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(54) **RADIANT TUBE BURNER.**

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Description

This invention relates to a radiant tube burner comprising a combustion tube installed in a radiant tube, a primary air supply tube and a gas burner having a nozzle of the divergent flame type and coaxially placed in the combustion tube so that, in use, fuel gas coming out of the gas burner undergoes primary combustion by primary air supplied through the annular space between the gas burner and the combustion tube and further undergoes secondary combustion by secondary air supplied through the annular space between the combustion tube and the radiant tube.

Such a burner is described, for instance, in JP—B2—52-29007.

There has further been a proposal in the design of radiant tube burners in which a damper is provided at the inlet of the primary air admitted into the combustion tube, for example, to restrain the generation of NOx, thereby making it possible to change the primary and the secondary air ratio. (See Japanese Utility Model Laid-open No. Sho 52-21036).

However, it has been found out that the amount of generated NO_x cannot be sufficiently reduced only by adjusting the primary and the secondary air ratio.

Further, there has been known another proposal in which a steam tube is provided in the fuel gas nozzle to eject steam into the flame formed by burner combustion, to make it possible to reduce the flame temperature to restrain the generation of NO_x (See JP—B2—52-29007 mentioned above).

When comparing the case of ejecting steam with that of atomizing water, the latter is more effective in reducing the flame temperature, thus leading to higher reduction of NO_x. However, an adverse effect on the radiant tube and instability of the flame may be expected due to the relatively large particle size of atomized water so that the practical use has been considered to be impossible.

Embodiments of the present invention may provide a radiant tube burner in which high heat load primary combustion is caused to happen in satisfactory and stable way by swirling the primary air and soft secondary combustion takes place in a radiant tube, thereby making it possible to obtain low NO_x.

According to the invention there is provided a radiant tube burner of the type described at the beginning, characterised in that the gas burner is designed to be movable in the axial direction, primary air swirling vanes are located at the end of the burner, for forming a swirled flame, and an air damper is fitted on the primary air supply tube, which is connected to the combustion tube, for adjusting the ratio of primary air to secondary air.

In some embodiments of the present invention the flame temperature is reduced by means of adding atomized water into the combustion flame, thereby making it possible to obtain low NO_x, while high heat load combustion is going on in satisfactory and stable way owing to the two-stage combustion described above. For this purpose a water spray nozzle may be placed at the centre of the divergent flame type nozzle, the water nozzle being connected to an atomized water generator capable of supplying pressurized gas and additive water through an additive water transfer tube installed in the gas burner.

Further, as a different advantageous embodiment of the present invention, the atomized water generator is composed of a cylinder having a conical hole to be connected to the additive water transfer tube, a recessed disk having grooves for the injection of pressurized gas and additive water and fitted to the said cylinder, and a housing for accommodating the cylinder and the disk.

Embodiments of the present invention may also provide a radiant tube burner in which, in addition to the aforementioned features, the exhaust gas is used as atomizing medium, thereby accomplishing enhanced reduction of NO_x while high heat load and low NO_x combustion occurs due to the swirling of the primary air and addition of atomized water into the combustion flame. Here the atomized water generator may be connected to the exhaust gas pipe, while other parts remain the same as described above.

Alternatively, low pressure fuel gas can be used as an atomizing medium, in which case the water atomizer is connected to the fuel gas while other parts remain the same as described in the preceding.

In addition, as another advantageous means, an exhaust gas introducing tube and a water outflow nozzle may both be placed at the central portion of the divergent flame tube nozzle to utilise the kinetic energy of low pressure exhaust gas to atomize the water supplied from the additive water transfer tube.

Various embodiments of this invention will now be described in detail, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a longitudinal sectional view showing an embodiment of a radiant tube burner representing a first embodiment of the present invention;

Figures 2 and 3 are a front view and a sectional view showing the divergent flame type nozzle;

Figures 4 and 5 are a longitudinal sectional view and a front view showing primary air swirling vanes;

Figure 6 shows the amount of generated NO_x versus the maximum temperature of the radiant tube for explaining the effect of NO_x reduction in a radiant tube burner in accordance with the present invention;

Figure 7 is a longitudinal sectional view showing a second embodiment of the radiant tube burner in accordance with the present invention;

Figure 8 is a longitudinal sectional view showing a divergent flame type nozzle;

Figures 9 and 10 are a fragmentary exploded perspective view and an assembled sectional view showing an atomized water generator;

Figure 11 explains the mechanism of atomized water generation;

Figure 12 is a longitudinal sectional view showing a third embodiment;

Figure 13 is a longitudinal sectional view showing a further divergent flame type nozzle;

Figure 14 is a view, in partial cross-section, showing a major portion of a fourth embodiment of the present invention using a water atomizing system with low pressure fuel gas;

Figure 15 is a view, in partial cross-section, showing a major portion of a fifth embodiment of the present invention using a water atomizing system with low pressure exhaust gas; and

Figure 16 shows the amount of additive water versus the reduction rate of NO_x in a radiant tube burner in accordance with the present invention.

Referring to Figure 1 showing the first embodiment, a gas burner 1 is coaxially placed with a combustion tube 2. A divergent flame type nozzle 3a (see Figures 2 and 3) is mounted at the end of the burner 1. At the rear end of the burner 1, there is a fuel gas connection 4. A primary air supply tube 5 joins the rear end of the combustion tube 2 to form an integral piece extending coaxially with the burner 1. The primary air supply tube 5 has four rectangular ports 6 evenly spaced over the entire periphery thereof. The area of the inlet 6 can be changed by moving, with an operating rod 8 and a nut 9, a cylindrical air damper 7, into which the air supply tube 5 is loosely fitted. Primary air swirling vanes 10 having an angle within the range from 15 to 60° are secured on a retaining tube 11 at the front end of said burner 1, as shown in Figures 4 and 5. The combustion tube 2 and the primary air supply tube 5 are coaxially housed in a radiant tube 12. An air supply connection 13 is provided at the rear section of the radiant tube 12 in which the inlet ports 6 are located. An end cover 14 closes rear ends of the primary air supply tube 5 and radiant tube 12. The gas burner 1 is installed across said end cover 14 to extend rearward. Reference numeral 15 designates a pilot burner. The gas burner 1 extends movably through the end cover 14 in the axial direction within the range of the combustion tube 2 together with the pilot burner 15. Accordingly, the divergent flame type nozzle 3a is supported in the combustion tube 2 through the swirling vanes 10 so that the nozzle position is changeable.

