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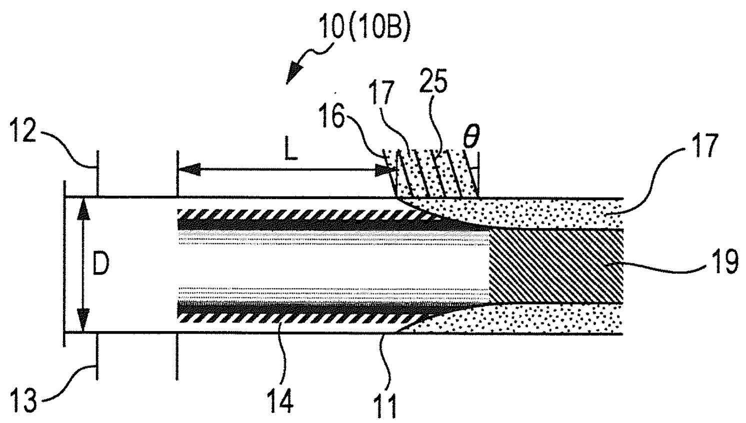
(54) TUBULAR FLAME BURNER

(57) A tubular flame burner includes a tubular combustion chamber having an open end, a fuel gas injection nozzle, and an oxygen-containing gas injection nozzle, each of the injection nozzles being disposed on a closed end side of the combustion chamber so as to be oriented in a direction tangential to an inner wall surface of the combustion chamber. The tubular flame burner further includes a temperature-adjustment gas injection nozzle and backflow preventing means, the temperature-adjustment gas injection nozzle being disposed on the open end side of the combustion chamber and injecting a temperature-adjustment gas for adjusting a temperature of a combustion exhaust gas, the backflow preventing means preventing backflow of the temperature-adjustment gas, which has been injected from the temperature-adjustment gas injection nozzle, toward the fuel gas injection nozzle.

FIG. 3



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Description

Technical Field

[0001] The present invention relates to a tubular flame burner.

Background Art

[0002] As illustrated in Fig. 1, a tubular flame burner 10 includes a tubular combustion chamber 11 having an open end, a fuel gas injection nozzle 12, and an oxygen-containing gas injection nozzle 13. The injection nozzles 12 and 13 are each disposed on a closed end side of the combustion chamber 11 so as to be oriented in a direction tangential to the combustion chamber 11. The tubular flame burner 10 forms a tubular flame 14 in the combustion chamber 11. The tubular flame burner 10 is an epoch-making burner that can reduce the size of combustion facility and that can reduce the amounts of hazardous substances, such as NOx, which may increase depending on the combustion conditions; unburned substances, such as hydrocarbon; and environmental pollutants, such as soot and smoke, and the like (see, for example, PTLs 1 and 2).

Citation List

Patent Literature

[0003]

PTL 1: Japanese Unexamined Patent Application Publication No. 11-281015
PTL 2: Japanese Unexamined Patent Application Publication No. 2012-097918

Summary of Invention

Technical Problem

[0004] In order to use such a tubular flame burner as a hot-blast generating device or the like, it is necessary to adjust the temperature of a combustion exhaust gas to a desired temperature. However, PTL 1 does not describe a method for adjusting the temperature of the combustion exhaust gas.

[0005] In contrast, PTL 2 describes a method for adjusting the temperature of a combustion exhaust gas by disposing a temperature-adjustment gas injection nozzle for injecting a temperature-adjustment gas on an open end side of a combustion chamber and by injecting the temperature-adjustment gas from the nozzle. However, as described below in detail in "Description of Embodiments", with the technology described in PTL 2, a flame failure (extinguishment of combustion) may occur.

[0006] An object of the present invention, which has been achieved under the circumstances described above, is to provide a tubular flame burner that can appropriately adjust the temperature of a combustion exhaust gas and that can continue a stable combustion in a case where the tubular flame burner is used as a hot-blast generating device or the like.

Solution to Problem

[0007] In order to solve the problem described above, the present invention has the following characteristics.

[1] A tubular flame burner includes a tubular combustion chamber having an open end, a fuel gas injection nozzle, and an oxygen-containing gas injection nozzle, each of the injection nozzles being disposed on a closed end side of the combustion chamber so as to be oriented in a direction tangential to an inner wall surface of the combustion chamber. The tubular flame burner further includes a temperature-adjustment gas injection nozzle and backflow preventing means, the temperature-adjustment gas injection nozzle being disposed on the open end side of the combustion chamber and injecting a temperature-adjustment gas for adjusting a temperature of a combustion exhaust gas, the backflow preventing means preventing backflow of the temperature-adjustment gas, which has been injected from the temperature-adjustment gas injection nozzle, toward the fuel gas injection nozzle.

[2] In the tubular flame burner described in [1], the backflow preventing means is provided by inclining an injection direction of the temperature-adjustment gas from the temperature-adjustment gas injection nozzle in a downstream direction at an angle in the range of 10° to 60° with respect to a plane perpendicular to an axis of the tubular combustion chamber.

[3] In the tubular flame burner described in [1], the backflow preventing means is a turbulence generating mechanism disposed upstream of the temperature-adjustment gas injection nozzle.

[4] In the tubular flame burner described in [3], the turbulence generating mechanism is one of an orifice, a grid, and a packed bed.

[5] In the tubular flame burner described in [1], the temperature-adjustment gas injection nozzle is separated from the fuel gas injection nozzle by a distance that is 2.5 to 3.5 times an inside diameter D of the combustion chamber.

[6] In the tubular flame burner described in [1], the temperature-adjustment gas injection nozzle is separated from the fuel gas injection nozzle by a distance that is 3.5 to 6 times an inside diameter D of the combustion chamber.

[7] A tubular flame burner includes a tubular combustion chamber having an open end, a fuel gas injection nozzle, and an oxygen-containing gas injection nozzle, each of the injection nozzles being disposed on a closed end side of the combustion cham-

ber so as to be oriented in a direction tangential to an inner wall surface of the combustion chamber. The tubular flame burner further includes a temperature-adjustment gas injection nozzle disposed on the open end side of the combustion chamber and injecting a temperature-adjustment gas for adjusting a temperature of a combustion exhaust gas, and an injection direction of the temperature-adjustment gas from the temperature-adjustment gas injection nozzle is inclined in a downstream direction at an angle in the range of 10° to 60° with respect to a plane perpendicular to an axis of the tubular combustion chamber.

[8] In the tubular flame burner described in [7], the injection direction of the temperature-adjustment gas is inclined in the downstream direction at an angle in the range of 25° to 60° with respect to the plane perpendicular to the axis of the tubular combustion chamber.

Advantageous Effects of Invention

[0008] The tubular flame burner according to the present invention can appropriately adjust the temperature of a combustion exhaust gas and can continue a stable combustion in a case where the tubular flame burner is used as a hot-blast generating device or the like.

Brief Description of Drawings

[0009]

Fig. 1 illustrates a conventional tubular flame burner.

Fig. 2 illustrates a tubular flame burner on which an embodiment of the present invention is based.

Fig. 3 illustrates a tubular flame burner according to a first embodiment of the present invention.

Fig. 4 is a cross-sectional view of the tubular flame burner according to the first embodiment of the present invention, taken along a plane passing through a temperature-adjustment gas injection nozzle.

Fig. 5 illustrates another example of the tubular flame burner according to the first embodiment of the present invention.

Fig. 6 is a cross-sectional view of the tubular flame burner according to the other example of the first embodiment of the present invention, taken along a plane passing through temperature-adjustment gas injection nozzles.

Fig. 7 illustrates another example of the tubular flame burner according to the first embodiment of the present invention.

Fig. 8 is a cross-sectional view of the tubular flame burner according to the other example of the first embodiment of the present invention, taken along a plane passing through temperature-adjustment gas injection nozzles.

Fig. 9 illustrates another example of the tubular flame burner according to the first embodiment of the present invention.

