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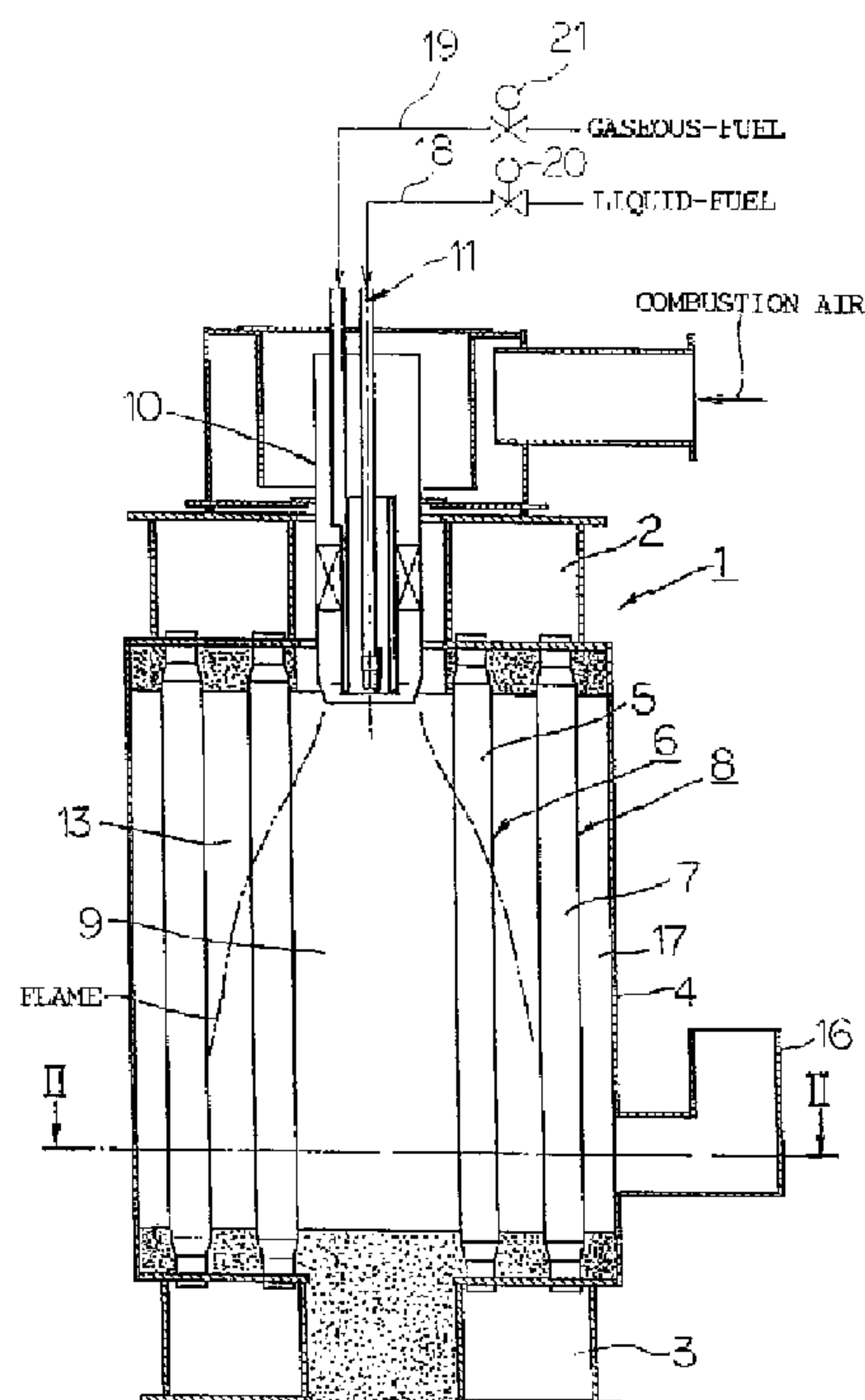
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(54) Titre : CHAUDIERE A TUBES D'EAU ET BRULEUR

(54) Title: WATER-TUBE BOILER AND BURNER



(57) Abrégé/Abstract:

The invention provides a water-tube boiler and a burner capable of realizing a reduction in NO_x and CO in both the combustion of liquid fuel and the combustion of gaseous fuel. The water-tube boiler comprises a burner (10) which uses liquid fuel or gaseous fuel switchably, characterized in that a plurality of water tubes (5) are arranged into an annular shape in a zone where burning-reaction ongoing gas derived from the burner (10) is present within a combustion chamber (9). The water-tube boiler comprises a burner (10) which uses liquid fuel or gaseous fuel switchably, characterized in that: a first water tube array (6) is formed by arranging a plurality of water tubes (5) into an annular shape in a zone where burning-reaction ongoing gas derived from the burner (10) is present within a combustion chamber (9); gaps (12) are provided between adjacent water tubes (5) of the first water tube array (6) so as to permit the burning-reaction ongoing gas to flow therethrough; and that a zone (13) is provided around the first



(57) **Abrégé(suite)/Abstract(continued):**

water tube array (6) to allow burning reaction to be continuously effected.

ABSTRACT OF THE DISCLOSURE

The invention provides a water-tube boiler and a burner capable of realizing a reduction in NO_x and CO in both the combustion of liquid fuel and the combustion of gaseous fuel. The water-tube boiler comprises a burner (10) which uses liquid fuel or gaseous fuel switchably, characterized in that a plurality of water tubes (5) are arranged into an annular shape in a zone where burning-reaction ongoing gas derived from the burner (10) is present within a combustion chamber (9). The water-tube boiler comprises a burner (10) which uses liquid fuel or gaseous fuel switchably, characterized in that: a first water tube array (6) is formed by arranging a plurality of water tubes (5) into an annular shape in a zone where burning-reaction ongoing gas derived from the burner (10) is present within a combustion chamber (9); gaps (12) are provided between adjacent water tubes (5) of the first water tube array (6) so as to permit the burning-reaction ongoing gas to flow therethrough; and that a zone (13) is provided around the first water tube array (6) to allow burning reaction to be continuously effected.

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TITLE OF THE INVENTION

Water-Tube Boiler and Burner

BACKGROUND OF THE INVENTION

5 The present invention relates to water-tube boilers such as once-through boilers, natural circulation water-tube boilers and forced circulation water-tube boilers as well as to burners used in these boilers.

 The water-tube boiler is a boiler the body of
10 which is made up by water tubes. The body arrangement of such a water-tube boiler is, for example, that a plurality of water tubes are arranged into an annular shape. In the water-tube boiler of this form, a cylindrical space surrounded by the annular water tube array is used as a
15 combustion chamber. In such a water-tube boiler, heat transfer primarily by radiation is performed within the combustion chamber, and then heat transfer primarily by convection is done in the downstream of the combustion chamber.

20 In recent years, such water-tube boilers are also desired to be further reduced in NO_x and CO. The reduction in NO_x, as it stands now, is implemented by fitting low-NO_x burners or exhaust-gas re-circulation equipment to the existing boiler bodies. The reduction in CO is implemented
25 by adjusting the state of combustion of the burner.

