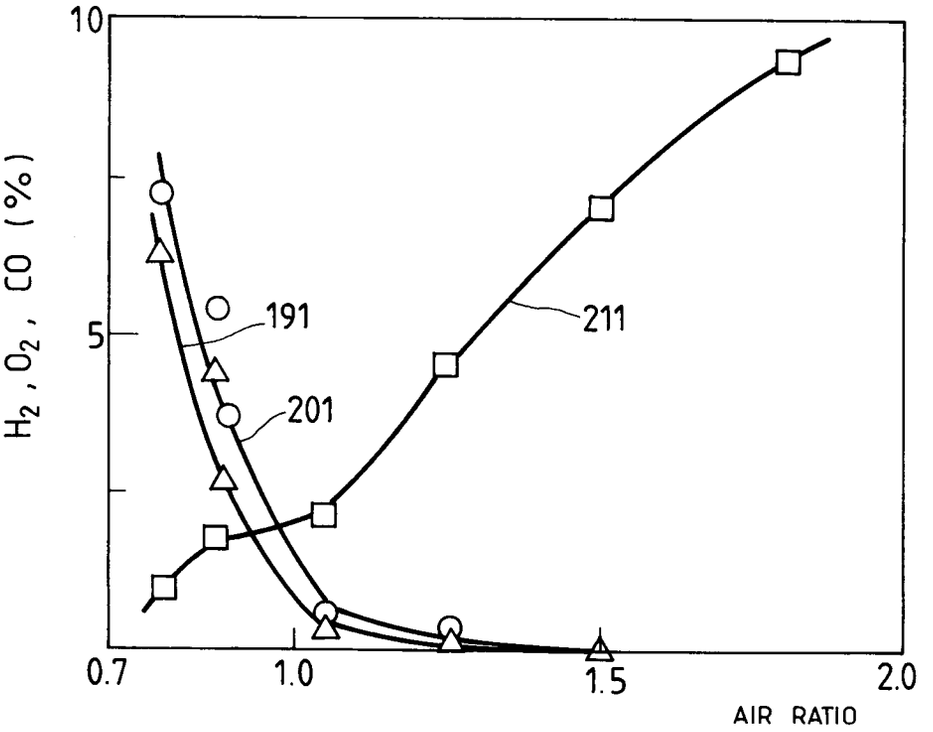

10
5
H_2, O_2, CO (%)
191
201
211
0.7
1.0
1.5
2.0
AIR RATIO

FIG. 6(a)

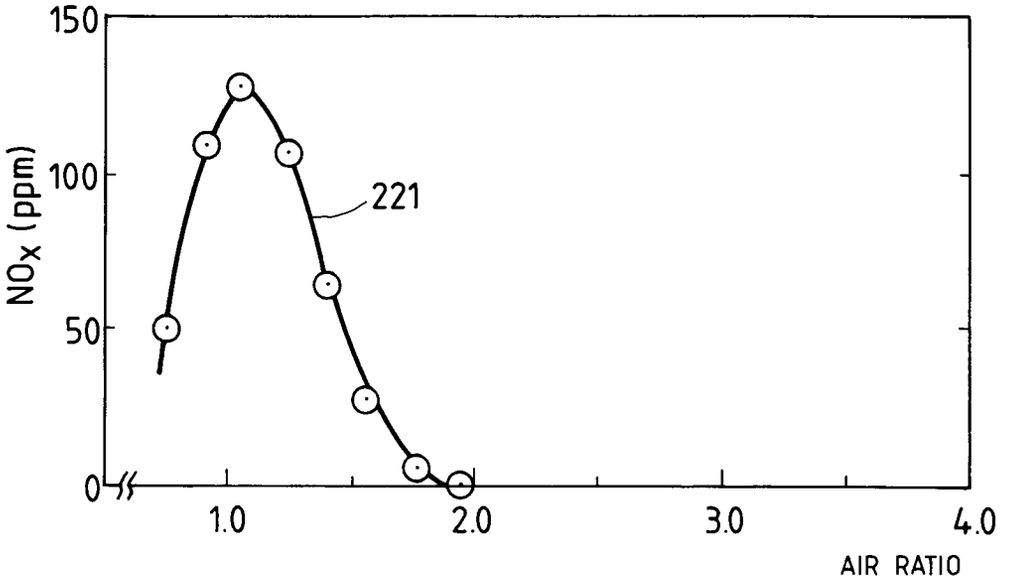

150
100
50
0
NOx (ppm)
221
1.0
2.0
3.0
4.0
AIR RATIO

FIG. 6(b)