Fig. 10 is a cross-sectional view of the tubular flame burner according to the other example of the first embodiment of the present invention, taken along a plane passing through temperature-adjustment gas injection nozzles.

Fig. 11 illustrates a tubular flame burner according to a second embodiment of the present invention.

Fig. 12 illustrates a tubular flame burner according to the second embodiment of the present invention.

Fig. 13 illustrates a tubular flame burner according to the second embodiment of the present invention.

Fig. 14 is a cross-sectional view of the tubular flame burner according to the second embodiment of the present invention, illustrating a configuration of a temperature-adjustment gas injection nozzle.

Fig. 15 is a cross-sectional view of the tubular flame burner according to the second embodiment of the present invention, illustrating another configuration of temperature-adjustment gas injection nozzles.

Fig. 16 is a cross-sectional view of the tubular flame burner according to the second embodiment of the present invention, illustrating another configuration of temperature-adjustment gas injection nozzles.

Fig. 17 illustrates a combustion test device used to test the performance of a tubular flame burner.

Description of Embodiments

[0010] Embodiments of the present invention will be described with reference to the drawings.

[0011] Fig. 1 illustrates a conventional tubular flame burner described in PTL 1. Fig. 2 illustrates a tubular flame burner 10A having a temperature-adjustment gas injection nozzle, on which an embodiment of the present invention is based. The tubular flame burner 10A corresponds to a tubular flame burner described in PTL 2 cited above.

[0012] As in the existing tubular flame burner 10 shown in Fig. 1, the tubular flame burner 10A of Fig. 2 includes a tubular combustion chamber 11 having an open end, a nozzle for injecting a fuel gas (fuel gas injection nozzle) 12, and a nozzle for injecting an oxygen-containing gas (oxygen-containing gas injection nozzle) 13. Each of the nozzles 12 and 13 is disposed on a closed end side of the combustion chamber so as to be oriented in a direction tangential to an inner wall surface of the combustion chamber 11. The tubular flame burner 10A forms a tubular flame 14 in the combustion chamber 11. In addition to the fuel gas injection nozzle 12 and the oxygen-containing gas injection nozzle 13, the tubular flame burner 10A further includes a nozzle for injecting a temperature-adjustment gas (temperature-adjustment gas injection nozzle) 16 for injecting a temperature-adjustment gas 17 for adjusting the temperature of a combustion exhaust gas 19. The temperature-adjustment gas injection nozzle

16 is disposed on the open end side of the combustion chamber 11 so as to be oriented in a direction tangential to the inner wall surface of the combustion chamber 11.

[0013] The tubular flame burner 10A is capable of adjusting the temperature of the combustion exhaust gas 19 by injecting the temperature-adjustment gas 17 from the temperature-adjustment gas injection nozzle 16 and mixing the combustion exhaust gas 19 with the temperature-adjustment gas 17.

[0014] However, the tubular flame burner 10A occasionally caused a flame failure (extinguishment of combustion) when the temperature-adjustment gas 17 having a low temperature (such as room temperature) was injected in a certain amount or more. Moreover, it was observed that a smaller amount of the temperature-adjustment gas 17 caused a flame failure in a case where the fuel gas had a low heating value and the tubular flame 14 had a large length.

[0015] The inventors examined the cause of the flame failure by performing a combustion test using a combustion test device, a numerical simulation, and the like. As a result, the inventors found that the flame failure occurs through the following mechanism.

(a) Extinguishment of Combustion due to Mixing of Temperature-adjustment Gas prior to Complete Combustion

[0016] In the existing tubular flame burner 10 described in PTL 1, it is not necessary that the length of the combustion chamber 11 be considerably large relative the diameter D of the combustion chamber 11, provided that mixing of the temperature-adjustment gas 17 is not performed. This is because, a fuel gas, once ignited, can complete combustion without being extinguished, as long as mixing of the temperature-adjustment gas 17 is not performed. A fuel, oxygen, and a gas temperature are three essential factors for a substance to burn. In the tubular flame burner 10A, when the temperature-adjustment gas 17, which is a gas at room temperature, is mixed into the tubular flame 14, the temperature of the tubular flame 14 falls sharply and a flame failure occurs. As the temperature-adjustment gas 17, three gases at room temperature, i.e., a combustible gas, air, and an inert gas (argon) were used. In any of these cases, a flame failure occurred, and it was confirmed that a fall in the temperature of the tubular flame 14 is the biggest cause of a flame failure.

(b) Backflow of Temperature-adjustment Gas toward Upstream

[0017] According to conventional ideas, regarding the tubular flame burner 10A, it was considered that the temperature-adjustment gas 17 injected from the temperature-adjustment gas injection nozzle 16 in a direction tangential to the inner wall surface of the combustion chamber 11 was supplied to only a region located downstream of the injection position. Therefore, it was not considered that the temperature-adjustment gas 17 might influence a portion of the tubular flame 14 that is located upstream of the injection position (and might extinguish the tubular flame 14). However, in reality, it was observed in a combustion test that, when the temperature-adjustment gas 17 was injected, not only the diameters of the tubular flame 14 at the injection position and a position downstream of the injection position but also the diameter of the tubular flame 14 at a position upstream of the injection position decreased. Moreover, as a result of a numerical simulation, it was found that, even when the exhaust gas (combustion exhaust gas) 19 of the tubular flame 14 was flowing downstream, the temperature-adjustment gas 17 injected from the temperature-adjustment gas injection nozzle 16 tended to diffuse from the injection position in a concentric manner. Accordingly, as illustrated in Fig. 2, a portion 18 of the temperature-adjustment gas 17 flowed upstream (flowed back) along the inner wall surface of the combustion chamber 11, even if over a short distance.

[0018] From the above results, the inventors obtained the following conclusion. In order to mix the temperature-adjustment gas 17 while reliably preventing a flame failure, it is necessary to inject the temperature-adjustment gas 17 to a position behind a position at which a fuel gas and an oxygen-containing gas forming the tubular flame 14 have completed combustion and to prevent backflow of the temperature-adjustment gas 17 toward the fuel gas injection nozzle 12. To be specific, it is necessary to inject the temperature-adjustment gas 17 to a position downstream of the position at which the tubular flame 14 is formed and to prevent backflow of the temperature-adjustment gas 17 toward the fuel gas injection nozzle 12.

[0019] In order to realize prevention of backflow, the inventors conceived tubular flame burners according to embodiments (a first embodiment and a second embodiment) of the present invention described below.

First Embodiment

[0020] Fig. 3 illustrates a flame burner 10B according to the first embodiment of the present invention. Fig. 4 is a cross-sectional view of the tubular flame burner 10B illustrating a configuration of the temperature-adjustment gas injection nozzle 16.

[0021] The tubular flame burner 10B according to the first embodiment is configured to prevent backflow of the portion 18 of the temperature-adjustment gas 17 in the upstream direction, which is shown in Fig. 2.

[0022] In other words, as illustrated in Fig. 3, the temperature-adjustment gas injection nozzle 16 is disposed at an angle θ so that the temperature-adjustment gas 17 is injected in a direction that is inclined in the downstream direction at the angle θ with respect to a direction perpendicular to the axis of a tubular combustion chamber 117. To be specific, the angle θ is in the range of 10° to 60° (10° $\leq \theta \leq$ 60°). It is preferable that the angle θ be in the range of 25° to 60°.

[0023] It was confirmed in a numerical simulation that, when the angle θ was 10° or more, backflow of the temperature-adjustment gas 17 decreased, and, when the angle θ was 45°, backflow of the temperature-adjustment gas 17 was almost eliminated. By setting the angle θ to be 60° or less, production is very easy because interference between the temperature-adjustment gas injection nozzle 16 and the combustion chamber 11 is small.

[0024] The temperature-adjustment gas 17 may be injected in a direction that is inclined in the downstream direction at the angle θ by, instead of disposing the temperature-adjustment gas injection nozzle 16 so as to be inclined at the angle θ, providing a mechanism (such as straightening vanes 25) for making the flow of the temperature-adjustment gas 17 be inclined at the angle θ in the adjustment gas injection nozzle 16.