The set position L of the divergent flame type nozzle 3a is changeable within the range from 100 to 500 mm. The burner 1 is fixed by a bolt 16 attached on the end cover 14.

Next, the operating mechanism of the radiant tube burner according to the first embodiment of the present invention will be described in the following. Referring to Figure 1, the gas supplied to the gas burner 1 through the connection 4 is ejected from the divergent flame type nozzle 3a into the combustion tube 2 at the maximum ejection angle of 60° and at the speed ranging from 10 to 100 m/sec. The jetted fuel gas mixes with primary air C_1 which flows through the inlet 6 and is swirled by the swirling vanes 10 before being burnt in reduced primary combustion at the high heat load within the range from 500×10^4 kcal/m^3-h—$1{,}000\times10^4$ kcal/m^3-h. The primary combustion gas issues from the combustion tube 2 in the axial direction into the radiant tube 12 at a speed within the range from 10 to 30 m/sec. Secondary air C_2 (90 to 50%) throttled by the air damper 7 to be at a required ratio with respect to the primary air C_1 (10 to 50%) is fed through the annular passage between the combustion tube 2 and the radiant tube 12, cooling said combustion tube 2, at a speed slower than that of the primary combustion gas. The secondary air C_2 flows along the inside of the radiant tube 12 due to the kinetic energy differential between the secondary air C_2 and the primary combustion gas, while making the secondary combustion occur in a less concentrated way to prevent localized heating at the boundary with the primary combustion gas, thereby controlling the generation of NOx.

Test results with a 7 inch (17.5 cm) radiant tube burner according to the first embodiment of the present invention are as follows. The heat rate was as much as 145,000 kcal/h while generally accepted limit had been 110,000 kcal/h with prior art. NOx may be reduced to between 80 and 150 ppm by changing the position of the nozzle 3a and the primary and secondary air ratio. Furthermore, there was little soot and carbon monoxide even under the stringent condition that the residual O_2 in the exhaust gas to be less than one percent. It is also possible to obtain a turn-down ratio less than 10% down at which stable combustion can be performed without blowout even when combustion air flow capacity is held at 100% and fuel gas is throttled down to 10%.

Regarding the tube temperature, which is an important factor in the operation of radiant tube burners, it is possible to obtain uniform tube temperature due to the rotation of the flame, with the temperature variation in the circumferential direction within 10°C. Further, the temperature difference in the axial direction between the maximum and the minimum in the furnace is made within 150°C, so that extended tube life can be expected.

Figure 6 shows the maximum temperature of the radiant tube versus the amount of generation of NOx to explain the effect of NOx reduction according to the present invention. It is obvious that NOx can be reduced by approximately 30% compared with a prior art radiant tube burner.

Next, a second embodiment of the present invention is described in the following with reference to Figure 7. The numbers in Figure 7 refer to the corresponding parts which are the same as illustrated in Figure 1.

Referring to Figures 7 and 8, the gas burner 1 is placed coaxially with the combustion tube 2. The divergent flame type nozzle 3a is mounted at the end of the burner 1. At the rear end of the burner 1, there is the fuel gas connection 4. The primary air supply tube 5 joins the rear end of the combustion tube 5 to form an integral piece extending coaxially with the burner 1. The primary air supply tube 5 has four rectangular ports 6 evenly spaced over the entire periphery thereof. The primary air swirling vanes 10 having an angle within the range from 15 to 60° are secured on a retaining tube (not shown) at the end of said burner 1. The combustion tube 2 and the primary air supply tube 5 are coaxially housed in the radiant tube 12. The primary air supply tube and the radiant tube are closed by the end cover 14 through flanges respectively, whereas the gas burner 1 passes through the end cover 14 to extend rearward.

A water spray nozzle 18 communicating with an additive water transfer tube 17 placed in said gas burner 1 is provided at the center of the divergent flame type nozzle 3a, and a number of gas injection ports 19 communicating with the gas connection 4 are provided around said nozzle 18 as shown in Figure 8. Further, an air supply connection 13 is connected to the rear section of the radiant tube 12. An atomized water generator 22 connected to a pressurized gas tube 20 and an additive water transfer tube 21 is fitted to the rear end of water transfer tube 17.

Referring to Figures 9 and 10, the atomized water generator 22 consists of a disk 24 having a circular recess 23 and a conical hole 25 with its diameter gradually decreasing from that corresponding to said recess. Further, a cylinder 26 having the same diameter as that of said disk 24 is coaxially fitted to said disk so that they mate with each other, and they are then built in a housing 27. The disk 24 is surely pressed by a plug 28 and the cylinder 26 is connected to the additive water transfer tube 17. When the disk is fitted to the cylinder, an atomized water generating chamber 29 is formed. Grooves 30 and 31 for introducing the pressurized gas and the additive water and communicating with said recess 23 in the tangential direction thereof are provided on one plane perpendicular to the center axis at the end face of the disk 24 near the cylinder 26. These grooves 30, 31 are connected to the pressurized gas suply tube 20 and the additive water supply tube 21 respectively.

The second embodiment of the present invention is a combination of the first embodiment and atomized water injection. For ease of understanding explanation on the air and the gas flow will be repeated. Referring to Figure 7, the fuel gas supplied to the gas burner 1 through the connection 4 is ejected from the divergent flame type nozzle 3a into the combustion tube 2. The jetted fuel gas mixes with the primary air C_1 which flows through the inlet 6 and is swirled by the primary air swirling vanes 10 before being burnt in reduced primary combustion at the high heat load. Then, the primary combustion gas issues from the combustion tube 2 similarly to the first embodiment noted above.

On the other hand, the secondary air C_2 throttled by the air damper 7 as shown in Figure 1 to be at a required ratio with respect to the primary air C_1 is fed through the annular passage between the combustion tube 2 and the radiant tube 12, cooling said combustion tube 2, and then flows along the inside of the radiant tube 12. Thus, the secondary combustion successively occurs to prevent localized heating at the boundary with the primary combustion gas. The atomized water is obtained by the atomized water generator 22, as shown in Figures 10 and 11, being injected from the water spray nozzle 18 located at the center of the divergent flame type nozzle 3a, thereby reducing the flame temperature to restrain the generation of NOx. In this case, bubbles of the atomized water are sharply expanded to blow up through injection due to the differential pressure across the bubbles and the combustion tube. Since the thickness of the bubble is very thin, i.e., 0.1 µm or above, the pieces of the blown-up bubbles are very fine. Therefore, the fine water particles will quickly absorb the latent heat from the flame, thereby greatly reducing the generation of NOx due to the lowered flame temperature.

