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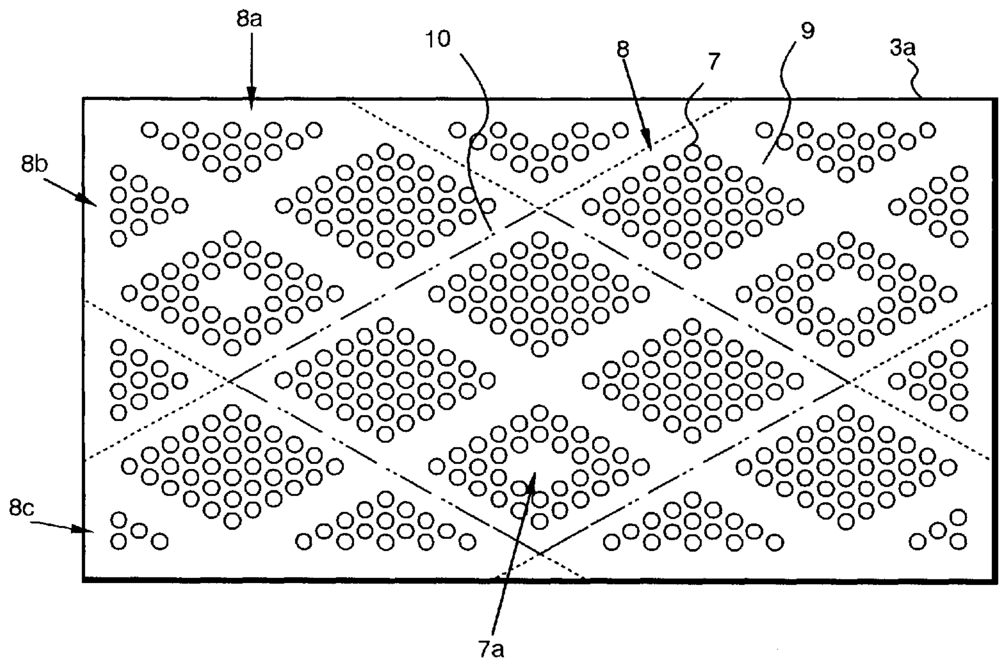
(54) **Burner plate**

(57) A burner plate (3a) is incorporated in a gas burner for burning a mixture of a fuel gas and air added at a predetermined excess air ratio in total primary combustion to heat a heat exchanger. The burner plate comprises a heat-resistant plate having a plurality of burner ports (7) defined therein and extending from a surface of the plate to an opposite surface thereof. The burner ports are divided into a plurality of burner port groups (8) which are spaced from each other by gaps (9). The burner port groups include burner port groups each having in a central area (7a) thereof as many burner ports closed as effective to limit an extension of flames produced from the burner port groups and suppress combustion resonant sounds generated by vibrations of the flames in coaction with a natural frequency of the gas burner.

FIG. 2



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Description

BACKGROUND OF THE INVENTION

Field of the Invention:

[0001] The present invention relates to a burner plate for use in a gas burner, which has a heat exchanger, for burning a fuel gas in total primary combustion.

Description of the Related Art:

[0002] There has heretofore been known a gas burner, which has a heat exchanger, for burning a fuel gas in total primary combustion.

[0003] In such a gas burner, a mixture of the fuel gas and air added at a predetermined excess air ratio is supplied to a burner plate mounted on a gas burner unit and burned in total primary combustion. The burner plate comprises a heat-resistant plate of ceramics or the like which has a number of burner ports defined therein and extending from a surface of the plate to the opposite surface thereof. For example, as shown in FIG. 5 of the accompanying drawings, a burner plate 3b has a plurality of burner ports 7 divided into a plurality of lozenge-shaped patterns each having burner ports 7 arranged in six rows and six columns as a burner port group 8. Adjacent lozenged burner port groups 8 are spaced from each other by spaces or gaps 9. With the burner plate 3b shown in FIG. 5, flames formed by the respective burner ports 7 are combined together in each of the burner port groups 8, but are prevented from being spread out of each of the burner port groups 8 by the gaps 9. The burner plate 3b is effective in limiting flames to an appropriate size and stabilizing them without the danger of being lifted off the burner plate 3b and extinguished.

[0004] In the total primary combustion, the excess air ratio represents the ratio of an amount of air to be actually mixed with the fuel gas to a theoretical amount of air, which is assumed to be "1", required for the complete combustion of a given amount of fuel gas. The excess air ratio is indicated as a dimensionless number.