[0025] Thus, the tubular flame burner 10B according to the first embodiment prevents backflow of the temperature-adjustment gas 17 by injecting the temperature-adjustment gas 17 at an injection angle that is inclined in the downstream direction by a predetermined angle θ ($10° \leq \theta \leq 60°$). As a result, without increasing the length of the combustion chamber 11, it is possible to appropriately adjust the temperature of the combustion exhaust gas 19 while reliably preventing a flame failure.

[0026] As illustrated in Fig. 4, which is a cross-sectional view of the tubular flame burner 10B taken along a plane passing through the temperature-adjustment gas injection nozzle 16, a single temperature-adjustment gas injection nozzle 16 injects the temperature-adjustment gas 17 in a direction tangential to the inner wall surface of the combustion chamber 11. However, the temperature-adjustment gas injection nozzle 16 may be configured in a different manner.

[0027] For example, Fig. 5 illustrates a tubular flame burner $10B_1$, and Fig. 6 is a cross-sectional view of the tubular flame burner $10B_1$ taken along a plane passing through temperature-adjustment gas injection nozzles 16. As shown in Figs. 5 and 6, a plurality of (three, in Fig. 6) temperature-adjustment gas injection nozzles 16 may inject the temperature-adjustment gas 17 in directions tangential to the inner wall surface of the combustion chamber 11.

[0028] It is not necessary that the temperature-adjustment gas be injected in a direction tangential to the inner wall surface of the combustion chamber 11. Fig. 7 illustrates a tubular flame burner $10B_2$, and Fig. 8 is a cross-sectional view of the tubular flame burner $10B_2$ taken along a plane passing through temperature-adjustment gas injection nozzles 16. As shown in Figs. 7 and 8, a plurality of (three, in Fig. 8) temperature-adjustment gas injection nozzles 16 may inject the temperature-adjustment gas 17 toward a central part of the combustion chamber 11.

[0029] Fig. 9 illustrates a tubular flame burner $10B_3$, and Fig. 10 is a cross-sectional view of the tubular flame burner $10B_3$ taken along a plane passing through temperature-adjustment gas injection nozzles 16. As shown in Fig. 9 and 10, the combustion chamber 11 may have a portion having a decreasing inside diameter near an end of the tubular flame 14, and a predetermined number of (three, in Fig. 10) temperature-adjustment gas injection nozzles 16 may inject the temperature-adjustment gas 17 at the portion toward a central part of the combustion chamber 11.

[0030] The shape of each temperature-adjustment gas injection nozzle 16 may be the same as that of the tubular flame burner 10B (Figs. 3 and 4), which has a rectangular cross section (slit nozzle); or any one of those of the tubular flame burner $10B_1$ (Figs. 5 and 6), the tubular flame burner $10B_2$ (Figs. 7 and 8), and the tubular flame burner $10B_3$ (Figs. 9 and 10), each of which has a circular cross section.

[0031] In short, the shapes and the number of the temperature-adjustment gas injection nozzles 16 may be appropriately determined so that the temperature-adjustment gas may have a desired flow rate and a desired flow speed.

Second Embodiment

[0032] Figs. 11, 12, and 13 respectively illustrate tubular flame burners 10C, 10D, and 10E according to the second embodiment of the present invention.

[0033] The tubular flame burners 10C, 10D, and 10E according to the second embodiment actively accelerate combustion of the tubular flame 14 so that a burnout position at which combustion is completed is moved upstream from a position at which combustion is completed naturally, and the temperature-adjustment gas injection nozzle 16 is disposed downstream of the burnout position.

[0034] In other words, a turbulence generating mechanism 20 is disposed at a position downstream of the tubular flame 14 and upstream of the temperature-adjustment gas injection nozzle 16. By dosing so, oxygen and a fuel gas are mixed with each other at a high temperature and combustion is accelerated and forcibly completed without allowing the temperature of the tubular flame 14 to fall due to backflow of the temperature-adjustment gas 17.

[0035] To be specific, the tubular flame burner 10C illustrated in Fig. 11 has an orifice 21 as the turbulence generating mechanism 20. The tubular flame burner 10D illustrated in Fig. 12 has a grid (mesh) 22 as the turbulence generating mechanism 20. The tubular flame burner 10E illustrated in Fig. 13 has a packed bed 23 (including, for example, sintered ceramic balls) as the turbulence generating mechanism 20.

[0036] By disposing the turbulence generating mechanism 20, an advantageous effect is obtained in that the tubular flame 14 is maintained to be stable, because backflow of the temperature-adjustment gas 17 in the upstream direction along the inner wall surface of the combustion chamber 11 is prevented.

[0037] Thus, in the tubular flame burners 10C, 10D, and 10E according to the second embodiment, the turbulence generating mechanism 20 is disposed downstream of the tubular flame 14. Accordingly, without increasing the length of the combustion chamber 11, it is possible to appropriately adjust the temperature of the combustion exhaust gas 19 while reliably preventing a flame failure.

[0038] In the second embodiment (Figs. 11 to 13), as illustrated in Fig. 14, which is a cross-sectional view taken along a plane passing through the temperature-adjustment gas injection nozzle 16, a single temperature-adjustment gas injection nozzle 16 injects the temperature-adjustment gas 17 in a direction tangential to the inner wall surface of the combustion chamber 11. However, the temperature-adjustment gas injection nozzle 16 may be configured in a different manner.

[0039] For example, as illustrated in Fig. 15, which is a cross-sectional view, a plurality of (three, in Fig. 15) temperature-adjustment gas injection nozzles 16 may inject the temperature-adjustment gas 17 in directions tangential to the inner wall surface of the combustion chamber 11. It is not necessary that the temperature-adjustment gas be injected in a direction tangential to the inner wall surface of the combustion chamber 11. For example, as illustrated in Fig. 16, which is a sectional view, a plurality of (three, in Fig. 16) temperature-adjustment gas injection nozzles 16 may inject the temperature-adjustment gas 17 toward a central part of the combustion chamber 11.

[0040] The shape of each temperature-adjustment gas injection nozzle 16 may be the same as any one of those of the tubular flame burner 10C (Figs. 11 and 14), the tubular flame burner 10D (Figs. 12 and 14), and the tubular flame burner 10E (Figs. 13 and 14), each of which has a rectangular cross section (slit nozzle); or any one of those of Figs. 15 and 16, each of which has a circular cross section.

[0041] In short, the shapes and the number of the temperature-adjustment gas injection nozzles 16 may be appropriately determined so that the temperature-adjustment gas may have a desired flow rate and a desired flow speed.

[0042] A fuel gas used in the present invention is not particularly limited. However, the present invention provides a greater advantage in a case where a low-heating-value gas, which is more likely to cause a flame failure when the temperature-adjustment gas 17 is injected as illustrated in Fig. 2, is used as the fuel gas. Examples of a low-heating-value gas include gases having heating values in the range of 600 to 900 kcal/Nm^3 and in particular in the range of 600 to 800 kcal/Nm^3, such as a blast furnace gas (BFG), a CDQ gas, an exhaust gas including a small amount of combustible component, and the like.

[0043] It is preferable that the temperature-adjustment gas injection nozzle 16 be disposed at a position behind a position at which the gases (a fuel gas and an oxygen-containing gas), which form the tubular flame 14, have complete combustion. This position changes depending on the heating value of the fuel gas and the flow speeds of gases in the combustion chamber.

[0044] For example, in a case where a gas having a comparatively high heating value is used as a fuel gas, it is preferable that the distance L between the position of the fuel gas injection nozzle 12 and the position of the temperature-adjustment gas injection nozzle 16 be in the range of 2.5 to 3.5 times the inside diameter D of the combustion chamber 11. It is more preferable that the distance L be in the range of 2.5 to 3.0 times the inside diameter D, because, in this case, the length of the combustion chamber 11 (burner length) can be decreased.