Next, a third embodiment of the radiant tube burner in accordance with the present invention will be described with reference to Figures 12 and 13. The number in Figures 12 and 13 refer to the corresponding parts which are the same as illustrated in Figures 7 and 8. However, it differs from the second embodiment in that the exhaust gas is ejected into the center of the fuel gas as atomizing medium while in the second embodiment water is used as atomizing medium.

Since the mechanism of the radiant tube burner in the third embodiment of the present invention is similar to that of the second embodiment with the only difference that the nozzle is constituted as a divergent flame type nozzle 3b, it will not be further described here.

Next, Figure 14 shows a modification of the third embodiment of the present invention making use of an atomizing system due to low pressure fuel gas. As shown in Figure 14, the gas burner 1 is placed coaxially with the combustion tube 2. The divergent flame type nozzle 3c is provided at the front end of the burner 1. A water outflow nozzle 32 is provided at the center of the nozzle 3c. In the annular space defined by the water outflow nozzle 32 and the exhaust gas nozzle are installed gas swirling vanes 33 having an angle within the range from 15 to 40°.

Next, the operating mechanism of the radiant tube burner of the modification of the third embodiment employing the atomizing system with low pressure fuel gas will be described in the following. As shown in Figure 14, the gas G introduced into the gas burner 1 from the gas connection 4 is fed in the direction shown by the arrow to be swirled at high speed by the gas swirling vanes 33, while the water W introduced into the additive water transfer tube 17 (See Figures 12 and 13) connected to an additive water connection port 36 is fed in the direction shown by an arrow to issue from the water outflow nozzle 32. In this case, the water discharged from the water outflow nozzle is atomized by the kinetic energy of the fuel gas.

Thus, since the water is atomized by the kinetic energy of the fuel gas, the atomized water and fuel gas are sufficiently mixed with each other and the effect of water addition is greatly enhanced.

Figure 15 shows a further modification of the third embodiment of the present invention in which the atomizing system uses low pressure exhaust gas. As shown in the Figure, an exhaust gas introducing tube 34 for atomizing the water supplied from the water outflow nozzle 32 is placed at the center of the divergent flame type nozzle 3d. The additive water transfer tube 17 is placed at the center of the introducing tube 34. In the annular space defined by the water outflow nozzle 32 and the exhaust gas nozzle are provided exhaust-gas-swirling vanes 35 having an angle within the range from 15 to 40°.

The mechanism of the radiant tube burner of the modification of the third embodiment employing the atomizing system with the low pressure exhaust gas will be described in the following. As shown in Figure 15, the exhaust gas WG is swirled at high speed by the exhaust gas swirling vanes 35 to atomize the water W discharged from the water outflow nozzle 32. The atomized water is mixed with the fuel gas G, supplied from the divergent flame type nozzle 3d, by the high speed swirling flow of the exhaust gas. Therefore, the mixing of the exhaust gas and the fuel gas and that of the fuel gas and the atomized water occur rapidly to reduce the flame temperature by making the flame temperature uniform due to the combustion delay of the fuel gas and absorption of the latent heat by the atomized water, thereby greatly reducing the generation of NOx.

The radiant tube burners including two modifications of the third embodiment noted above has two types of water atomizing system. One is using pressurized gas (air, vapor and inert gas) within the range from 2 to 6 kg/cm^2 and the other is using low pressure gas (fuel gas, exhaust gas or the like) in the range from 300 to 1,000 mm Hg.

NOx reduction rate by adding water in the radiant tube burner according to these embodiments of the present invention is represented by the relation between the amount of additive water and the NOx reduction rate as shown in Figure 16.

Operational factors of the radiant tube burner according to the embodiments noted above are shown as follows:

Fuel COG: 4,500 kcal/Nm^3
calorific force: 145,000 kcal/h
air temperature for combustion: 400°C
Residual O_2 contained in the exhaust gas: 4%
radiant tube type: 7 inch W type

The amount of additive water is gradually increased to obtain higher NOx reduction rate (%).

As is obvious from the result, NOx can be efficiently reduced by adding water in the radiant tube burner. Furthermore, since the maximum tube temperature may be lowered, an extended tube life can be expected.

As has been described in the foregoing, the radiant tube burner according to the present invention will give utmost effectiveness when used for a furnace in which direct exposure of workpieces to waste gas is not desirable, e.g. non-oxidation furnaces, heat treatment furnaces and the like utilizing atmospheric gas, and indirect heating systems in which workpieces and waste gas should not come in contact. Applicable fields will include those industries such as metal working industry, ceramics, glass industry, chemical industry, paper and fiber industry and food industry or the like.

Claims

1. A radiant tube burner comprising a combustion tube (2) installed in a radiant tube (12), a primary air supply tube (5) and a gas burner (1) having a nozzle (3a) of the divergent flame type and coaxially placed in the combustion tube (2) so that, in use, fuel gas coming out of the gas burner (1) undergoes primary combustion by primary air (C_1) supplied through the annular space between the gas burner (1) and the combustion tube (2) and further undergoes secondary combustion by secondary air (C_2) supplied through the annular space between the combustion tube (2) and the radiant tube (12), characterised in that:

the gas burner (1) is designed to be movable in the axial direction;

primary air swirling vanes (10) are located at the end of the burner (1), for forming a swirled flame; and

an air damper (7) is fitted on the primary air supply tube (5), which is connected to the combustion tube (2), for adjusting the ratio of primary air to secondary air.

2. A radiant tube burner according to Claim 1, wherein the air ratio can be controlled by the air damper (7) so that the proportion of secondary air (C_2) is between 90 and 50% and the proportion of primary air (C_1) between 10 and 50%.

3. A radiant tube burner according to Claim 1 or 2, wherein the nozzle (3) has a set position L changeable within the range from 100 to 500 mm.