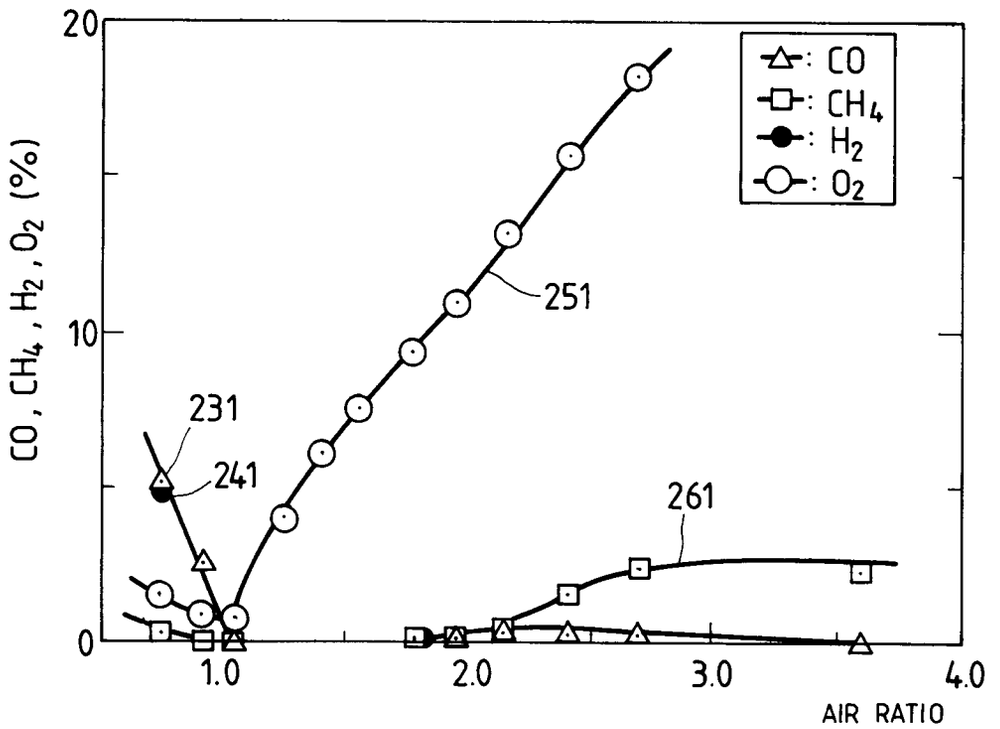

20
10
0
CO, CH4, H2, O2 (%)
: CO
: CH4
: H2
: O2
251
231
241
261
1.0
2.0
3.0
4.0
AIR RATIO

FIG. 7

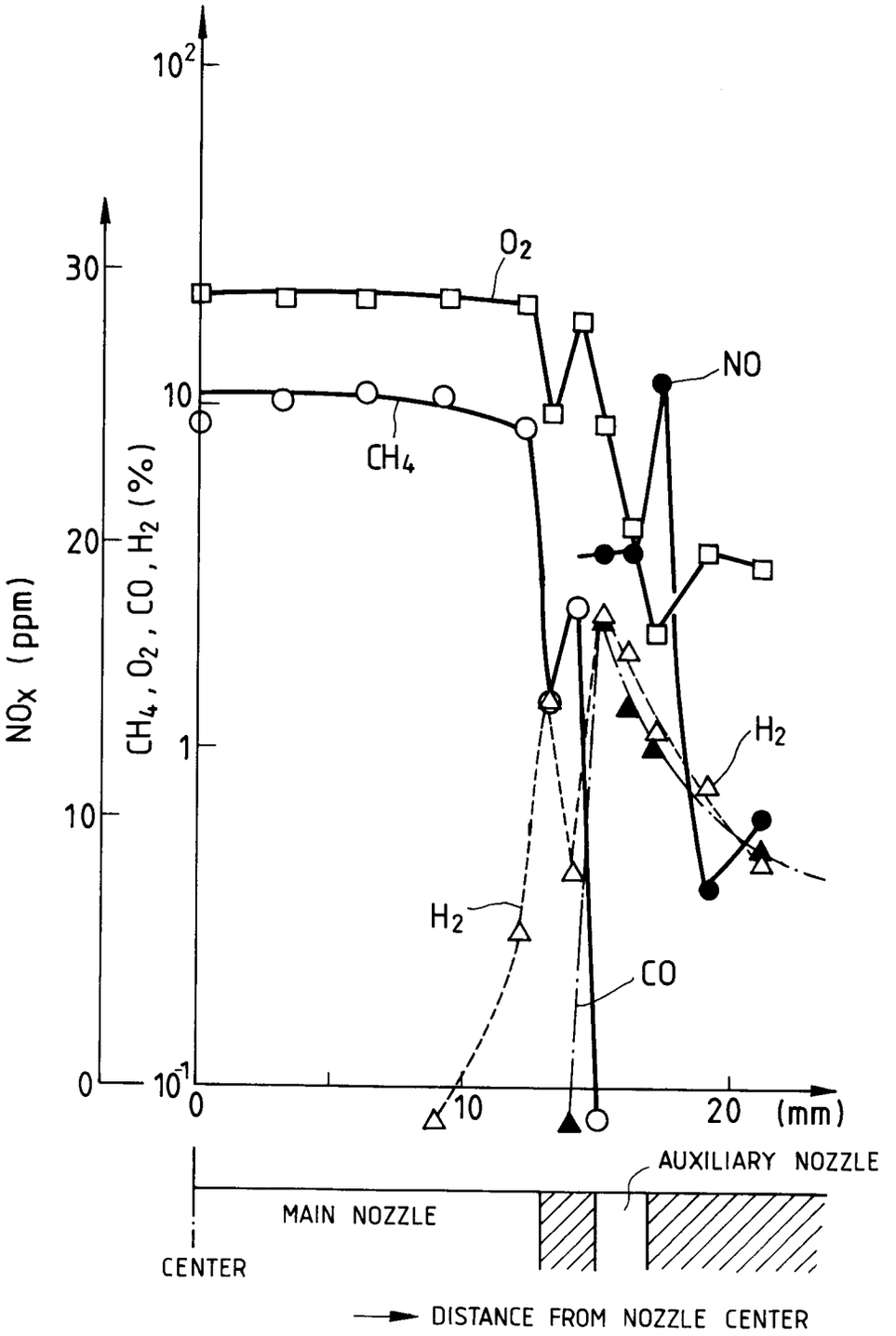

10^2
30
10
20
1
10
0
10^{-1}
NO_x (ppm)
CH_4, O_2, CO, H_2 (%)
O_2
NO
CH_4
H_2
H_2
CO
0
10
20
(mm)
AUXILIARY NOZZLE
MAIN NOZZLE
CENTER
DISTANCE FROM NOZZLE CENTER