[0045] For example, in a case where a low-heating-value gas having a heating value of 800 kcal/Nm^3 or less is used a fuel gas, it is preferable that the distance L between the position of the fuel gas injection nozzle 12 and the position of the temperature-adjustment gas injection nozzle 16 be in the range of 3.5 to 6 times the inside diameter D of the combustion chamber 11. It is more preferable that the distance L be in the range of 4.0 to 5.0 times the inside diameter D, because, in this case, the length of the combustion chamber 11 (burner length) can be decreased.

[0046] As described above, a necessary length of the combustion chamber 11 (the length of a combustion zone of the tubular flame) changes depending on the heating value of the fuel gas. In any of the cases, the length of the combustion chamber 11 can be easily decreased with the present invention.

[0047] Regarding the temperature-adjustment gas, the temperature and the feed amount of the temperature-adjustment gas may be appropriately set so that the temperature of the combustion exhaust gas can be adjusted to a desired temperature. For example, in a case where the combustion exhaust gas is injected into a blast furnace as a preheating gas, it is preferable that the temperature of the preheating gas be 500°C or higher and it is more preferable that the temperature be 800°C or higher. In this case, the temperature and the feed amount of the temperature-adjustment gas may be set so that the preheating gas can have such a temperature. In a case where the temperature-adjustment gas needs to also have a function of adjusting the composition of the preheating gas, it is preferable that the temperature-adjustment gas include a reduction gas such as CO or H_2. For example, at least one of a blast furnace gas, a converter gas, a coke-oven gas, and the like may be used. In particular, it is preferable that a part of a blast furnace gas be extracted and used as the temperature-adjustment gas.

Example 1

[0048] As Example 1 of the present invention, the performance of the tubular flame burner 10B according to the first embodiment of the present invention was examined by using a combustion test device 30 shown in Fig.

17.

[0049] In this test, the tubular flame burner 10 was attached to a furnace body 31, and a diluted LPG (diluted propane gas, having a heating value of 2400 kcal/Nm^3) made by diluting LPG (propane gas) with nitrogen at a ratio of ten was used as a fuel gas, and air was used as an oxygen-containing gas. The sizes of the fuel gas injection nozzle 12 and the oxygen-containing gas injection nozzle 13 were adjusted so that the injection speeds of the fuel gas and air respectively injected in directions tangential to the inner wall surface of the combustion chamber 11 would be about 9 times the speed of a mixed gas formed in the combustion chamber 11.

[0050] As the temperature-adjustment gas 17, three types of gases, which were a diluted LPG (diluted propane gas) made by diluting LPG with nitrogen at a ratio of ten, nitrogen, and air, were used. The injection amount of the temperature-adjustment gas 17 was set to be the same as the amount of combustion exhaust gas, and the size of the temperature-adjustment gas injection nozzle 16 was adjusted so that the injection speed of the temperature-adjustment gas 17 would be about 9 times the speed of a mixed gas formed in the combustion chamber 11.

[0051] The inside diameter of the combustion chamber 11 was about 200 mm. The entirety of the tubular flame burner 10 had a length of 3 m so that the influence the injection position of the temperature-adjustment gas could be examined.

[0052] Because the temperature of the combustion exhaust gas would become as high as about 2000°C when the temperature-adjustment gas 17 was not injected, the combustion exhaust gas discharged from the furnace body 31 is cooled by using a sprinkler device 32 and then discharged from a smokestack 33. The entirety of the furnace body 31 was covered with refractories, and pipes to an upper roof portion and the sprinkler device 32 had a water-cooling structure. An inspection window, an ignition plug, and a luminance detector were disposed at the rear end of the tubular flame burner 10. The tubular flame burner 10 was configured so that supply of propane gas could be instantaneously stopped upon detection of a flame failure by the luminance detector.

[0053] The results of assessing and examining the performances of tubular flame burners will be described below. A case where air was used as the temperature-adjustment gas 17 will be described here, because the same results were obtained for the cases where a diluted LPG (diluted propane gas), nitrogen, and air were used as the temperature-adjustment gas 17.

[0054] In order to examine the performance of the tubular flame burner 10A, on which the first embodiment of the present invention is based, an experiment was performed in which the distance L from the position of the fuel gas injection nozzle 12 to the position of the temperature-adjustment gas injection nozzle 16 was changed.

[0055] As a result, in a case where the distance L was 2.5 times the inside diameter D of the combustion chamber 11, a flame failure occurred as soon as the temperature-adjustment gas (air) was mixed. After the temperature-adjustment gas (air) was mixed, it was not possible to ignite by using the ignition plug. In a case the distance L was 3 times the inside diameter D of the combustion chamber, when the temperature-adjustment gas (air) was injected, combustion occurred but continued for only 20 minutes or shorter, and it was necessary to reignite after a flame failure occurred. On the other hand, in a case where the distance L was 3.5 times the inside diameter D of the combustion chamber 11, combustion continued when the temperature-adjustment gas (air) was injected, and stable combustion continued for at least for 60 minutes. Also in a case where the distance L was 4 times the inside diameter D of the combustion chamber 11, stable combustion continued for 60 minutes or longer.

[0056] In order to examine the performance of the tubular flame burner 10B according to the first embodiment of the present invention, the temperature-adjustment gas injection nozzle 16 was disposed at an inclination angle θ of 30°, and an experiment was performed in which the distance L from the position of the fuel gas injection nozzle 12 to the position of the temperature-adjustment gas injection nozzle 16 was changed. In the experiment, in order to smooth out the flow of the temperature-adjustment gas 17, four straightening vanes 25 were disposed in the temperature-adjustment gas injection nozzle 16.

[0057] As a result, stable combustion continued for 60 minutes or longer in any of cases where the distance L was 2.5 times and 3.5 times the inside diameter D of the combustion chamber 11.

[0058] Next, the fuel gas was changed to a blast furnace gas (having a heating value of 760 kcal/Nm^3), the temperature-adjustment gas 17 was also changed to the blast furnace gas, the oxygen-containing gas was not changed from air, and the same experiment was performed.

[0059] As a result, for the tubular flame burner 10A, on which the first embodiment of the present invention is based, in a case where the distance L was 3 times the inside diameter D of the combustion chamber 11, a flame failure occurred as soon as the temperature-adjustment gas (air) was mixed. In cases where the distance L was 3.5 times, 4 times, and 5 times the inside diameter D of the combustion chamber, combustion continued for 5 minutes or shorter, 20 minutes or shorter, and 60 minutes or shorter, respectively. On the other hand, when the distance L was 6 times the inside diameter D of the combustion chamber 11, stable combustion continued for 60 minutes or longer.

[0060] In contrast, with the tubular flame burner 10B according to the first embodiment of the present invention, in the case where the distance L was 3 times the inside diameter D of the combustion chamber 11, combustion continued for 60 minutes or shorter. In any of the cases where the distance L was 3.5 times, 4 times, 5 times, and 6 times the inside diameter D of the combustion chamber, stable combustion continued for 60 minutes or longer.

[0061] An experiment the same as that for the tubular flame burner 10B described above was performed for each of other examples of the tubular flame burner 10B according to the first embodiment of the present invention, which were the tubular flame burner $10B_1$ (Figs. 5 and 6), the tubular flame burner $10B_2$ (Figs. 7 and 8), and the tubular flame burner $10B_3$ (Figs. 9 and 10). A result the same as that for the tubular flame burner 10B was obtained for any of these burners.

[0062] Thus, the effectiveness of the present invention was proved.

Example 2

[0063] As Example 2 of the present invention, the performances of the tubular flame burners 10C, 10D, and 10E according to the second embodiment of the present invention were examined by using the combustion test device 30 shown in Fig. 17.