4. A radiant tube burner according to any preceding claim, in which the gas burner (1) has a water spray nozzle (3) at its centre, and further comprising an atomized water generator (22) capable of supplying pressurized gas and additive water, the nozzle (3) being connected with the atomized water generator (22) through an additive water transfer tube (17) installed in the gas burner.

5. A radiant tube burner according to Claim 4, wherein the atomized water generator (22) consists of a cylinder (26) having a conical hole (25) to be connected to the additive water transfer tube (17), a recessed disk (24) having grooves (30, 31) for allowing injection of pressurized gas and additive water into it and fitted to the said cylinder (26), and a housing (27) for accommodating the

cylinder (26) and the disk (24).

6. A radiant tube burner according to Claim 4, wherein a water outflow nozzle (32) is placed at the center of the divergent flame type nozzle (3c) to atomize the water supplied from the additive water transfer tube (17) by the kinetic energy of low pressure fuel gas.

7. A radiant tube burner according to Claim 4, wherein an exhaust gas introducing tube and a water outflow nozzle (32) are placed at the center of the divergent flame type nozzle (3d) to atomize the water supplied from the additive water transfer tube (17) by the kinetic energy of low pressure exhaust gas.

8. A radiant tube burner according to any one of Claims 4 to 7, wherein the atomized water addition is performed by using the pressurized gas (air, vapor and inert gas) within the range from 2 to 6 kg/cm^2 or the low pressure gas (fuel gas, exhaust gas or the like) within the range from 300 to 1,000 mmHg.

Patentansprüche

1. Strahlungsrohrbrenner mit einem in einem Strahlungsrohr (12) angebrachten Verbrennungsrohr (2), einem Primärluftzuführrohr (5) und einem Gasbrenner (1) mit einer Düse (3a) mit divergierender Flamme, welche Düse derart koaxial in dem Verbrennungsrohr (2) angeordnet ist, daß aus dem Gasbrenner (1) austretendes Brenngas beim Gebrauch einer primären Verbrennung durch Primärluft (C_1) unterliegt, die durch den ringförmigen Raum zwischen dem Gasbrenner (1) und dem Verbrennungsrohr (2) zugeführt wird, und die ferner einer sekundären Verbrennung durch Sekundärluft (C_2) unterliegt, die durch den ringförmigen Raum zwischen dem Verbrennungsrohr (2) und dem Strahlungsrohr (12) zugeführt wird, dadurch gekennzeichnet, daß

der Gasbrenner (1) zur Bewegung in axialer Richtung ausgebildet ist;

Primärluftverwirbelungsflügeln (10) am Ende des Brenners (1) zur Bildung einer verwirbelten Flamme angeordnet sind; und

eine Luftdämpfungsvorrichtung (7), die mit dem Verbrennungsrohr (2) verbunden ist, an dem Primärluftzuführrohr (5) zur Einstellung des Verhältnisses zwischen der Primärluft und der Sekundärluft angebracht ist.

2. Strahlungsrohrbrenner nach Anspruch 1, bei dem das Luftverhältnis über die Lufteinlaßklappe (7) derart geregelt werden kann, daß der Anteil der Sekundärluft (C_2) zwischen 90 und 50% und der Anteil der Primärluft (C_1) zwischen 10 und 50% beträgt.

3. Strahlungsrohrbrenner nach Anspruch 1 oder 2, bei dem die Düse (3) eine Einstellposition L aufweist, die innerhalb eines Bereichs von 100 bis 500 mm veränderbar ist.

4. Strahlungsrohrbrenner nach einem der vorhergehenden Ansprüche, bei dem der Gasbrenner (1) in seiner Mitte eine Wassersprühdüse (3) aufweist und ferner mit einem Wassernebelerzeuger (22), der in der Lage ist druckbaufschlagtes Gas und Zusatzwasser zuzuführen, wobei die Düse (3) mit dem Wassernebelerzeuger (22) über ein in dem Gasbrenner angebrachtes Zusatzwasserübertragungsrohr (17) verbunden ist.

5. Strahlungsrohrbrenner nach Anspruch 4, bei dem der Wassernebelerzeuger (22) aus einem Zylinder (26) mit einem konischen Loch (25), das mit dem Zusatzwasserübertragungsrohr (17) zu verbinden ist, aus einer abgesetzten Scheibe (24) mit Nuten (30, 31), um das Einspritzen von druckbeaufschlagtem Gas und Zusatwasser in diese zu ermöglichen, wobei die Scheibe an dem Zylinder (26) angebracht ist, und aus einem Gehäuse (27) zum Aufnehmen des Zylinders (26) und der Scheibe (24) besteht.

6. Strahlungsrohrbrenner nach Anspruch 4, bei dem eine Wasseraustrittsdüse (32) in der Mitte der Düse (3c) mit divergierender Flamme angeordnet ist, um das aus dem Zusatzwasserübertragungsrohr (17) zugeführte Wasser durch die kinetische Energie des Niederdruck-Brenngases zu zerstäuben.

7. Strahlungsrohrbrenner nach Anspruch 4, bei dem ein Abgaseinführrohr und eine Wasseraustrittsdüse (32) in der Mitte der Düse (3d) mit divergierender Flamme angeordnet sind, um das aus dem Zusatzwasserübertragungsrohr (17) zugeführte Wasser durch die kinetische Energie des Niederdruck-Abgases zu zerstäuben.

8. Strahlungsrohrbrenner nach einem der Ansprüche 4 bis 7, bei dem das Zusetzen von zerstäubtem Wasser durch Verwendung des druckbeaufschlagten Gases (Luft, Dampf und Inertgas) innerhalb eines Bereichs von 2 bis 6 kg/cm^2 oder des Niederdruckgases (Brenngas, Abgas oder dergleichen) innerhalb des Bereichs von 300 bis 1000 mmHg erfolgt.

Revendications

1. Brûleur à tube rayonnant comprenant un tube de combustion (2) installé dans un tube rayonnant (12), un tube (5) d'alimentation an air primaire et un brûleur (1) à gaz comportant une buse (3a) du type à flamme divergente et placé coaxialement dans le tube de combustion (2) de manière que, pendant l'utilisation, le gaz combustible sortant du brûleur (1) à gaz soit soumis à une combustion primaire par l'air primaire (C_1) arrivant par l'espace annulaire entre le brûleur (1) à gaz et le tube de combustion (2) et soit en outre soumis à une combustion secondiare par l'air secondaire (C_2) arrivant par l'espace annulaire entre le tube de combustion (2) et le tube rayonnant (12), caractérisé en ce que:

le brûleur (1) à gas est conçu de manière à pouvoir être déplacé dans la direction axiale;

des ailettes (10) pour communiquer un tourbillonnement à l'air primaire sont placées à l'extrémité du brûleur (1) afin de former une flamme tourbillonnante; et

un registre (7) de commande d'air est monté sur le tube (5) d'alimentation en air primaire, qui est raccordé au tube de combustion (2), pour régler le rapport de l'air primaire à l'air secondaire.