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SUMMARY OF THE INVENTION

An object of the present invention is to achieve reduction in both NO_x and CO in the combustion of both liquid fuel and gaseous fuel.

5 The present invention having been accomplished to attain the above object, first with a view to fulfilling the reduction in NO_x , there is provided a water-tube boiler comprising a burner which uses liquid fuel or gaseous fuel switchably, characterized in that a plurality of water
10 tubes are arranged into an annular shape in a zone where flame derived from the burner is present within a combustion chamber.

 Further with a view to fulfilling the reduction in NO_x and the reduction in CO at the same time, there is
15 provided a water-tube boiler comprising a burner which uses liquid fuel or gaseous fuel switchably, characterized in that: a first water tube array is formed by arranging a plurality of water tubes into an annular shape in a zone where flame derived from the burner is present within a
20 combustion chamber; gaps are provided between adjacent water tubes of the first water tube array so as to permit the flame to flow therethrough; and that a zone is provided around the first water tube array to allow burning reaction to be continuously effected.

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The above water-tube boiler is also characterized in that the burner is a diffusion-combustion burner.

Further, according to the present invention, there is provided a burner which uses liquid fuel or
5 gaseous fuel switchably, characterized in that: a gaseous-fuel feed pipe having a flow path of a generally annular-shaped cross section as well as a cylindrical air resister are arranged coaxially around a liquid-fuel nozzle pipe; a first air flow path is formed between the nozzle pipe and
10 the gaseous-fuel feed pipe; a second air flow path is formed between the gaseous-fuel feed pipe and the air resister; a first baffle plate is provided at an end of the first air flow path; a second baffle plate is provided at an end of the second air flow path; and that a taper
15 portion is provided at an end of the air resister. The present invention is also characterized in that the second baffle plate is disposed at a midpoint of the taper portion. The burner is also characterized in that the second baffle plate is disposed at a midpoint of the taper
20 portion, or that an outer nozzle for spouting gaseous fuel outward and an inner nozzle for spouting gaseous fuel inward are provided at an end portion of the gaseous-fuel feed pipe.

Also according to the present invention, the
25 burner is used in the water-tube boilers as defined above.

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The present invention is embodied both as a water-tube boiler of the multiple-tube type and as a burner to be used in this water-tube boiler. Further, the water-tube boiler of the present invention is applied not only as
5 steam boilers or hot water boilers, but also as heat medium boilers in which a heat medium is heated.

Referring first to the invention for designing the implementation of the reduction in NO_x , the water-tube boiler as described in the first aspect of the invention
10 comprises a burner which uses liquid fuel or gaseous fuel switchably, wherein a plurality of water tubes are arranged into an annular shape in a zone where burning-reaction ongoing gas is present within a combustion chamber (hereinafter, referred to as "burning reaction zone"). The
15 combustion chamber is so formed that part or entirety of its interior serves as a space for burning reaction, where the space is defined by water tube arrays in one case or by exterior walls formed of refractory materials in another case. The burning-reaction ongoing gas refers to a high-
20 temperature gas during the process that burning reaction is taking place in the combustion chamber. The burning reaction zone is preferably a zone where a flame is taking place in the burning-reaction ongoing gas, or a zone where a high-temperature burning-reaction ongoing gas is present
25 with the temperature of the burning-reaction ongoing gas

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above 900°C. The flame herein referred to is a phenomenon that occurs to burning-reaction ongoing gas that is in the course of a vigorous burning reaction. This flame may be visually discerned in some cases or may be different to visually discern or impossible to visually discern in other cases.

Therefore, in the water-tube boiler according to the first aspect of the invention, by arranging a plurality of water tubes in the burning reaction zone, the flame is cooled by the plurality of water tubes so that the temperature is lowered, by which the generation of thermal NOx is suppressed. The reason of this is that, as explained in the Zeldovich mechanism, the more the temperature of burning reaction is high, the more the thermal NOx is accelerated in its generation rate with its generation amount increasing; that is, the more the temperature of burning reaction is low, the more the thermal NOx is decelerated in its generation rate with its generation amount decreasing. Especially when the temperature of burning reaction is under 1400°C, the generation rate of the thermal NOx is remarkably retarded. Then, according to the first aspect of the invention, in which a plurality of water tubes are arranged into an annular shape, because the flame performs heat transfer upon contact with the individual

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water tubes, thermal load can be generally uniformed. Further, because the flame is cooled by the individual water tubes, the effect of reducing NOx is also conducted generally uniformly on the entire circumference of the
5 annular water tube array.

Also, in the first aspect of the invention, in which a plurality of water tubes are arranged into an annular shape, the annular arrangement may be such that the plurality of water tubes may be arranged into a circular
10 shape, or into an elliptical shape. Otherwise, the plurality of water tubes may be arranged into triangular, quadrangular or higher polygonal shapes. Furthermore, for the arrangement of the plurality of water tubes into an annular shape, the water tubes may be arranged in such a
15 way that the lines connecting center to center of the water tubes form projections and recesses.

In the first aspect of the invention, gaps which permit the burning-reaction ongoing gas to flow therethrough are formed between adjacent water tubes. Each
20 of these gaps has such a width that the burning-reaction ongoing gas passing through these gaps will keep burning reaction even if cooled by the water tubes, where the width needs to be at least 1 mm.

In the first aspect of the invention, heat-
25 recovery water tubes are arranged outside the water tubes

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arranged into an annular shape. These heat-recovery water tubes perform further heat recovery from the flame that has passed through the gaps between the water tubes as well as a gas that has completed the burning reaction (hereinafter, referred to as "burning-reaction completed gas"), so that the efficiency of the water-tube boiler is enhanced.

Referring next to the invention for designing the simultaneous implementation of NO_x reduction and CO reduction, the water-tube boiler as described in the second aspect of the invention comprises: a burner which uses liquid fuel or gaseous fuel switchably, wherein: a first water tube array is formed by arranging a plurality of water tubes into an annular shape in a zone (hereinafter, referred to as "combustion reaction zone" as in the foregoing case) where burning-reaction ongoing gas derived from the burner is present within a combustion chamber; and gaps are provided between adjacent water tubes of the first water tube array so as to permit the burning-reaction ongoing gas to flow therethrough. The combustion chamber, the combustion-reaction ongoing gas and the combustion reaction zone herein have the same meanings as described for the first aspect, while the case is the same also with the flame.