[0064] In this test, the tubular flame burner 10 was attached to a furnace body 31, and a diluted LPG (diluted propane gas, having a heating value of 2400 kcal/Nm^3) made by diluting LPG (propane gas) with nitrogen at a ratio of ten was used as a fuel gas, and air was used as an oxygen-containing gas. The sizes of the fuel gas injection nozzle 12 and the oxygen-containing gas injection nozzle 13 were adjusted so that the injection speeds of the fuel gas and air respectively injected in directions tangential to the inner wall surface of the combustion chamber 11 would be about 9 times the speed of a mixed gas formed in the combustion chamber 11.

[0065] As the temperature-adjustment gas 17, three types of gases, which were a diluted LPG (diluted propane gas) made by diluting LPG with nitrogen at a ratio of ten, nitrogen, and air, were used. The injection amount of the temperature-adjustment gas 17 was set to be the same as the amount of combustion exhaust gas, and the size of the temperature-adjustment gas injection nozzle 16 was adjusted so that the injection speed of the temperature-adjustment gas 17 would be about 9 times the speed of a mixed gas formed in the combustion chamber 11.

[0066] The inside diameter of the combustion chamber 11 was about 200 mm. The entirety of the tubular flame burner 10 had a length of 3 m so that the influence the injection position of the temperature-adjustment gas could be examined.

[0067] Because the temperature of the combustion exhaust gas would become as high as about 2000°C when the temperature-adjustment gas 17 was not injected, the combustion exhaust gas discharged from the furnace body 31 is cooled by using a sprinkler device 32 and then discharged from a smokestack 33. The entirety of the furnace body 31 was covered with refractories, and pipes to an upper roof portion and the sprinkler device 32 had a water-cooling structure. An inspection window, an ignition plug, and a luminance detector were disposed at the rear end of the tubular flame burner 10. The tubular flame burner 10 was configured so that supply of propane gas could be instantaneously stopped upon detection of a flame failure by the luminance detector.

[0068] The results of assessing and examining the performances of tubular flame burners will be described below. A case where air was used as the temperature-adjustment gas 17 will be described here, because the same results were obtained for the cases where a diluted LPG (diluted propane gas), nitrogen, and air were used as the temperature-adjustment gas 17.

[0069] As in Example 1, in order to examine the performance of the tubular flame burner 10A, on which the second embodiment of the present invention is based, an experiment was performed in which the distance L from the position of the fuel gas injection nozzle 12 to the position of the temperature-adjustment gas injection nozzle 16 was changed.

[0070] As a result, as in Example 1, in a case where the distance L was 2.5 times the inside diameter D of the combustion chamber 11, a flame failure occurred as soon as the temperature-adjustment gas (air) was mixed. After the temperature-adjustment gas (air) was mixed, it was not possible to ignite by using the ignition plug. In a case the distance L was 3 times the inside diameter D of the combustion chamber, when the temperature-adjustment gas (air) was injected, combustion occurred but continued for only 20 minutes or shorter, and it was necessary to reignite after a flame failure occurred. On the other hand, in a case where the distance L was 3.5 times the inside diameter D of the combustion chamber 11, combustion continued when the temperature-adjustment gas (air) was injected, and stable combustion continued for at least for 60 minutes. Also in a case where the distance L was 4 times the inside diameter D of the combustion chamber 11, stable combustion continued for 60 minutes or longer.

[0071] In order to examine the performance of each of the tubular flame burners 10C, 10D, and 10E according to the second embodiment of the present invention, the turbulence generation mechanism 20 (orifice 21, grid 22, or packed bed 23) was disposed immediately upstream of the temperature-adjustment gas injection nozzle 16, and an experiment was performed in which the distance L from the position of the fuel gas injection nozzle 12 to the position of the temperature-adjustment gas injection nozzle 16 was changed. A ring-shaped ceramic plate having a hole having an inside diameter of 120 mm was used as the orifice 21. Due to the presence of the orifice 21, the cross-sectional area of a flow path in the combustion chamber 11 was decreased by half in a part of the combustion chamber 11 and the pressure loss increased. The grid 22 was made of a ceramic and had eight bars. Due to the presence of the grid 22, the cross-sectional area of the flow passage in the combustion chamber 11 decreased in a part thereof. The packed bed

23 included five layers of sintered ceramic particles each having an inside diameter D that was 1/10 of the diameter of the combustion chamber 11.

[0072] As a result, stable combustion continued for 60 minutes or longer in any of cases where the distance L was 2.5 times and 3.5 times the inside diameter D of the combustion chamber 11.

[0073] Next, the fuel gas was changed to a blast furnace gas (having a heating value of 760 kcal/Nm^3), the temperature-adjustment gas 17 was also changed to the blast furnace gas, the oxygen-containing gas was not changed from air, and the same experiment was performed.

[0074] As a result, for the tubular flame burner 10A, on which the second embodiment of the present invention is based, in a case where the distance L was 3 times the inside diameter D of the combustion chamber 11, a flame failure occurred as soon as the temperature-adjustment gas (air) was mixed. In cases where the distance L was 3.5 times, 4 times, and 5 times the inside diameter D of the combustion chamber, combustion continued for 5 minutes or shorter, 20 minutes or shorter, and 60 minutes or shorter, respectively. On the other hand, when the distance L was 6 times the inside diameter D of the combustion chamber 11, stable combustion continued for 60 minutes or longer.

[0075] In contrast, with the tubular flame burners 10C, 10D, and 10E according to the second embodiment of the present invention, in the case where the distance L was 3 times the inside diameter D of the combustion chamber 11, combustion continued for 60 minutes or shorter. In any of the cases where the distance L was 3.5 times, 4 times, 5 times, and 6 times the inside diameter D of the combustion chamber, stable combustion continued for 60 minutes or longer.

[0076] An experiment the same as those for the tubular flame burners 10C, 10D, and 10E described above (each having a configuration shown in Fig. 14) was performed for each of the tubular flame burners 10C, 10D, and 10E according to the second embodiment of the present invention having the temperature-adjustment gas injection nozzles 16 having other configurations (Figs. 15 and 16). In any of these cases, the results the same as those for the tubular flame burners 10C, 10D, and 10E (Fig. 14) were obtained.

[0077] Thus, the effectiveness of the present invention was proved.

Reference Signs List

[0078]

10	tubular flame burner
10A	tubular flame burner
10B	tubular flame burner
$10B_1$	tubular flame burner
$10B_2$	tubular flame burner
$10B_3$	tubular flame burner
10C	tubular flame burner
10D	tubular flame burner
10E	tubular flame burner
11	combustion chamber
12	fuel gas injection nozzle
13	oxygen-containing gas injection nozzle
14	tubular flame
16	temperature-adjustment gas injection nozzle
17	temperature-adjustment gas
18	backflow portion of temperature-adjustment gas
19	combustion exhaust gas
20	turbulence generating mechanism
21	orifice
22	grid
23	packed bed
25	straightening vanes
30	combustion test device
31	furnace body
32	sprinkler device
33	smokestack

Claims

1. A tubular flame burner comprising a tubular combustion chamber having an open end, a fuel gas injection nozzle, and an oxygen-containing gas injection nozzle, each of the injection nozzles being disposed on a closed end side of the combustion chamber so as to be oriented in a direction tangential to an inner wall surface of the combustion chamber,
   wherein the tubular flame burner further comprises a temperature-adjustment gas injection nozzle and backflow preventing means, the temperature-adjustment gas injection nozzle being disposed on the open end side of the combustion chamber and injecting a temperature-adjustment gas for adjusting a temperature of a combustion exhaust gas, the backflow preventing means preventing backflow of the temperature-adjustment gas, which has been injected from the temperature-adjustment gas injection nozzle, toward the fuel gas injection nozzle.

2. The tubular flame burner according to Claim 1, wherein the backflow preventing means is provided by inclining an injection direction of the temperature-adjustment gas from the temperature-adjustment gas injection nozzle in a downstream direction at an angle in the range of 10° to 60° with respect to a plane perpendicular to an axis of the tubular combustion chamber.