2. Brûleur à tube rayonnant selon la revendication 1, dans lequel le rapport d'air peut être commandé à l'aide du registre (7) de manière que la proportion d'air secondaire (C_2) soit comprise entre 90 et 50% et que la proportion d'air primaire (C_1) soit comprise entre 10 et 50%.

3. Brûleur à tube rayonnant selon la revendication 1 ou 2, dans lequel la buse (3) présente une position de réglage (L) pouvant être modifiée dans la plage allant de 100 à 500 mm.

4. Brûleur à tube rayonnant selon l'une quelconque des revendications précédentes, dans lequel le brûleur (1) à gaz comporte une buse (3) de pulvérisation d'eau en son centre et comprend, en outre, un générateur (22) d'eau atomisée pouvant fournir un gaz comprimé et de l'eau d'addition, la buse (3) étant raccordée au générateur (22) d'eau atomisée par un tube (17) de transfert d'eau d'addition installé dans le brûleur à gaz.

5. Brûleur à tube rayonnant selon la revendication 4, dans lequel le générateur (22) d'eau atomisée comprend un cylindre (26) comportant un trou conique (25) destiné à être raccordé au tube (17) de transfert d'eau d'addition, un disque évidé (24) comportant des rainures (30, 31) pour que du gaz sous pression et de l'eau d'addition puissent y être injectés et monté sur le cylindre (26), et un boîtier (27) pour loger le cylindre (26) et le disque (24).

6. Brûleur à tube rayonnant selon la revendication 4, dans lequel une buse (32) de sortie d'eau est placée au centre de la buse (3c) du type à flamme divergente pour atomiser l'eau arrivant du tube (17) de transfert d'eau d'addition sous l'effet de l'énergie cinétique du gaz combustible sous basse pression.

7. Brûleur à tube rayonnant selon la revendication 4, dans lequel un tube d'introduction de gaz d'échappement et une buse (32) de sortie d'eau sont placés au centre de la buse (3d) du type à flamme divergente pour atomiser l'eau arrivant du tube (17) de transfert d'eau d'addition sous l'effet de l'énergie cinétique du gaz d'échappement sous basse pression.

8. Brûleur à tube rayonnant selon l'une quelconque des revendications 4 à 7, dans lequel l'addition d'eau atomisée est effectuée par utilisation du gaz (air, vapeur et gaz inerte) sous une pression comprise entre 2 et 6 kg/cm^2 ou du gaz (gaz combustible, gaz d'échappement ou analogue (sous une pression basse comprise entre 300 et 1000 mmHg.