FIG. 8

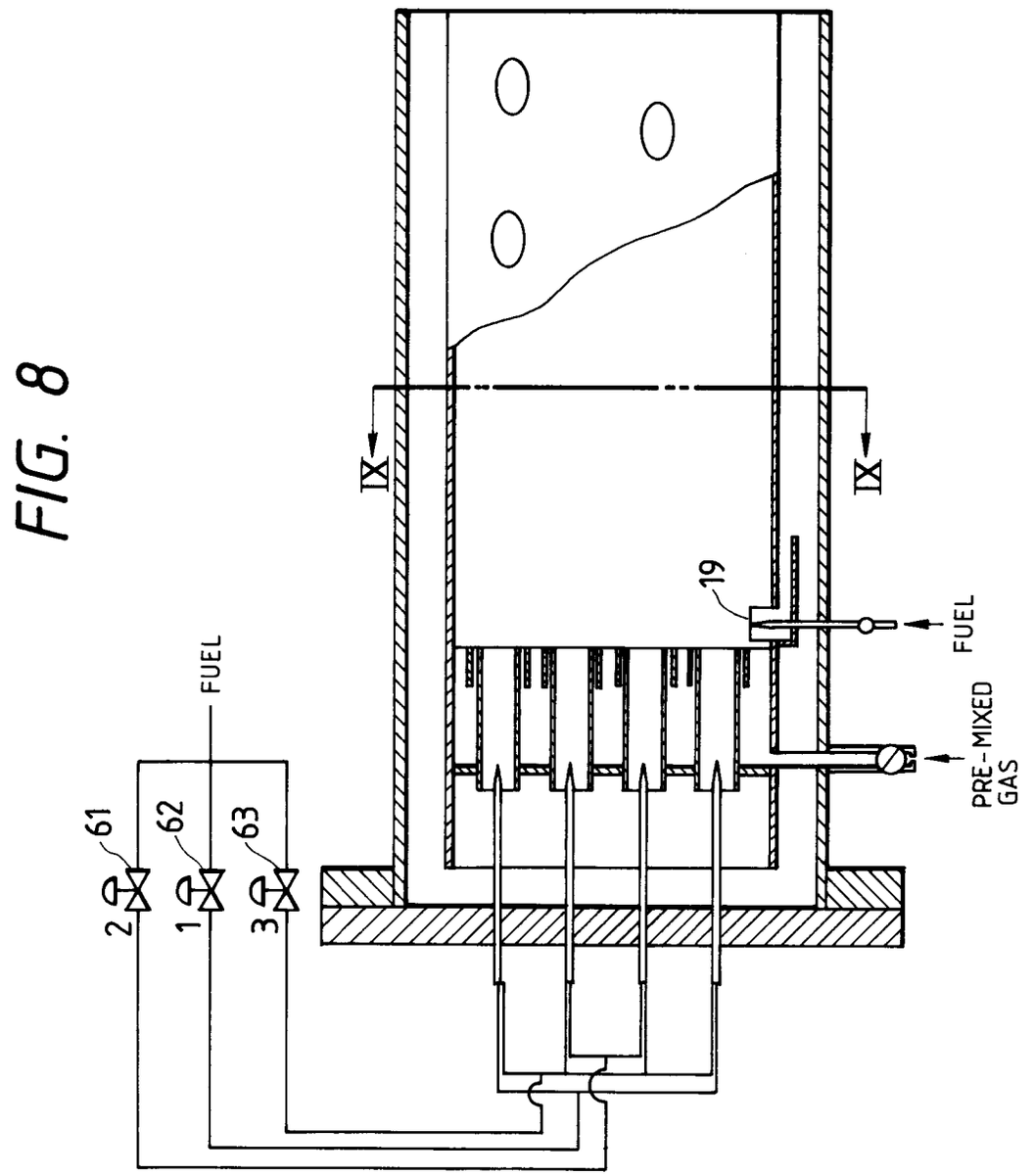


FIG. 9

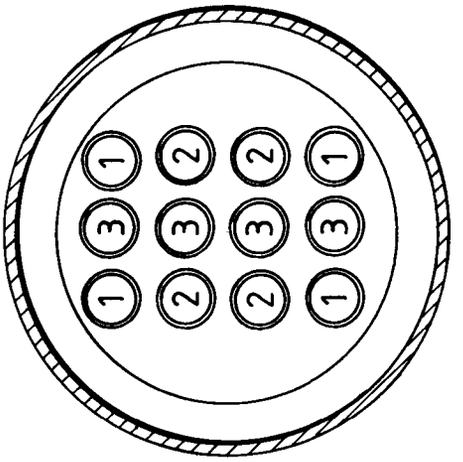
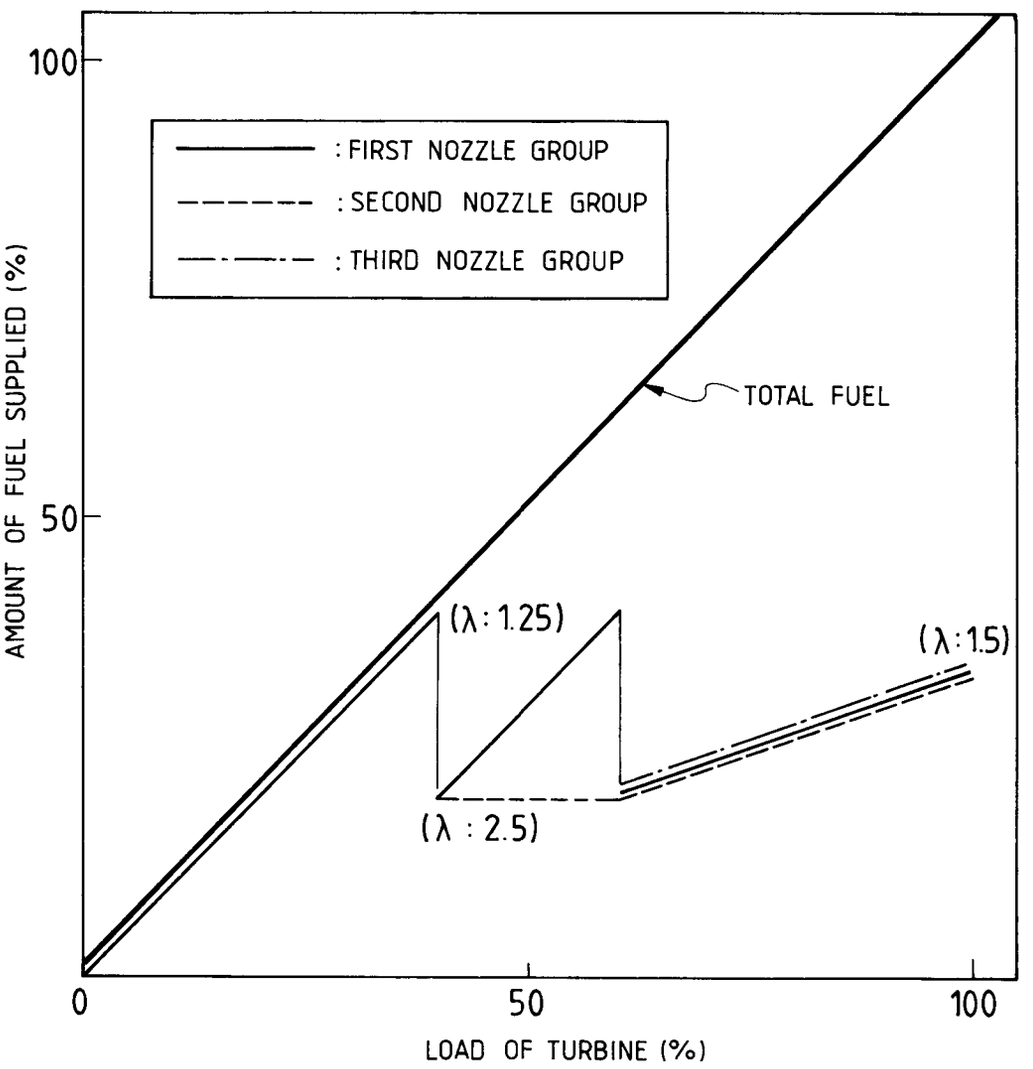


FIG. 10


100
50
0
50
100
AMOUNT OF FUEL SUPPLIED (%)
LOAD OF TURBINE (%)
: FIRST NOZZLE GROUP
: SECOND NOZZLE GROUP
: THIRD NOZZLE GROUP
TOTAL FUEL
(λ : 1.25)
(λ : 1.5)
(λ : 2.5)