3. The tubular flame burner according to Claim 1, wherein the backflow preventing means is a turbulence generating mechanism disposed upstream of the temperature-adjustment gas injection nozzle.

4. The tubular flame burner according to Claim 3,

wherein the turbulence generating mechanism is one of an orifice, a grid, and a packed bed.

5. The tubular flame burner according to Claim 1, wherein the temperature-adjustment gas injection nozzle is separated from the fuel gas injection nozzle by a distance that is 2.5 to 3.5 times an inside diameter D of the combustion chamber.

6. The tubular flame burner according to Claim 1, wherein the temperature-adjustment gas injection nozzle is separated from the fuel gas injection nozzle by a distance that is 3.5 to 6 times an inside diameter D of the combustion chamber.

7. A tubular flame burner comprising a tubular combustion chamber having an open end, a fuel gas injection nozzle, and an oxygen-containing gas injection nozzle, each of the injection nozzles being disposed on a closed end side of the combustion chamber so as to be oriented in a direction tangential to an inner wall surface of the combustion chamber,
wherein the tubular flame burner further comprises a temperature-adjustment gas injection nozzle disposed on the open end side of the combustion chamber and injecting a temperature-adjustment gas for adjusting a temperature of a combustion exhaust gas, and an injection direction of the temperature-adjustment gas from the temperature-adjustment gas injection nozzle is inclined in a downstream direction at an angle in the range of 10° to 60° with respect to a plane perpendicular to an axis of the tubular combustion chamber.

8. The tubular flame burner according to Claim 7, wherein the injection direction of the temperature-adjustment gas is inclined in the downstream direction at an angle in the range of 25° to 60° with respect to the plane perpendicular to the axis of the tubular combustion chamber.