FIG. 1

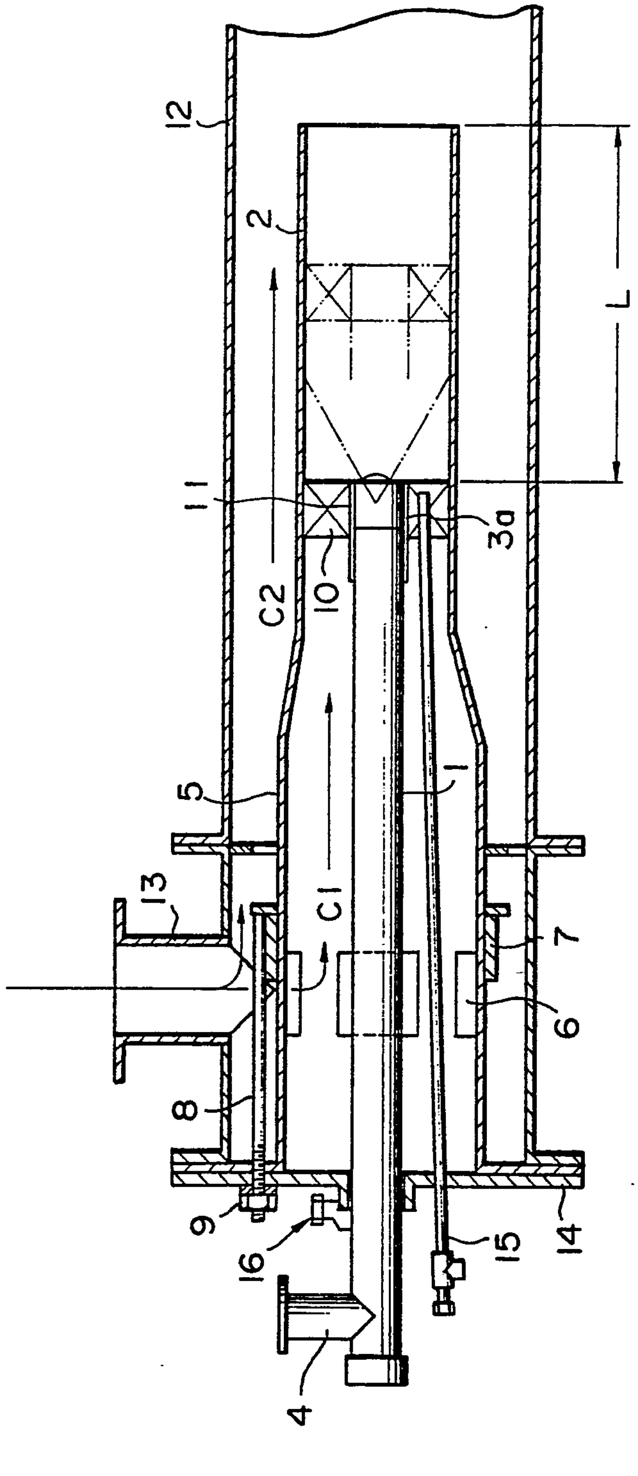


FIG. 2

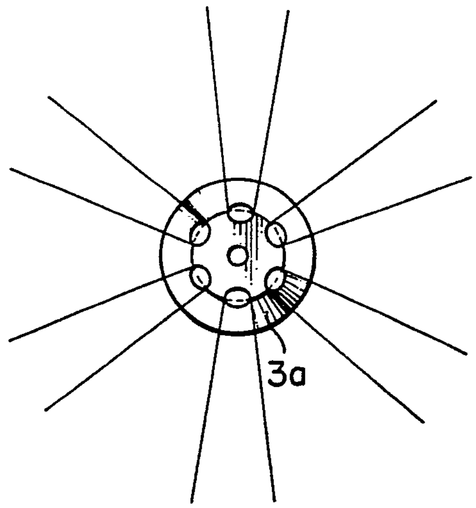


FIG. 3

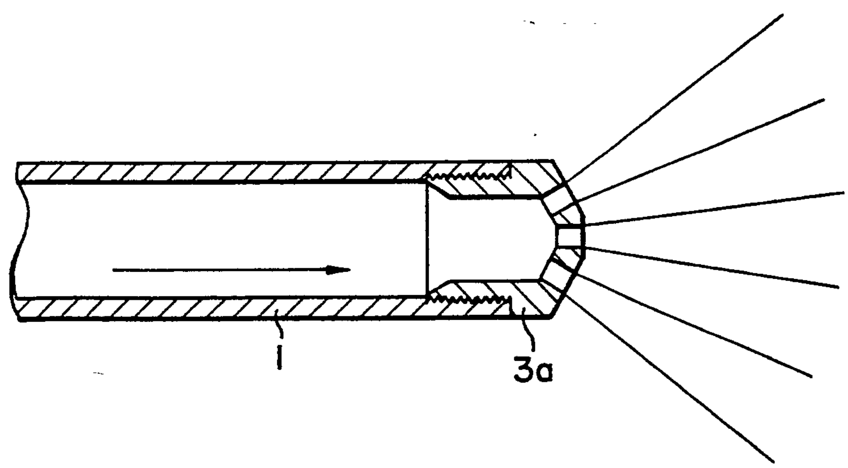


FIG. 4

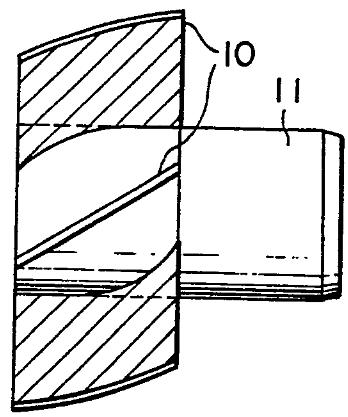


FIG. 5

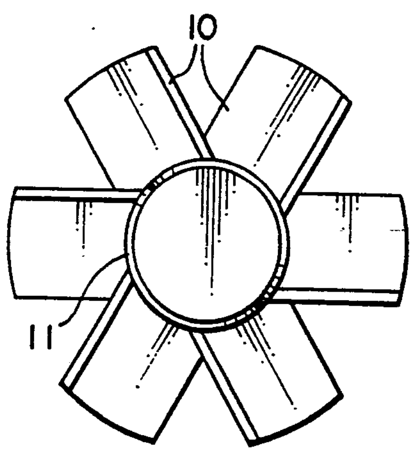
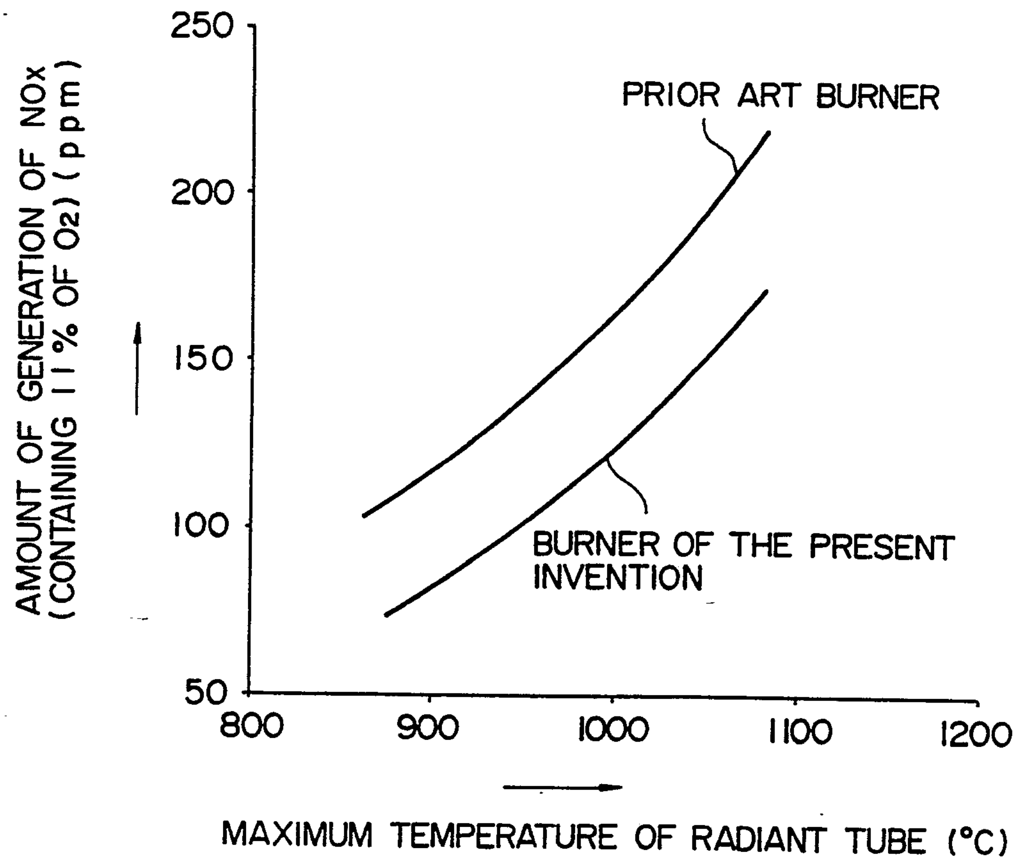


FIG. 6


AMOUNT OF GENERATION OF NOx
(CONTAINING 11 % OF O2) (ppm)
250
200
150
100
50
PRIOR ART BURNER
BURNER OF THE PRESENT INVENTION
800
900
1000
1100
1200
MAXIMUM TEMPERATURE OF RADIANT TUBE (°C)