[0005] If the excess air ratio of a mixture supplied to a gas burner designed for total primary combustion is greater than "1", then since air is available in an amount greater than necessary to completely combust the fuel gas, no incomplete combustion should not occur from a theoretical point of view. Actually, however, even when the excess air ratio of a mixture supplied to the burner plate is greater than "1", the fuel gas suffers incomplete combustion, producing carbon monoxide (CO).

[0006] For gas burners for use in water heaters, JIS S 2109 provides that the produced amount of carbon monoxide should not exceed a certain reference level, e.g., 0.28 %. Those gas burners should not produce an amount of carbon monoxide in excess of the prescribed reference level during operation.

[0007] In order for gas burners of different designs to produce respective amounts of carbon monoxide not greater than corresponding prescribed reference levels, a certain range of excess air ratios of a supplied mixture is established for each gas burner design. The range of excess air ratios is represented not by excess air ratios themselves, but by an excess air ratio allowance because the mixture is a dynamic mixture and its excess air ratio tends to vary.

[0008] An excess air ratio allowance for a gas burner is determined when the gas burner is designed. If an excess air ratio allowance is too small, then depending on the supplied mixture, an actual excess air ratio may fall out of the excess air ratio allowance due to individual gas burner fabrication errors. When an actual excess air ratio falls out of the excess air ratio allowance, the gas burner may be liable to produce an undue amount of carbon monoxide. For this reason, the excess air ratio allowance should preferably be as large as possible, and may be set to 0.5 or more, for example.

[0009] For gas burners for use in gas-combusted water heaters equipped with heat exchangers, efforts have been made in recent years to reduce the distance between the burner plate and the heat exchanger for more compact gas burner sizes. However, such compact gas burner configurations are apt to produce an increased amount of carbon monoxide upon full-capacity combustion even if the excess air ratio allowance is set to 0.5 or more.

[0010] The inventors have conducted research activities and found a couple of reasons why carbon monoxide is produced in the total primary combustion even if the excess air ratio is set to a value greater than 1.

[0011] The first reason is that since the mixture is a dynamic mixture, the excess air ratio may become smaller than 1 in local areas, and incomplete combustion may occur in those local areas. However, the phenomenon in which the excess air ratio becomes smaller than 1 in local areas is less intensive as the excess air ratio becomes greater than 1. Therefore, the produced amount of carbon monoxide becomes smaller as the excess air ratio becomes greater than a value near 1.

[0012] The second reason is that if the excess air ratio becomes sufficiently greater than 1, the mixture ejected from the burner ports flows at an increased speed and flames tend to contact fins of the heat exchanger. When the flames contact fins of the heat exchanger, the flames are quickly cooled, interrupting the combustive reaction in the flames.

As a result, the amount of carbon monoxide which is an intermediate product of the combustive reaction increases.

[0013] Consequently, as the excess air ratio becomes greater than 1, the produced amount of carbon monoxide becomes smaller for the first reason described above. When the excess air ratio reaches a certain value, the reduction in the produced amount of carbon monoxide for the first reason and the increase in the produced amount of carbon monoxide for the second reason are brought into equilibrium, whereupon the produced amount of carbon monoxide is minimized. When the excess air ratio exceeds the certain value, the produced amount of carbon monoxide increases for the second reason.

[0014] FIG. 7 of the accompanying drawings shows a dot-and-dash-line curve representing how the produced amount of carbon monoxide varies with the excess air ratio when the mixture is supplied to the burner plate and burned in the total primary combustion.

[0015] It can be seen from the dot-and-dash-line curve shown in FIG. 7 that the plotted amount of carbon monoxide as it varies with the excess air ratio supports the above first and second reasons. Specifically, as the excess air ratio increases from 1 (the measured value is slightly greater than 1), the produced amount of carbon monoxide drops. When the excess air ratio reaches a certain value, the amount of carbon monoxide becomes minimum. As the excess air ratio exceeds the certain value, the produced amount of carbon monoxide increases.

[0016] In FIG. 7, a range of excess air ratios capable of limiting the produced amount of carbon monoxide to or below a certain reference level, e.g., 0.28 %, is indicated by W_1. The range W_1 is represented by the difference between an upper limit for excess air ratios for keeping the produced amount of carbon monoxide to or below the reference level and a lower limit for measurable excess air ratios for keeping the produced amount of carbon monoxide to or below the reference level.