FIG. 1

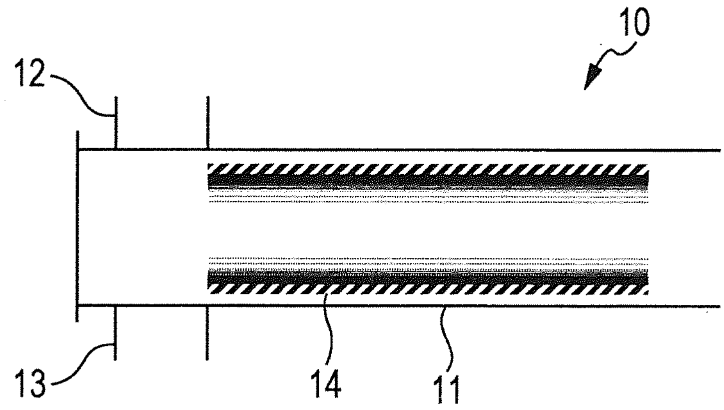


FIG. 2

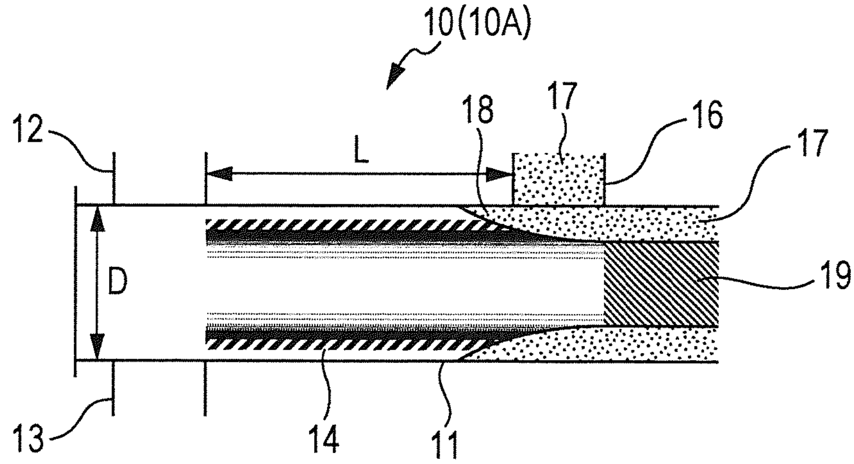


FIG. 3

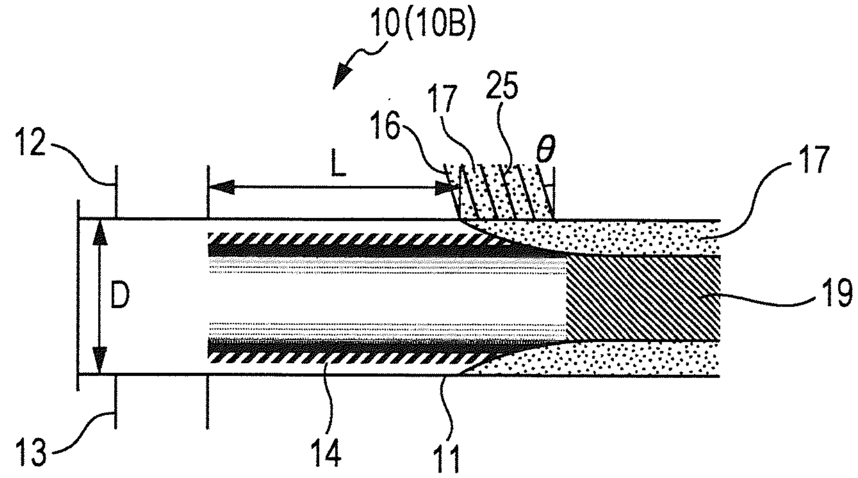


FIG. 4

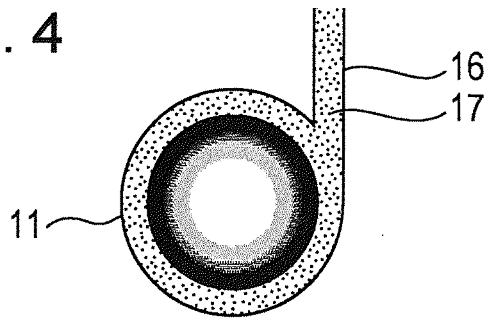


FIG. 5

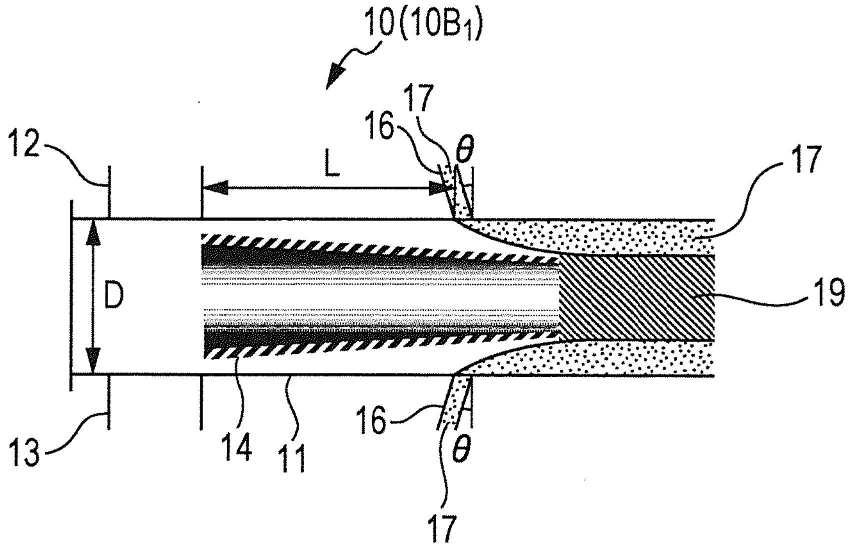


FIG. 6

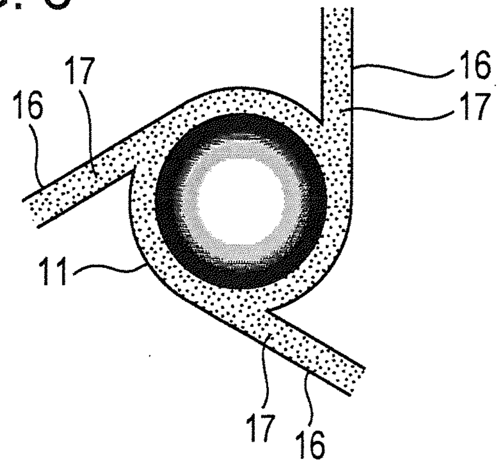


FIG. 7

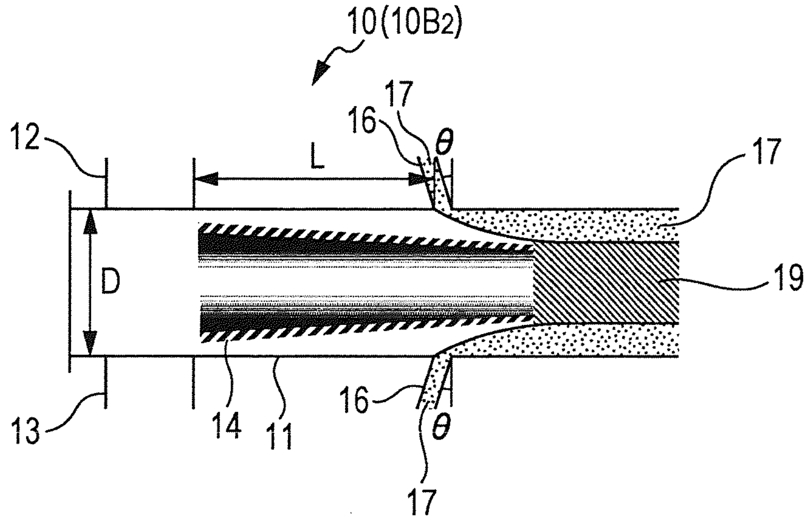


FIG. 8

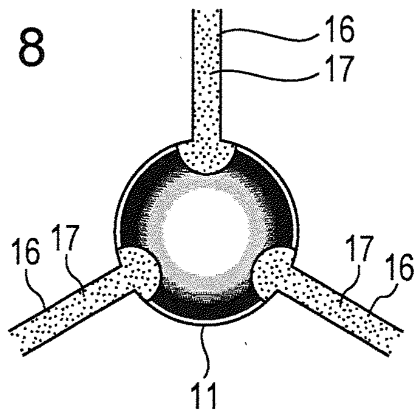


FIG. 9

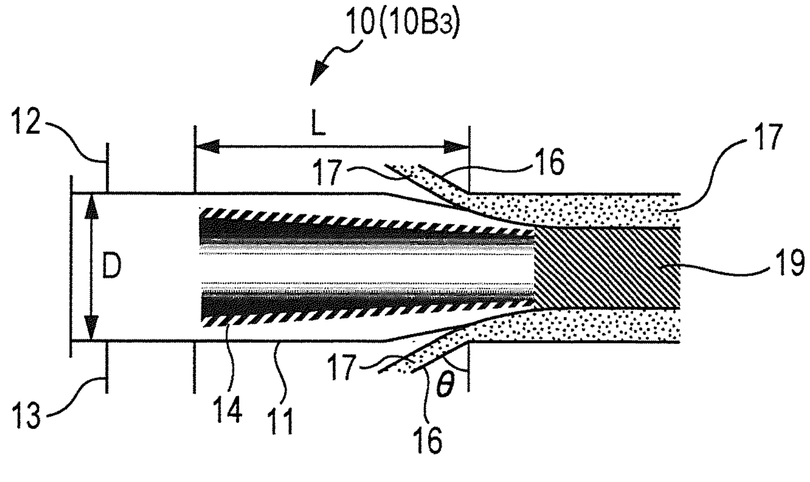


FIG. 10

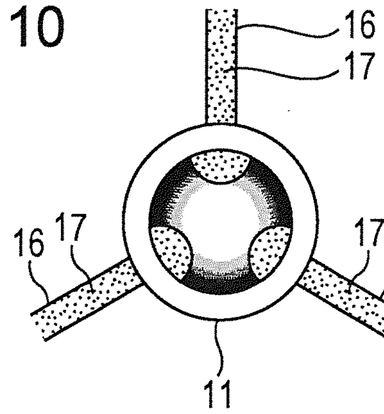


FIG. 11

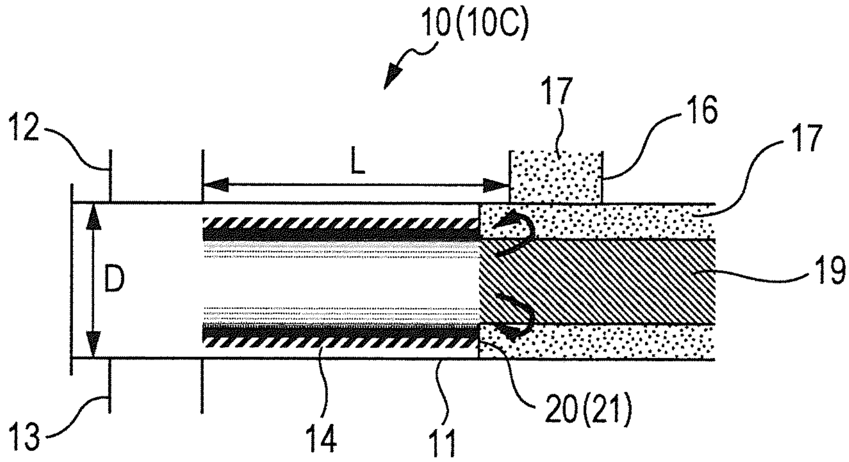


FIG. 12

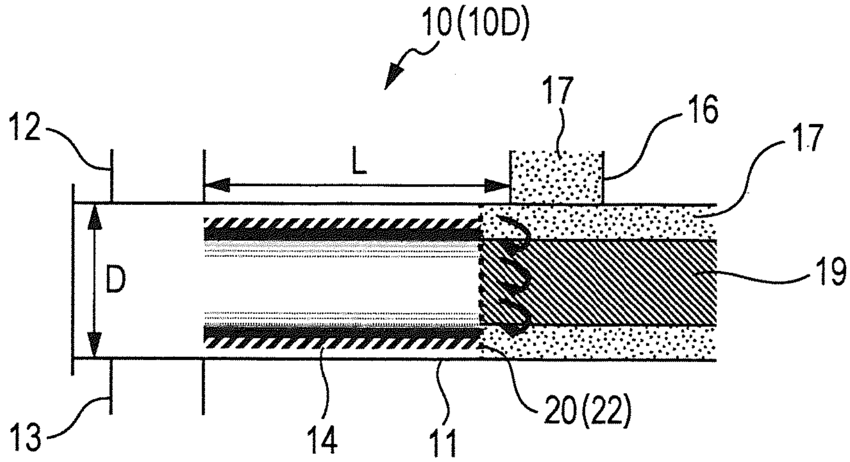


FIG. 13

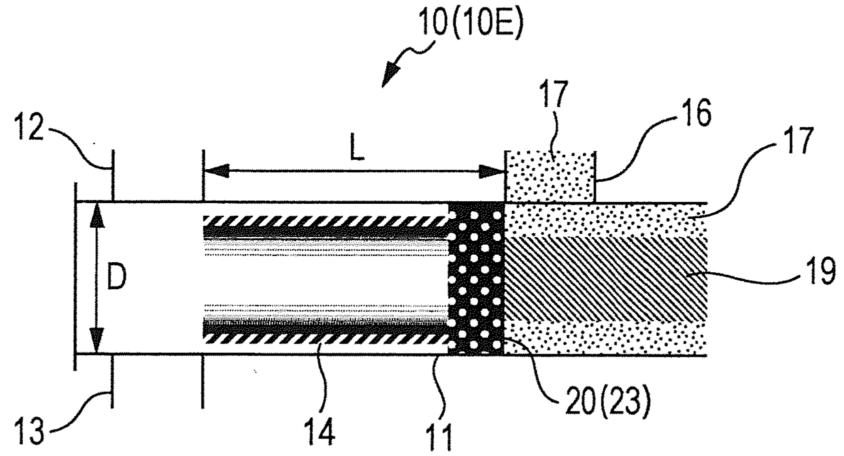


FIG. 14

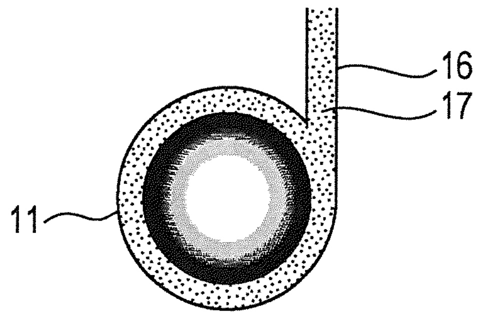


FIG. 15

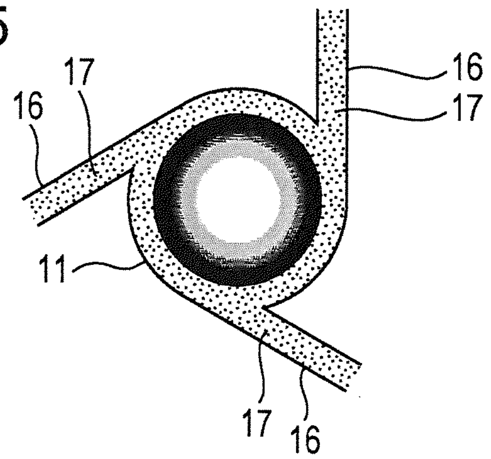
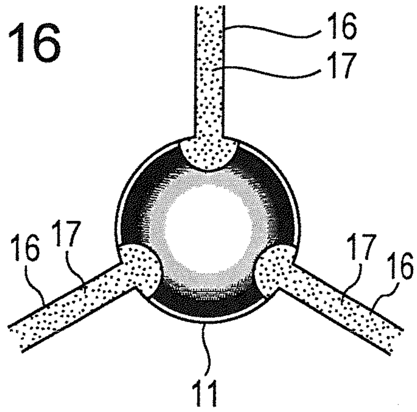


FIG. 16


16
17
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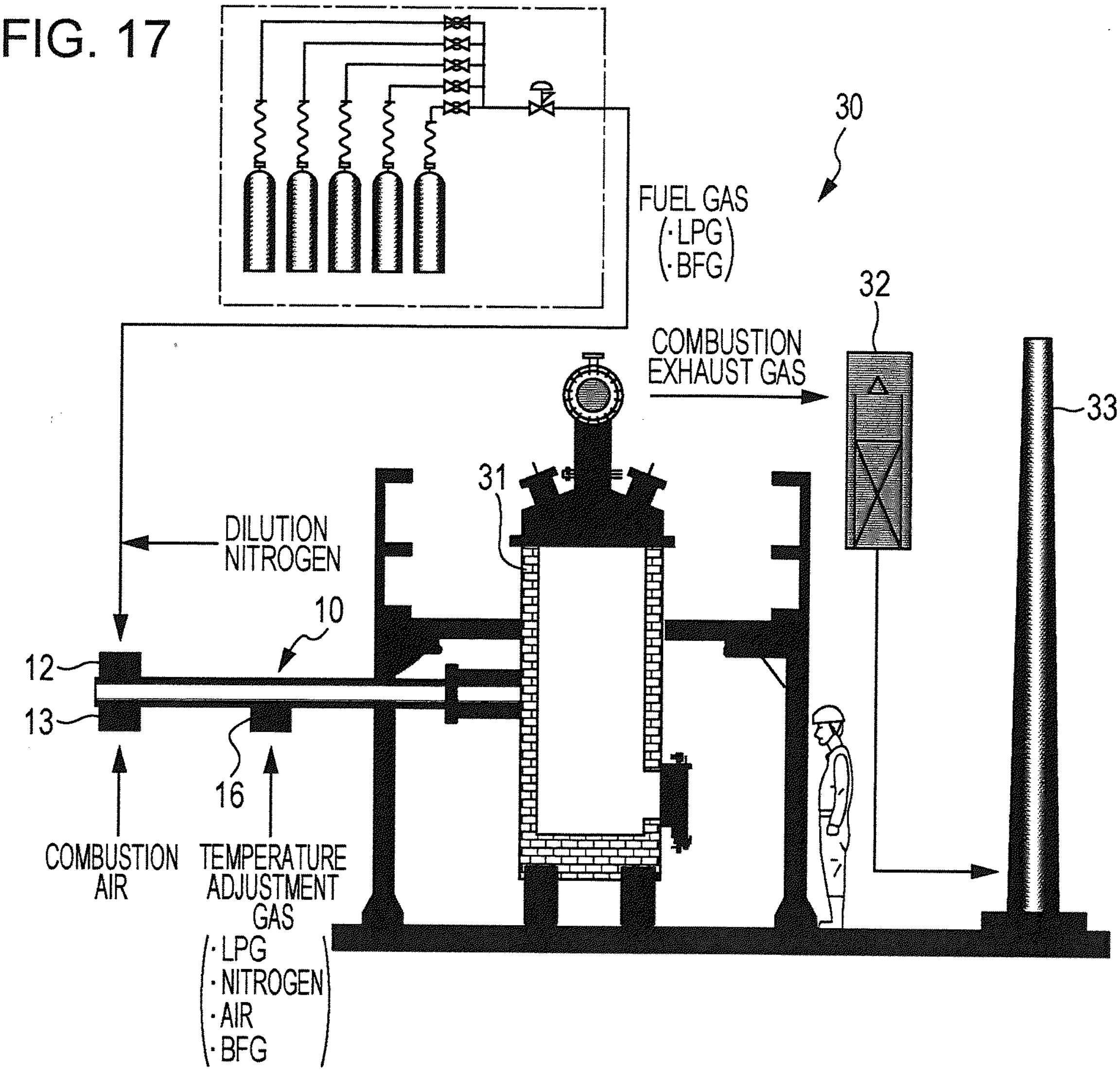
11

FIG. 17


30
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(·LPG
·BFG)
32
COMBUSTION
EXHAUST GAS
33
31
DILUTION
NITROGEN
10
12
13
16
COMBUSTION
AIR
TEMPERATURE
ADJUSTMENT
GAS
(·LPG
·NITROGEN
·AIR
·BFG)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/006226

A. CLASSIFICATION OF SUBJECT MATTER