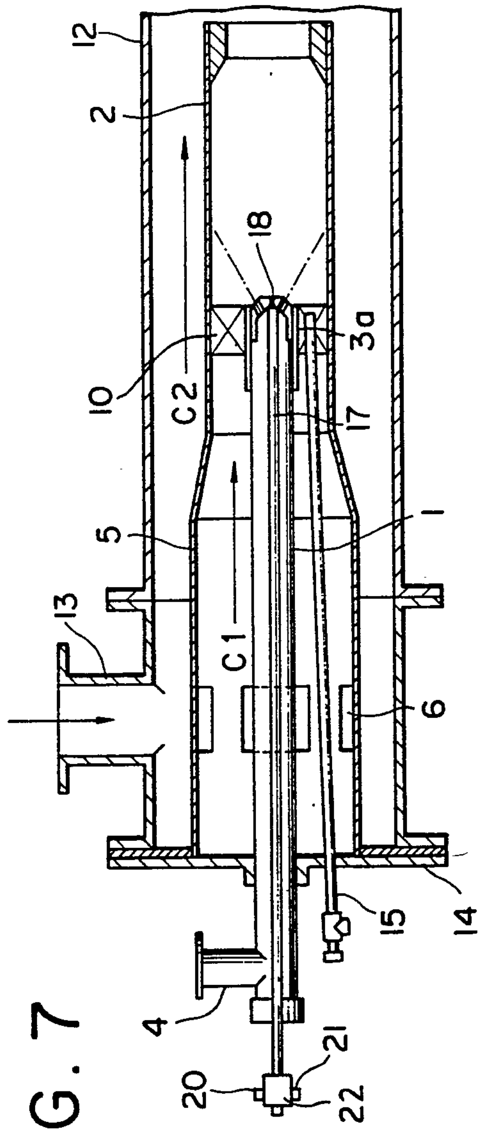


FIG. 7

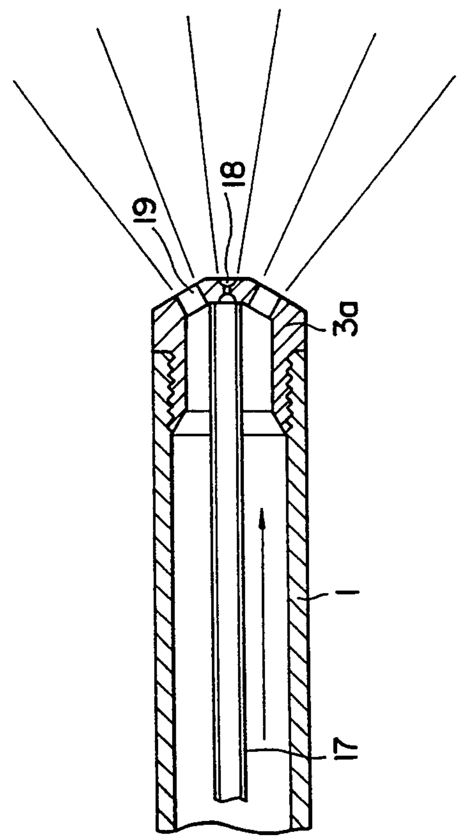


FIG. 8

FIG. 9

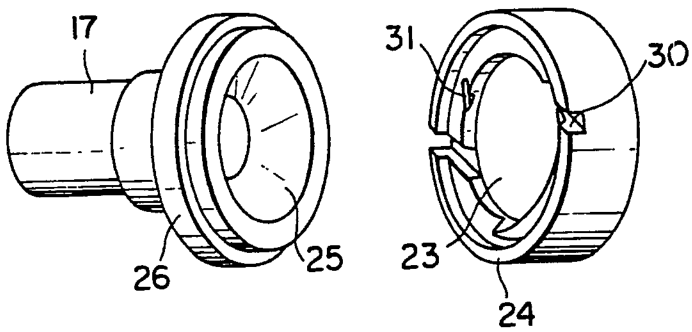
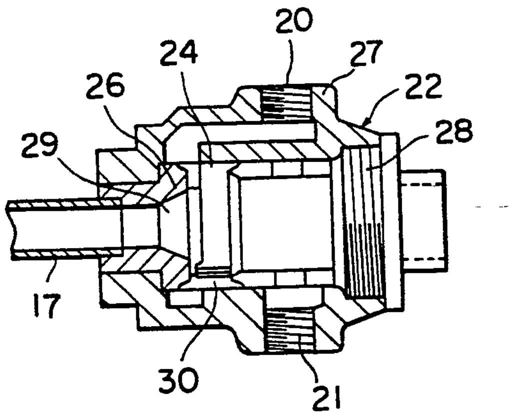