In the second aspect of the invention, by

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arranging a plurality of water tubes in the burning reaction zone, the burning-reaction ongoing gas is cooled by the plurality of water tubes so that the temperature is lowered, by which the generation of thermal NO_x is suppressed. During this process, the flame flows through the gaps between the water tubes, so that the NO_x reduction effect due to the cooling is enhanced. The reason of this is as explained in the Zeldovich mechanism, as has been described for the first aspect. Then, in the second aspect of the invention, a zone is provided around the first water tube array to allow burning reaction to be continuously effected (hereinafter, referred to as "burning-reaction continuing zone"). This burning reaction continuing zone is a zone where, after the burning reaction inside the first water tube array, intermediate products of burning reaction such as CO and HC as well as unburnt components of the fuel are subjected to burning reaction. The burning-reaction ongoing gas will flow into this burning-reaction continuing zone through the gaps. Because CO remaining in the burning-reaction ongoing gas will be oxidized into O₂ during the flow in the burning-reaction continuing zone, the discharge amount from CO from the water-tube boiler is lessened. Then, according to the second aspect of the invention, in which a plurality of water tubes are arranged into an annular shape, because

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the burning-reaction ongoing gas performs heat transfer upon contact with the individual water tubes, thermal load can be generally uniformed. Further, because the burning-reaction ongoing gas is cooled by the individual water
5 tubes, the effect of reducing NO_x is also conducted generally uniformly on the entire circumference of the first water tube array. In this case, the annular arrangement of the plurality of water tubes may be circular, elliptical, polygonal shapes, as described for
10 the first aspect, moreover the arrangement may be such that the lines connecting center to center of the water tubes form projections and recesses.

In the second aspect of the invention, in which gaps are provided between adjacent water tubes so as
15 permit the flame to flow therethrough, each of these gaps has such a width that the flame passing through these gaps will keep burning reaction even if cooled by the water tubes, where the width needs to be at least 1 mm. Then, the gaps do not need to be formed every adjacent water tubes;
20 instead, for example, the plurality of water tubes may be arranged so that a specified number of water tubes are gathered in close contact, and that gaps are provided between one group of such closely gathered water tubes and
25 another. Further, the gaps do not need to be all of the

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same width, but the plurality of water tubes may be arranged into an annular shape so that wider gaps and narrower gaps are provided.

In the second aspect of the invention, a
5 plurality of heat-recovery water tubes are arranged outside the first water tube array, and the plurality of heat-recovery water tubes are arranged into an annular shape to form a second water tube array. Within the burning-reaction continuing zone located outside the first water
10 tube array, the burning-reaction ongoing gas has generated heat due to the continued reaction, including the oxidation reaction of CO as well as the reaction of intermediate products of the burning reaction and unburnt components of the fuel. Therefore, heat recovery from the burning-
15 reaction ongoing gas and the burning-reaction completed gas including the aforementioned heat is performed by the heat-recovery water tubes. As a result, effective use of heat can be made by the heat-recovery water tubes, so that the thermal efficiency is enhanced. Then, by arranging the
20 second water tube array into an annular shape, the heat-recovery water tubes will make generally uniform contact with the burning-reaction ongoing gas as well as the burning-reaction completed gas, so that heat transfer from those gases can be conducted generally uniformly.

25 In the aforementioned water-tube boiler, the

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plurality of water tubes are arranged within the combustion chamber so that temperature of the burning-reaction ongoing gas after making contact with the water tubes will be below 1400°C. With this arrangement, the temperature of the
5 burning-reaction ongoing gas lowers so that the generation of thermal NO_x is lessened and therefore that the reduction in NO_x for the water-tube boiler can be achieved.

The invention as described in the third aspect is a water-tube boiler in which the burner is a diffusion-
10 combustion burner. Diffused combustion is effected in the space inside the water tubes arranged in an annular shape, so that a successful combustion is maintained. Especially in the combustion of liquid fuel, a remarkable effect is produced.

15 The invention as described in the fourth aspect relates to a burner, and is a diffused-combustion burner which uses liquid fuel or gaseous fuel switchably. In this burner, a gaseous-fuel feed pipe having a flow path of a generally annular-shaped cross section as well as a
20 cylindrical air resister are arranged coaxially around a liquid-fuel nozzle pipe. A first air flow path is formed between the nozzle pipe and the gaseous-fuel feed pipe, and primary air flows through this first air flow path. A second air flow path is formed between the gaseous-fuel
25 feed pipe and the air resister, and secondary air flows

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through this second air flow path. A first baffle plate is provided at an end of the first air flow path, and a second baffle plate is provided at an end of the second air flow path, these baffle plates serving to retain the flame. A
5 taper portion of a tapered shape is formed at an end of the air resister, so that the flow of the secondary air is directed toward the center of the burner. As a result, the mixing of the secondary air and the fuel is facilitated, thus making it possible to realize the reduction in CO.

10 The invention as described in the fifth aspect is a burner in which the second baffle plate is disposed on a midpoint of the taper portion. With this arrangement, the distance between the second baffle plate and the burner end is minimized to reduce the residence time of burning-
15 reaction ongoing gas in the downstream of the second baffle plate, thereby preventing the gas temperature from increasing under the radiant heat derived from the flame. As a result of this, the flame temperature is prevented from increasing, thus making is possible to realize the
20 reduction in NO_x.

 The invention as described in the sixth aspect is a burner in which an outer nozzle for spouting gaseous fuel outward and an inner nozzle for spout gaseous fuel inward are provided at an end portion of the gaseous-fuel feed
25 pipe. The gaseous fuel spouted from the inner nozzle mixes

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with the primary air to form a small flame at a position in the downstream of the first baffle plate. This small flame serves as a pilot flame, improving the stability of the flame.

5 The invention as described in the seventh aspect is a water-tube boiler in which the burner is applied as a burner as described in the first aspect or the second aspect. In both the combustion of liquid fuel and the combustion of gaseous fuel, further reduction in both NO_x and CO can be achieved by the combination of the boiler arrangement that realizes the reduction in both NO_x and CO and the aforementioned boiler.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an explanatory view of a vertical cross section of an embodiment of the water-tube boiler according to the present invention;

Fig. 2 is an explanatory view of a cross section taken along the line II - II of Fig. 1;

Fig. 3 is an explanatory view of a vertical cross section of an embodiment of the burner according to the present invention; and

Fig. 4 is an explanatory view of the bottom surface of Fig. 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

25 Hereinbelow, an embodiment in which the present

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invention is applied to a multiple-tube type once-through boiler is described with reference to Figs. 1 and 2. Fig. 1 is an explanatory view of a vertical cross section of the embodiment of the invention, and Fig. 2 is an explanatory
5 view of a cross section taken along the line II - II of Fig. 1.

In Figs. 1 and 2, a boiler body 1 has an upper header 2 and a lower header 3 arranged away from each other by a specified distance. An outer wall 4 is disposed
10 between outer circumferences of these upper header 2 and lower header 3.

Between the upper header 2 and the lower header 3, a plurality (ten in the embodiment) of water tubes 5 are arranged in an annular shape. These water tubes 5
15 constitute an annular first water tube array 6. Further between the upper header 2 and the lower header 3 and near the inner circumference of the outer wall 4, a plurality (thirty in the embodiment) of heat-recovery water tubes 7 are arrayed into an annular shape to form an annular second
20 water tube array 8. This second water tube array 8 in combination with the first water tube array 6 constitutes a double annular water tube array. The water tubes 5 and the heat-recovery water tubes 7 are connected at their both ends to the upper header 2 and the lower header 3,
25 respectively.