F23C3/00(2006.01)i, *F23D14/24*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F23C3/00, F23D14/24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2004-257673 A (JFE Steel Corp.), 16 September 2004 (16.09.2004), paragraphs [0015] to [0034]; fig. 1 (Family: none)	1-8
Y	JP 2007-255744 A (Mitsubishi Heavy Industries, Ltd.), 04 October 2007 (04.10.2007), paragraphs [0032] to [0034]; fig. 4 (Family: none)	1-8

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 December, 2012 (12.12.12)	25 December, 2012 (25.12.12)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2012/006226

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	JP 2006-194564 A (JFE Steel Corp.), 27 July 2006 (27.07.2006), entire text; all drawings (Family: none)	1-8
A	JP 2005-188776 A (JFE Steel Corp.), 14 July 2005 (14.07.2005), entire text; all drawings (Family: none)	1-8
A	JP 62-52313 A (NKK Corp.), 07 March 1987 (07.03.1987), entire text; all drawings & US 4969815 A & US 4993939 A & US 5000679 A & US 4971551 A & US 4971552 A & US 4971553 A & GB 2175684 A & DE 3614100 A & FR 2581163 A & ATA 00A113886 & AU 5657786 A & BR 8601899 A & CA 1295229 A & IT 1191273 B & CN 86102828 A & AU 597883 B & AT 113886 A	1-8
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- JP 2012097918 A **[0003]**