[0017] According to a further consideration based on the above reasons, in the compact gas burner described above, since flames contact the fins of the heat exchanger upon full-capacity combustion, the produced amount of carbon monoxide with respect to each excess air ratio increases. Specifically, the dot-and-dash-line curve is translated upwardly into a two-dot-and-dash-line curve, reducing the range W_1 of excess air ratios to a range W_2 of excess air ratios. If the range of excess air ratios or the excess air ratio allowance is reduced, then depending on the supplied mixture, an actual excess air ratio may fall out of the excess air ratio allowance due to individual gas burner fabrication errors, tending to produce a large amount of carbon monoxide, as described above.

[0018] In order to prevent flames from contacting the fins of the heat exchanger upon full-capacity combustion in the compact gas burner, some of the burner ports 7 of the burner port groups 8 may be closed to reduce flames generated by the burner port groups 8. However, if the number of closed burner ports 7 is increased, then the vibrations of flames caused by the combustive reaction in the flames produced from the open burner ports 7 generate combustion resonant sounds in coaction with the natural frequency of the gas burner.

SUMMARY OF THE INVENTION

[0019] It is therefore an object of the present invention to provide a burner plate which is effective to keep a produced amount of carbon monoxide to or below a reference level and make an excess air ratio allowance as large as possible for preventing combustion resonant sounds from being generated.

[0020] To achieve the above object, there is provided in accordance with the present invention a burner plate for use in a gas burner for burning a mixture of a fuel gas and air added at a predetermined excess air ratio in total primary combustion to heat a heat exchanger, comprising a heat-resistant plate having a plurality of burner ports defined therein and extending from a surface of the plate to an opposite surface thereof, the burner ports divided into a plurality of burner port groups which are spaced from each other by gaps, the burner port groups including burner port groups each having in a central area thereof as many burner ports closed as effective to limit an extension of flames produced from the burner port groups and suppress combustion resonant sounds generated by vibrations of the flames in coaction with a natural frequency of the gas burner.

[0021] In the burner plate according to the present invention, the burner ports are divided into a plurality of burner port groups which are spaced from each other by gaps. Flames ejected from the burner ports are combined together in each of the burner port groups, but are prevented from being spread out of each of the burner port groups by the gaps. The burner plate is effective in limiting flames to an appropriate size for combustion.

[0022] However, when the gas burner burns the mixture for full-capacity combustion, the flames produced by the burner port groups are extended and tend to contact the heat exchanger. Such a tendency is greater at the central areas of the burner port groups. According to the present invention, the burner port groups include burner port groups each having burner ports closed in a central area thereof. As a result, even upon full-capacity combustion of the gas burner, an extension of flames produced from the burner port groups is limited, and hence the flames are prevented from contacting the heat exchanger, for thereby reducing a produced amount of carbon monoxide. Because the closed burner ports are located in the central areas of the certain selected burner port groups, the number of those closed burner ports is limited for thereby preventing combustion resonance sounds from being generated.

[0023] Consequently, it is possible to maintain a wide excess air ratio allowance capable of reducing the produced amount of carbon monoxide and preventing combustion resonance sounds from being generated even when the gas burner is operated for full-capacity combustion.

[0024] Preferably, the closed burner ports are uniformly -distributed over the heat-resistant plate.

[0025] The closed burner ports preferably constitute 2 through 9 % of the total number of the burner ports on the heat-resistant plate. If the closed burner ports were less than 2 % of the total number of the burner ports, then the excess air ratio allowance capable of reducing the produced amount of carbon monoxide would be reduced. If the closed burner ports were in excess of 9 % of the total number of the burner ports, then the excess air ratio allowance capable of preventing combustion resonance sounds from being generated would be reduced.

[0026] Furthermore, the burner port groups are arranged in a plurality of burner port group clusters each comprising a plurality of burner port groups, the burner port group clusters being repeated in a predetermined pattern, each of the burner port group clusters including a predetermined number of burner port groups each having a predetermined number of burner ports closed in a central area thereof. With this arrangement, the closed burner ports can uniformly be distributed over the heat-resistant plate.

[0027] For example, each of the burner port groups may comprise 36 burner ports arranged in six rows and six columns in a lozenge-shaped pattern. Each of the burner port group clusters may comprise four lozenged burner port groups arranged in a similarly lozenge-shaped area larger than the lozenged burner port groups, the burner port group clusters being kept in a repeated arrangement.