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A combustion chamber 9 of the boiler is defined by the upper header 2, the lower header 3 and the second water tube array 8. On top of the combustion chamber 9 is fitted burner 10. This burner 10 is inserted from inside
5 (center) of the upper header 2 toward the combustion chamber 9, so that an axis 11 of the burner 10 is generally parallel to the water tubes 5 of the first water tube array 6. This burner 10 is a burner which uses liquid fuel or gaseous fuel switchably, selectable whichever it is. A
10 liquid-fuel feed line 18 and a gaseous-fuel feed line 19 are connected to this burner 10. Further, as means for switching the fuel, a liquid-fuel valve 20 is provided on the liquid-fuel feed line 18, and a gaseous-fuel valve 21 is provided on the gaseous-fuel feed line 19.

15 The burner 10 causes a zone where burning-reaction ongoing gas is present, i.e. a burning reaction zone, to be formed in the combustion chamber 9, whereas the first water tube array 6 is located in a zone out of the burning reaction zone where a flame is present
20 (hereinafter, referred to as "flame-present zone"). The first water tube array 6 is disposed in the burning reaction zone so that the temperature of the burning-reaction ongoing gas after making contact with the water tubes 5 will be below 1400°C. Further, in the first water
25 tube array 6, gaps 12 that allow the flow of burning-

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reaction ongoing gas are formed between one water tube 5 and another.

A zone 13 where burning reactions of intermediate products such as CO and HC and unburnt components of the fuel are continuously effected (hereinafter, referred to as "burning-reaction continuing zone") is provided between the first water tube array 6 and the second water tube array 8. Within this burning-reaction continuing zone 13, no heat-absorbing members such as the water tubes 5 are present.

In the second water tube array 8, gaps 14 between adjacent heat-recovery water tubes 7 (hereinafter, referred to as "second gap") are narrow, normally set to 1 to 4 mm. Further, on the outer circumferential side of the second water tube array 8, the heat-recovery water tubes 7 are each provided with a heat-transfer fin 15.

Further, the outer wall 4 is provided with an exhaust gas outlet 16. This exhaust gas outlet 16 communicates with an annular exhaust gas flow path 17 formed between the outer wall 4 and the second water tube array 8.

In the once-through boiler of the above constitution, when the burner 10 is activated, there arises burning-reaction ongoing gas within the combustion chamber 9. In the initial stage of the burning reaction of this burning-reaction ongoing gas, fuel decomposition is

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performed and then the decomposed fuel reacts with oxygen vigorously. Then at the succeeding stage, such intermediate products as CO and HC that have been generated in the burning reaction above are put into further
5 reaction, and thus burning-reaction completed gas, which has completed burning reaction, is exhausted from the boiler body 1 as exhaust gas. In the region where the burning reaction is vigorously effected, there occurs a flame, normally.

10 The burning-reaction ongoing gas flows through central part of the first water tube array 6 nearly along its axis, as the gas expands toward the lower header 3, thus flowing into the burning-reaction continuing zone 13 through the gaps 12. Accordingly, as shown in Fig. 1, the
15 flame is formed beyond the first water tube array 6 as the burning-reaction ongoing gas flows along. This means that the water tubes 5 are located inside the flame-present zone within the burning reaction zone. Then, the burning-reaction ongoing gas that causes the flame, when passing
20 through the gaps 12, exchanges heat with heated fluid in the water tubes 5. The burning-reaction ongoing gas that causes the flame is rapidly cooled by this heat exchange, with the temperature lowering, by which the generation of thermal NO_x is suppressed. In this case, because the first
25 water tube array 6 is an annular water tube array, the

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burning-reaction ongoing gas that causes the flame makes uniform contact with the individual water tubes 5, so that the thermal load on the water tubes 5 becomes generally uniform. Further, because this burning-reaction ongoing gas is cooled by generally uniform contact with the water tubes 5, the reduction in NO_x due to the individual water tubes 5 becomes generally uniform. Besides, as a result of this, the flame formation is lessened in this burning-reaction ongoing gas.

10 Then, the burning-reaction ongoing gas that has passed through the gaps 12 is flowed in the burning-reaction continuing zone 13 toward the second water tube array 8. Until the burning-reaction ongoing gas reaches the second water tube array 8, the burning-reaction ongoing gas will not make contact with any members that perform heat exchange, like the water tubes 5, so that the temperature of the burning-reaction ongoing gas little lowers. Therefore, the burning-reaction ongoing gas flows through the burning-reaction continuing zone 13 while continuing to make burning reaction, while an oxidation reaction from CO to CO_2 is accelerated. In this burning-reaction continuing zone 13, besides the aforementioned oxidation reaction, oxidation reactions of the intermediate products, unburnt components of the fuel and the like are also carried out.

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The burning-reaction ongoing gas, thus becoming a high-temperature gas that has completed the burning reaction before it reaches the second water tube array 8, passes through the second gaps 14, flowing into the exhaust gas flow path 17. When the burning-reaction ongoing gas passes through the second gaps 14, more heat is transferred to the heated fluid within the heat-recovery water tubes 7 by the heat-transfer fins 15. The burning-reaction completed gas that has passed through the second gaps 14 and flowed into the exhaust gas flow path 17, after performing heat transfer from the outside of the second water tube array 8 to the heated fluid within the heat-recovery water tubes 7, is discharged as exhaust gas through the exhaust gas outlet 16 out of the boiler. In this case, because the second water tube array 8 is an annular water tube array comprised of a plurality of heat-recovery water tubes 7, burning-reaction ongoing gas and the burning-reaction completed gas make generally uniform contact with the individual heat-recovery water tubes 7, so that heat recovery from burning-reaction ongoing gas and the burning-reaction completed gas is effected by the entire second water tube array 8. Thus, the thermal load on the heat-recovery water tubes 7 becomes generally uniform also in the second water tube array 8.

In the above description, the flow of burning-

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reaction ongoing gas has been one directed along the radius of the first water tube array 6. Next, the description is focused on the flow of the burning-reaction ongoing gas along the axis of the first water tube array 6. Since the
5 burning-reaction ongoing gas flows through central part of the first water tube array 6 generally along its axis while expanding toward the lower header 3 as described above, the burning-reaction ongoing gas has lowered in temperature due to the heat transfer to the water tubes 5 to more extents
10 in more downstream. Therefore, the generation of thermal NO_x is suppressed. Also, because the first embodiment is a once-through boiler, heated fluid is fed from the lower header 3 to the water tubes 5 and into the heat-recovery water tubes 7, ascends in the water tubes 5 and the heat-
15 recovery water tubes 7, while being heated, and is taken out from the upper header 2 as steam.