FIG. 10



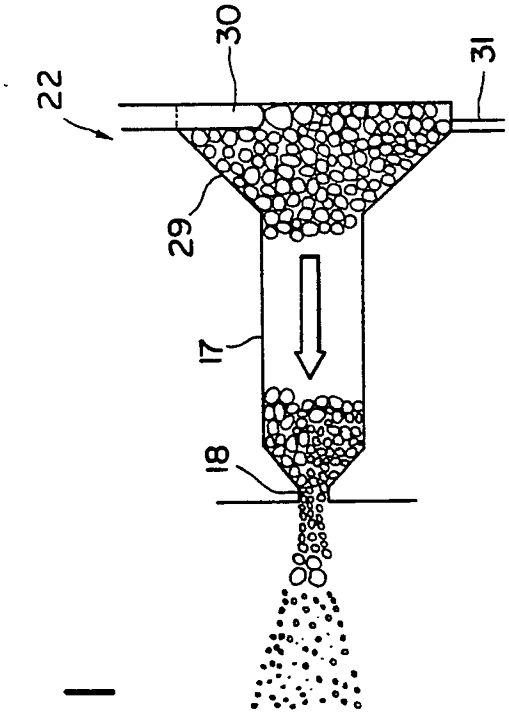


FIG. 11

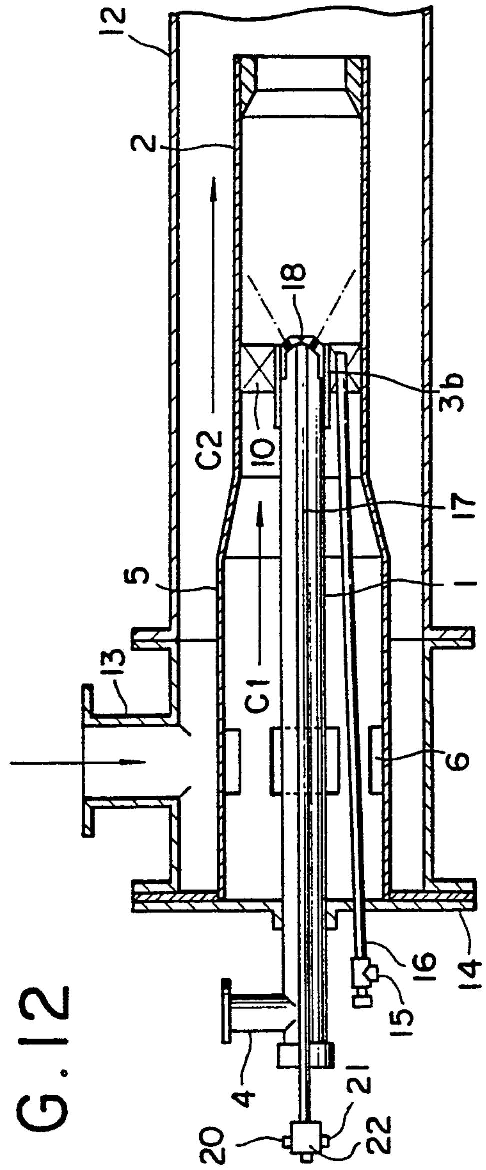


FIG. 12

FIG. 13

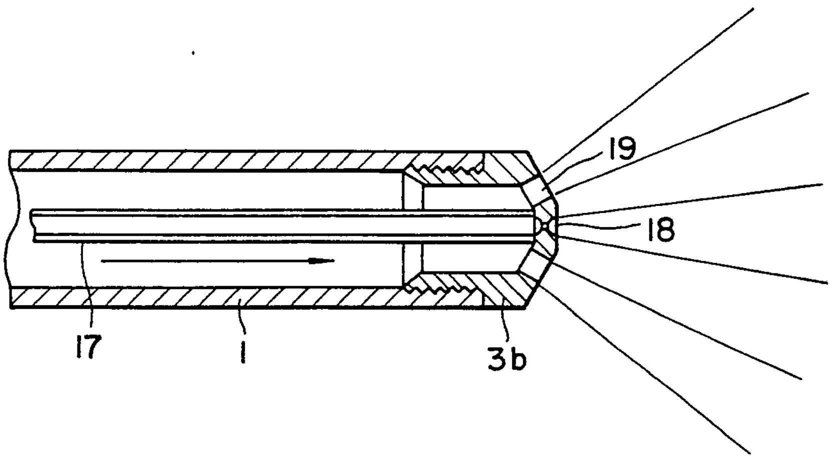


FIG. 14

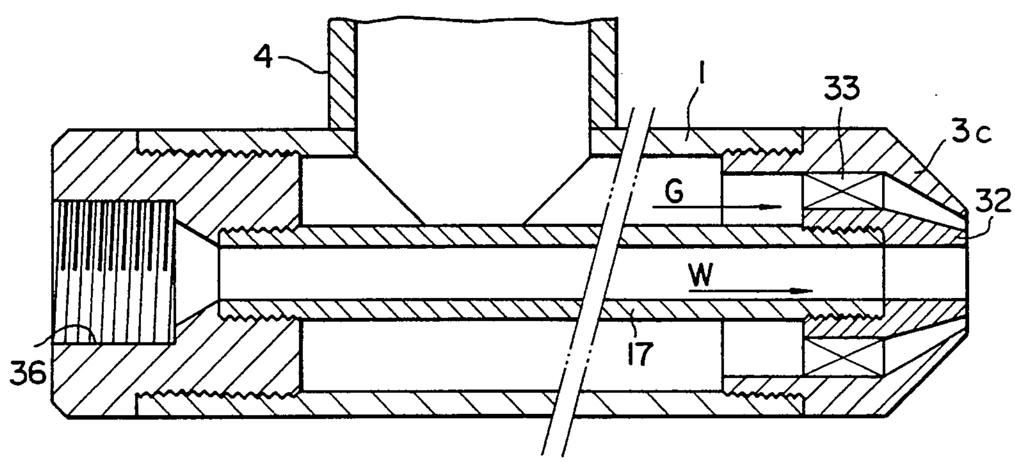


FIG. 15

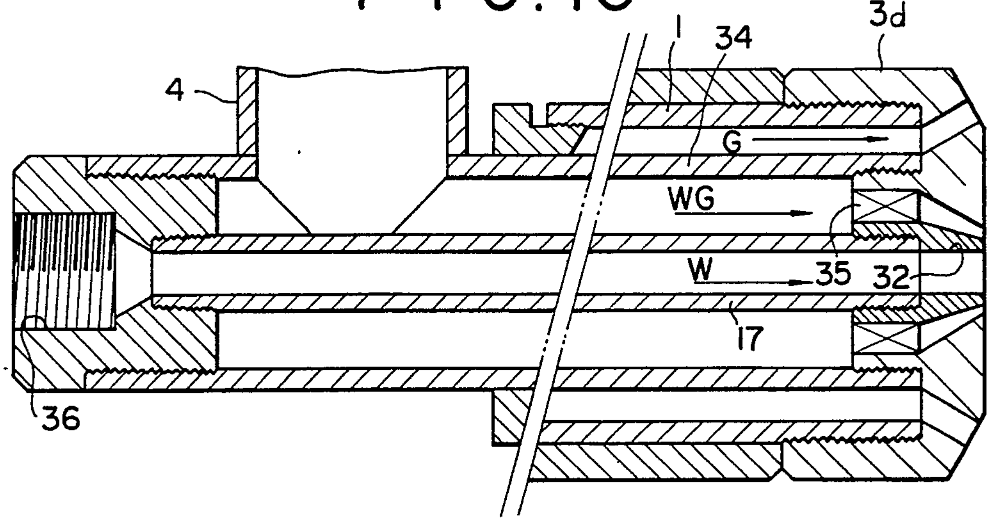


FIG. 16

AMOUNT OF ADDED WATER AND NOx REDUCTION RATE