Now the once-through boiler of this embodiment is explained in more detail. The embodiment is an embodiment of a once-through boiler with an evaporation of 500 to 4000
20 kg per hour. In the once-through boiler of the embodiment, the outside diameter B of the water tubes 5 is about 60 mm. While once-through boilers normally employ water tubes 5 having an outside diameter B of about 25 to 80 mm, water-tube boilers on the whole generally employ water tubes 5
25 having an outside diameter B of about 20 to 100 mm.

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Further in this embodiment, the diameter D of the pitch circle in arranging a plurality of water tubes 5 into a circularity as described before is about 344 mm. This diameter D needs to be at least 100 mm. That is, a smaller diameter D would result in a smaller space on the inner circumferential side of the first water tube array 6, making it difficult to continue a stable burning reaction. On the other hand, a larger diameter D would result in a larger space on the inner circumferential side of the first water tube array 6, making it more likely that high-temperature regions that accelerate the generation of thermal NO_x are generated inside the space. Therefore, with considerations to this point, the upper limit of the diameter D is determined. Further, the upper limit of the diameter D is determined depending on the required amount of evaporation of the boiler. For example, for a water-tube boiler with the amount of evaporation of 4000 kg/hr, the upper limit of its diameter D is 1000 mm.

Also in this embodiment, the center-to-center distance A of adjacent water tubes 5 in the first water tube array 6 is about 106 mm, and the ratio of this center-to-center distance A to the outside diameter B of the water tubes 5, A/B, is 1.8. Then, in the case where the gaps 12 are provided between the water tubes 5 as in this embodiment, the width C of the gaps 12 is set to such a

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value that the burning reaction will not be halted by the burning-reaction ongoing gas being cooled by the water tubes 5. The width C of the gaps 12 in this case needs to be at least 1 mm. Accordingly, for the gaps 12 to be
5 provided between adjacent water tubes 5, the aforementioned ratio A/B is so set that $1 < A/B \leq 2$. This ratio A/B may be changed depending on the degree to which the reduction in NO_x is required. In terms of this, the width C of the gaps 12 in the embodiment is equal to the difference between the
10 center-to-center distance A and the outside diameter B, being about 46 mm.

Further, the burner 10 in this embodiment has an air ratio set to 1.3, in which case the maximum temperature of the burning-reaction ongoing gas is about 1700°C.
15 Generally, the burner for water-tube boilers makes combustion with the air ratio set to within a range of 1.1 to 1.3, in which case the maximum temperature of burning-reaction ongoing gas is about 1800°C for an air ratio range of 1.1 to 1.2 and about 1700°C for another air ratio range
20 of 1.2 to 1.3.

By setting the center-to-center distance A, the outside diameter B and the like of the water tubes 5 in the way as described above, the temperature of the burning-reaction ongoing gas at the time when it has passed through
25 the gaps 12 drops to about 1100°C by cooling with the water

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tubes 5. This temperature is below such a temperature that the generation of thermal NO_x will be largely reduced (about 1400°C). This makes it possible to implement a once-through boiler which is low in the discharge amount of NO_x . In addition, the discharge amount of NO_x of the once-through boiler in the embodiment is about 30 ppm, as converted with 0% O_2 . Besides, this temperature is above such a temperature that the oxidation reaction from CO to CO_2 will be effected vigorously (about 800°C). This causes the oxidation reaction from CO to CO_2 to be effected vigorously when the burning-reaction ongoing gas passes through the inside of the burning-reaction continuing zone 13, making it possible to implement a once-through boiler which is low in the discharge amount of CO.

As seen above, in the once-through boiler of the embodiment, the temperature of burning-reaction ongoing gas that has flowed out from the gaps 12 of the first water tube array 6 is controlled to about 1100°C . However, it should be controlled to within a range of 800 to 1400°C depending on the degree to which NO_x reduction and CO reduction are required. In this connection, the temperature of burning-reaction ongoing gas that flows out from the gaps 12 is preferably as low as possible in terms of the NO_x reduction, while it is preferably as high as possible in terms of the CO reduction. From this point of

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view, the temperature is preferably set within a range of 900 to 1300°C.

Further, in the embodiment, the radial interval E between the first water tube array 6 and the second water tube array 8 is set as the width of the burning-reaction continuing zone 13. The interval E is about 84 mm, 1.4 times larger than the outside diameter B. By setting the interval E in this way, the residence time of burning-reaction ongoing gas within the burning-reaction continuing zone 13 is adjusted to about 47 milliseconds. In this case, the discharge amount of CO is about 15 ppm. That is, in order to ensure the occurrence of aforementioned oxidation reaction, the burning-reaction ongoing gas needs to be kept above a certain temperature (about 800°C), while more than a certain reaction time is necessary at the same time. The reaction time required becomes shorter with increasing temperature of the burning-reaction ongoing gas, while the reaction time required becomes longer with decreasing temperature of the burning-reaction ongoing gas. Therefore, the set value of the interval E is changed depending on the temperature of the burning-reaction ongoing gas that flows out from the gaps 12, by which the residence time of the burning-reaction ongoing gas in the burning-reaction continuing zone 13 is adjusted. Besides, the interval E is changed depending on the number and width

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C of the gaps 12. The lower limit for this residence time is selected from a range of 1 to 10 milliseconds. As a result, the lower limit of the interval E is about 0.5 time as large as the outside diameter B. Also, the residence time, although a somewhat longer set value thereof is advantageous in terms of the CO reduction, but is determined depending on the degree to which the CO reduction and the boiler downsizing are demanded. In this case, the upper limit of the interval E is preferably six times as large as the outside diameter B.

Next, an embodiment of the burner of the present invention is described with reference to Figs. 3 and 4. Fig. 3 is an explanatory view of a vertical cross section of the embodiment of the burner according to the present invention, and Fig. 4 is an explanatory view of the bottom surface of Fig. 4.

The burner 10 has a liquid-fuel nozzle pipe 22 in its center, in which burner 10 a gaseous-fuel feed pipe 23 having a flow path of a generally annular-shaped cross section as well as a cylindrical air resister 24 are arranged coaxially around the nozzle pipe 22. A first air flow path 25 through which primary air flows is formed between the nozzle pipe 22 and the gaseous-fuel feed pipe 23, and a second air flow path 26 through which secondary air flows is formed between the gaseous-fuel feed pipe 23

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and the air resister 24. These combustion airs are fed by air blowers (not shown). The ratio of the primary air to the secondary air is 10 to 20% of primary air to 90 to 80% of secondary air. The liquid fuel and the gaseous fuel are
5 fed selectively switchably.

At an end of the nozzle pipe 22, two nozzle tips 27 for spouting liquid fuel are provided. The liquid fuel is spouted from both nozzle tips 27 in the high combustion mode, and the liquid fuel is spouted from one nozzle tip 27
10 in the low combustion mode. At the end of the first air flow path 25, i.e., at a position downstream of the nozzle tips 27, the first baffle plate 28 is provided. This first baffle plate 28 has an opening 34 in its center, and the first baffle plate 28 has six swirl vanes 35 around the
15 opening 34. At the end of the second air flow path 26, the second baffle plate 29 is provided. This second baffle plate 29 has six cutout portions 30 circumferential and generally equidistantly in its outer peripheral portion. The secondary air flows through these cutout portions 30
20 (flow rate: 30 - 50 m/s). The secondary air is divided by these cutout portions 30 and fed as such to the fuel, by which divided flames are formed, thus allowing the reduction in NO_x to be realized.

The taper portion 31 is formed at the end of the
25 air resister 24, and the end of the air resister 24 is tapered. The taper angle is set to about 20 degrees. With

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this structure, the flow of the secondary air is directed toward the center of the burner 10, so that the mixing of the secondary air and the fuel is facilitated, thus allowing the reduction in CO to be realized.

5 The second baffle plate 29 is disposed at a midpoint of the taper portion 31. This arrangement makes it possible to divide the secondary air that has been put into the flow directed toward the center of the burner 10 by the taper portion 31, so that the secondary air can be
10 divided without causing any loss of the flow of secondary air toward the center. Also, the distance between the second baffle plate 29 and the end of the burner 10 is minimized to reduce the residence time of burning-reaction ongoing gas in the downstream of the second baffle plate
15 29, thereby preventing the gas temperature from increasing under the radiant heat derived from the flames. As a result of this, the flame temperature is prevented from increasing, thus making it possible to realize the reduction in NO_x.

20 At the end of the gaseous-fuel feed pipe 23, an outer nozzle 32 for spouting gaseous fuel outward and an inner nozzle 33 for spouting gaseous fuel inward are provided. These outer nozzle 32 and inner nozzle 33 are provided in some plural number circumferentially, where the
25 opening area of the outer nozzle 32 is larger than the

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opening area of the inner nozzle 33. Because the outer nozzle 32 is provided at a position downstream of the second baffle plate 29, gaseous fuel does not need to be fed with high pressure but may be fed with low pressure.

5 Also, the gaseous fuel spouted from the inner nozzle 33 mixes with the primary air to form a small flame at a position downstream of the first baffle plate 28. This small flame serves as a pilot flame, improving the stability of the flame.

10 The operation of the burner 10 is explained. In the case where liquid fuel is fed, the liquid fuel is spouted from the ends of the nozzle tips 27, first mixing with the primary air derived from the first air flow path 25 and then with the secondary air derived from the second
15 air flow path 26, by which a flame is formed at a position downstream of the first baffle plate 28. The secondary air is fed as it is divided by the second baffle plate 29, so that divisional flames are formed, thus making it possible to realize the reduction in NO_x . Also, by the effect of
20 the taper portion 31 of the air resistor 24, the mixing of the secondary air and the liquid fuel is facilitated, making it possible to achieve the reduction in CO.

In the case where gaseous fuel is fed, on the other hand, the gaseous fuel is spouted from the outer
25 nozzle 32 and the inner nozzle 33. The gaseous fuel

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spouted from the inner nozzle 33 mixes with the primary air derived from the first air flow path 25, thereby forming a small flame at a position downstream of the first baffle plate 28. This small flame serves as a pilot flame, improving the flame retainability. The gaseous fuel spouted from the outer nozzle 32 mixes with the secondary air derived from the second air flow path 26, forming a large flame at a position downstream of the second baffle plate 29. The secondary air is fed as it is divided by the second baffle plate 29, by which divisional flames are formed, allowing the reduction in NO_x to be realized. Also, by the effect of the taper portion 31 of the air resister 24, the mixing of the secondary air and the gaseous fuel is facilitated, making it possible to achieve the reduction in CO.

The burner 10 is capable of even further reduction in both NO_x and CO, when adopted as a burner for the aforementioned once-through boiler, by virtue of the effects of reduction in both NO_x and CO in the boiler's body structure and the burner 10. Also, because the burner 10 uses liquid fuel or gaseous fuel selectively and switchably, the burner 10 is enabled to continue operation by switching one fuel to the other even when the feed of the one fuel is disabled by some change in the fuel feed. For example, even if some disaster, accident or the like

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has interrupted the gaseous-fuel feed network, the burner 10 is enabled to continue operating by using liquid fuel.

As described above, according to the present invention, it has become a reality to provide a water-tube boiler as well as a burner which can achieve even further reduction in NO_x in both the combustion of liquid fuel and the combustion of gaseous fuel, while being capable of attaining a reduction in both NO_x and CO at the same time, and therefore which are of clean exhaust gas favorable in terms of environmental issues.

SUBSTITUTE CLAIMS

What is claimed is:

1. A water-tube boiler comprising:

5 a burner constructed and arranged to selectively use one of only a gaseous fuel and only a liquid fuel; and

a plurality of water tubes arranged in an annular shape in a zone in the boiler where a flame derived from said
10 burner is present;

wherein said burner comprises:

a liquid-fuel nozzle pipe;
15

an annular gaseous-fuel feed pipe arranged about said liquid-fuel nozzle pipe;

a first annular air flow path defined between said
20 liquid-fuel nozzle pipe and said gaseous-fuel feed pipe;

an air resister arranged around said gaseous-fuel feed pipe;

an annular second air flow path formed between said gaseous-fuel feed pipe and said air resister;

25 a first baffle plate provided at an end of said first air flow path and having an opening in its center; and

a second baffle plate provided at an end of said second air flow path and dividing secondary air in said second air flow path.

SUBSTITUTE CLAIMS

2. The water-tube boiler according to claim 1, wherein said burner is a diffusion-combustion burner.

3. The water-tube boiler according to claim 1, wherein
5 said burner comprises said liquid-fuel nozzle pipe having a plurality of nozzles on an end thereof, said burner being constructed and arranged such that liquid fuel is sprayed from a selective number of said plurality of nozzles.

10

4. The water-tube boiler according to claim 1, wherein said gaseous-fuel feed pipe comprises an outer nozzle constructed and arranged to spout gaseous fuel into said second air flow path, and an inner nozzle for spouting
15 gaseous fuel into said first air flow path, both said outer nozzle and said inner nozzle being provided at an end portion of said gaseous-fuel feed pipe.

5. The water-tube boiler according to claim 1, wherein
20 said first baffle plate includes a plurality of swirl vanes disposed around said opening.

6. The water-tube boiler according to claim 1, wherein a tapered portion is provided at an end of said air
25 resister.

7. The water-tube boiler according to claim 6, wherein said second baffle plate is disposed at a mid point of said tapered portion along an axial direction of said
30 gaseous-fuel feed pipe.

SUBSTITUTE CLAIMS

8. The water-tube boiler according to claim 1, wherein said burner includes separate gaseous-fuel and liquid-fuel feed lines, each having respective valves.

5

9. A water-tube boiler comprising:

a burner constructed and arranged to selectively use one of only a gaseous fuel and only a liquid fuel; and

10

a first water tube array comprising a plurality of water tubes arranged in an annular shape in a zone in the boiler where a flame derived from said burner is present, wherein gaps are provided between at least some of said water tubes for allowing the flame to pass therethrough,

15

wherein a zone is provided radially outward of said first water tube array wherein a burning reaction is maintained,

20

wherein said burner comprises:

a liquid-fuel nozzle pipe;

25 an annular gaseous-fuel feed pipe arranged about said liquid-fuel nozzle pipe;

a first annular air flow path defined between said liquid-fuel nozzle pipe and said gaseous-fuel feed pipe;

30 and

a cylindrical air resister arranged coaxially around said

SUBSTITUTE CLAIMS

gaseous-fuel feed pipe;

wherein an annular second air flow path is defined
between said gaseous-fuel feed pipe and said air
5 resister;

wherein said burner includes a first baffle plate
provided at an end of said first air flow path and having
an opening in its center, and a second baffle plate
10 provided at an end of said second air flow path and
dividing secondary air in said second air flow path.

10. The water-tube boiler according to claim 9, wherein a
tapered portion is provided at an end of said air
15 resister.

11. The water-tube boiler according to claim 10, wherein
said second baffle plate is disposed at a mid point of
said tapered portion along an axial direction of said
20 gaseous-fuel feed pipe.

12. The water-tube boiler according to claim 11, wherein
said second baffle plate includes a plurality of cutout
portions circumferential and generally equidistantly in
25 its outer peripheral portion.

13. The water-tube boiler according to claim 9, wherein
said burner comprises an outer nozzle constructed and
arranged to spout gaseous fuel into said second air flow
30 path, and an inner nozzle for spouting gaseous fuel into
said first air flow path, both said outer nozzle and said

SUBSTITUTE CLAIMS

inner nozzle being provided at an end portion of said gaseous-fuel feed pipe.

14. The water-tube boiler according to claim 9, wherein
5 said burner comprises a liquid-fuel nozzle pipe having a plurality of nozzles on an end thereof, said burner being constructed and arranged such that liquid fuel is sprayed from a selective number of said plurality of nozzles.

10 15. The water-tube boiler according to claim 9, wherein said first baffle plate includes a plurality of swirl vanes disposed around said opening.

16. The water-tube boiler according to claim 9, wherein
15 said burner includes separate gaseous-fuel and liquid-fuel feed lines, each having respective valves.

FIG. 1

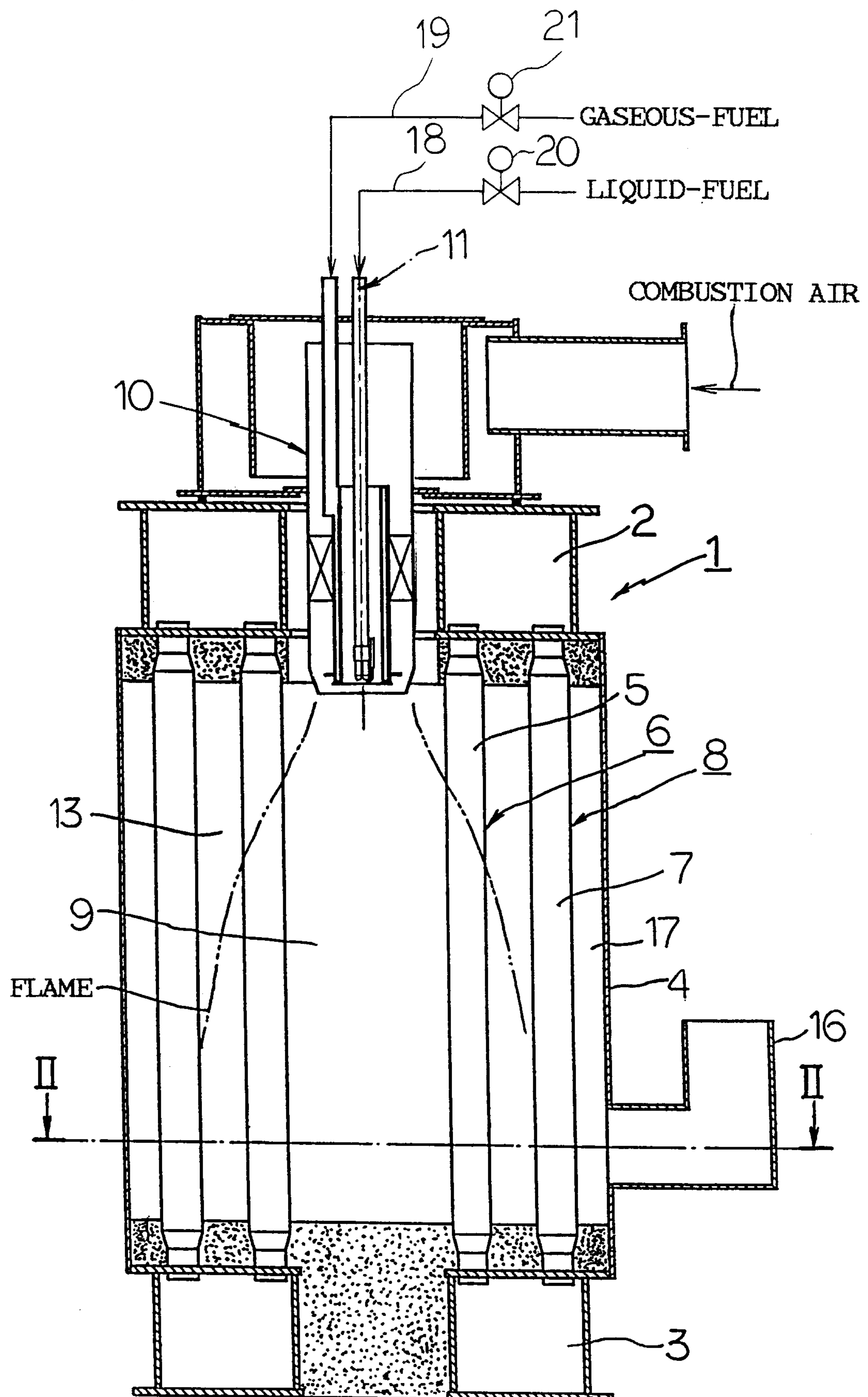


FIG. 2

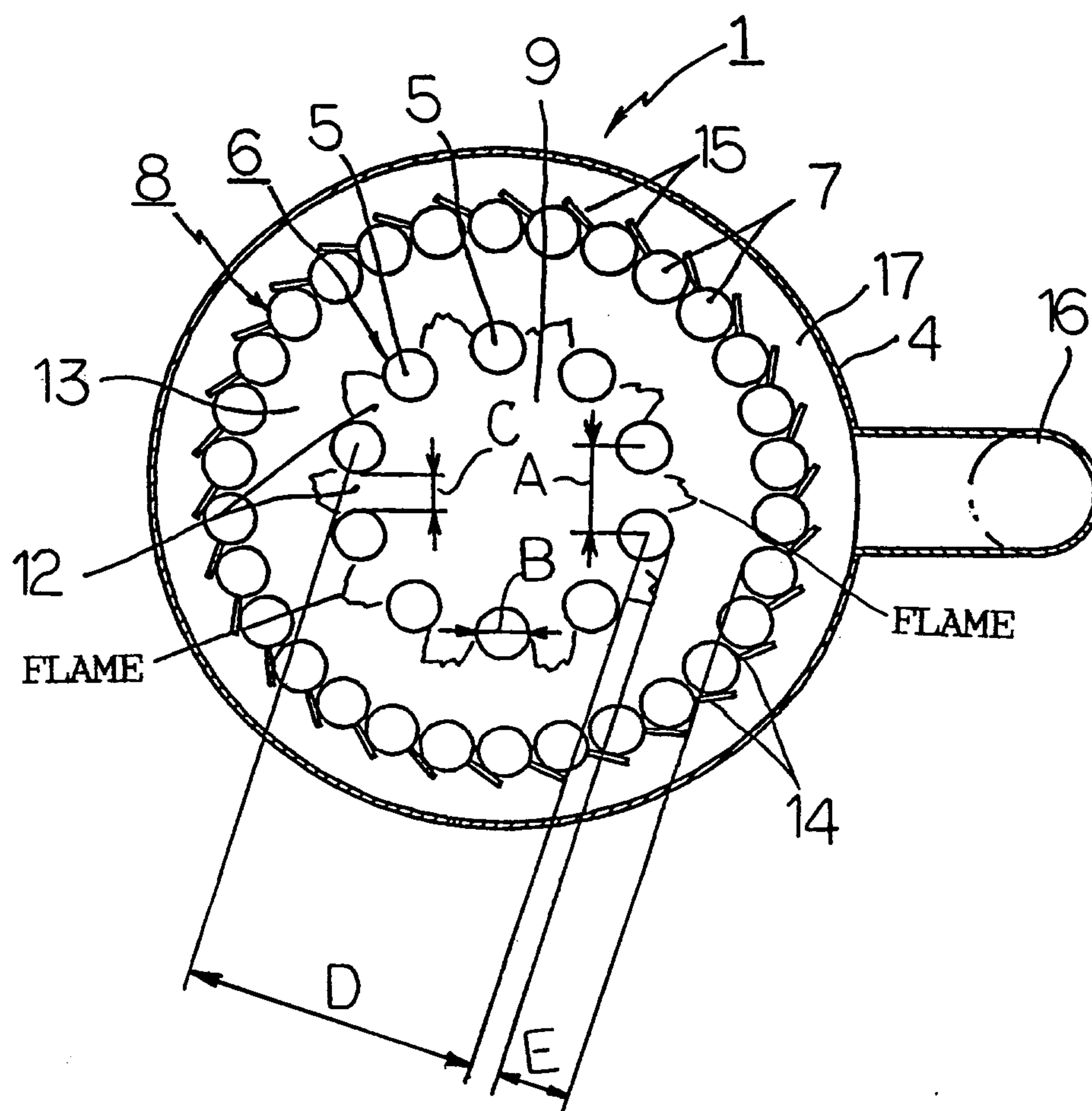


FIG. 3

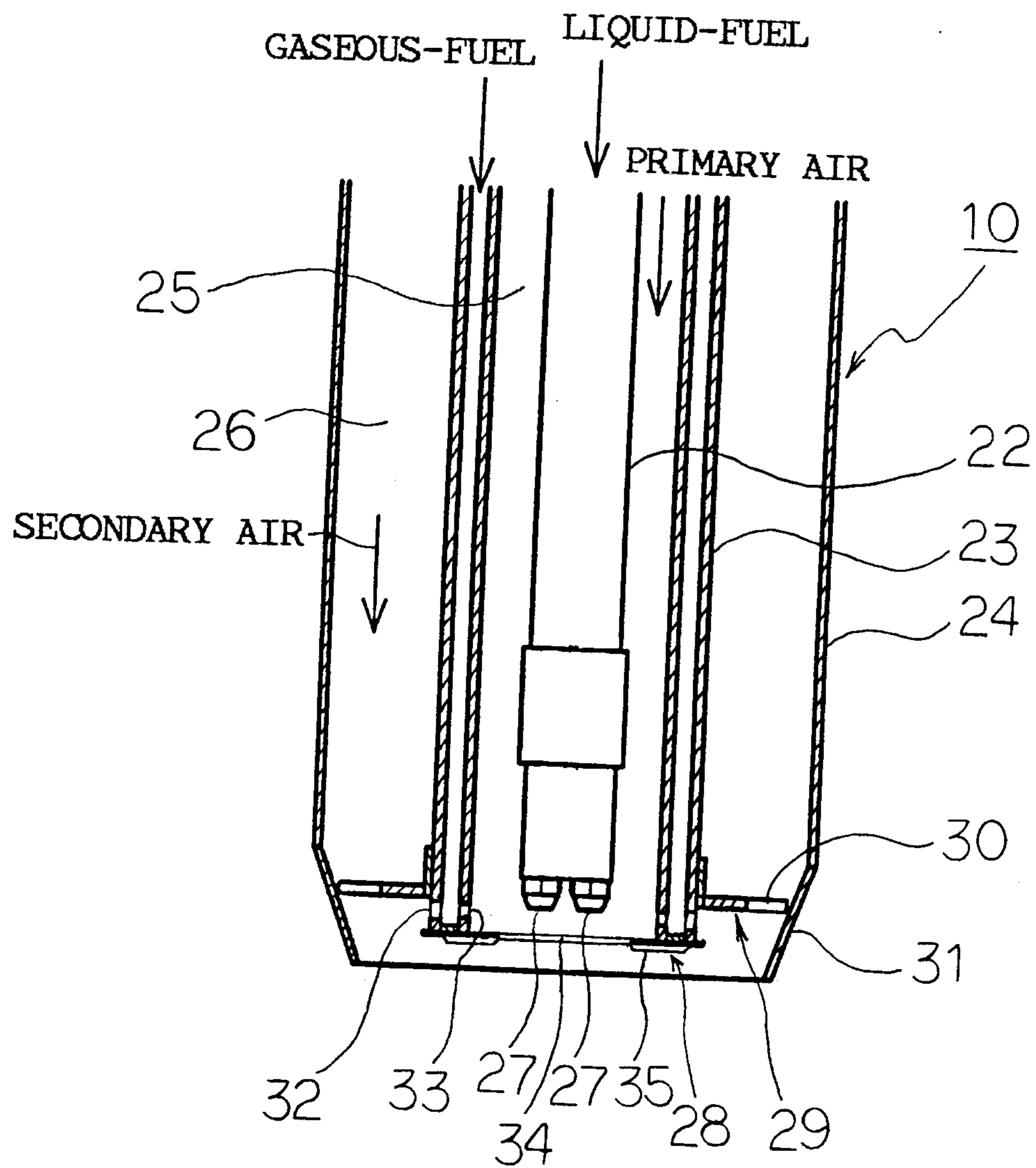


FIG. 4