[0028] The above and other objects, features, and advantages of the present invention will become apparent from the following description when taken in conjunction with the accompanying drawings which illustrate preferred embodiments of the present invention by way of example.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029]

FIG. 1 is a schematic cross-sectional view of a gas-combusted water heater which incorporates a burner plate according to the present invention in a gas burner;

FIG. 2 is a fragmentary plan view showing a pattern of burner ports and burner port groups for the burner plate according to the present invention;

FIG. 3 is a fragmentary plan view showing another pattern of burner ports and burner port groups for the burner plate according to the present invention;

FIG. 4 is a fragmentary plan view showing still another pattern of burner ports and burner port groups for the burner plate according to the present invention;

FIG. 5 is a fragmentary plan view showing a pattern of burner ports and burner port groups on a conventional burner plate;

FIG. 6 is a fragmentary plan view showing a pattern of burner ports and burner port groups on a burner plate for comparison with the burner plate according to the present invention;

FIG. 7 is a graph showing the manner in which a produced amount of carbon monoxide varies with an excess air ratio;

FIG. 8 is a histogram showing regions of excess air ratios where no combustion resonant sounds are generated; and

FIG. 9 is a graph showing an excess air ratio allowance where a produced amount of carbon monoxide is not greater than a reference level and an excess air ratio allowance where no combustion resonant sounds are generated, with respect to proportions of closed burner ports.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] FIG. 1 shows a gas-combusted water heater 1 which burns a mixture of a fuel gas and air added at a predetermined excess air ratio in total primary combustion. The gas-combusted water heater 1 comprises a gas burner 3 housed in a casing 2 and a heat exchanger 5 also housed in the casing 2 for heating water supplied from a water supply pipe 4 with the gas burner 3 thereby to produce hot water. The hot water produced by the heat exchanger 5 is supplied via a hot water supply pipe 6 to various places including a kitchen, a washroom, a bathroom, etc.

[0031] The gas burner 3 has a burner plate 3a comprising a heat-resistant plate of ceramics such as cordierite or the like which has a number of burner ports 7 defined therein and extending from a surface of the plate to the opposite surface thereof. The gas burner 3 is ignited by an igniting unit (not shown) when a mixture of a fuel gas and air added at a predetermined excess air ratio is supplied to the burner ports 7.

[0032] The burner plate 3a is shown in FIGS. 2 through 4. FIGS. 2 through 4 show respective different patterns of burner ports 7 for the burner plate 3a. FIG. 5 shows a conventional burner plate 3b, and FIG. 6 shows a comparative burner plate 3c.

[0033] The burner plate 3a shown in FIG. 2 has a total of 1269 burner ports 7 each having a diameter of 1.25 mm, defined in a heat-resistance plate having a size of 60 mm x 128 mm. Of the total of 1269 burner ports 7, 2 through 9 % of the burner ports 7 are closed. Two such burner plates 3a are longitudinally juxtaposed to provide a combined burner plate having a size of 60 mm x 256 mm. FIGS. 2 through 6 show portions of the burner plates 3a, 3b, 3c (corresponding to 483 burner ports 7) each having a total of 1269 burner ports 7, for illustrating different patterns of burner ports 7.

[0034] As shown in FIG. 2, the burner ports 7 are divided into a plurality of lozenge-shaped patterns each having 36 burner ports 7 arranged in six rows and six columns as a burner port group 8. In each of the burner port groups 8, the centers of adjacent burner ports 7 are spaced 1.8 mm from each other. Adjacent lozenged burner port groups 8 are spaced from each other by spaces or gaps 9. Four lozenged burner port groups 8 are arranged in a similarly lozenge-shaped area larger than the individual lozenged burner port groups 8, making up a burner port group cluster 10. A burner port pattern of the burner plate 3a is formed by a repeated arrangement of burner port group clusters 10.

[0035] Examples of the burner port pattern where 2 through 9 % of the total of 1269 burner ports 7 are closed will be described below.

[0036] On the burner plate 3a shown in FIG. 2, one of the four lozenged burner port groups 8 of each of the burner port group clusters 10 has four central burner ports 7 closed, providing a closed area 7a. The closed burner port percentage of the burner port group clusters 10 on the burner plate 3a shown in FIG. 2 is calculated according to the equation (1) below. The closed burner port percentage is defined as the proportion of closed burner ports 7 in the total number of burner ports 7 which would otherwise be present if no closed burner ports were present.

$$\begin{aligned}\text{Closed burner port percentage} &= (\text{closed burner ports 7/the total number of burner ports 7}) \times 100 \\ &= (4 \times 1)/(36 \times 4) \times 100 \\ &= 2.78\ (\%) \qquad \cdots (1)\end{aligned}$$

[0037] On the actual burner plate 3a, burner port groups 8a, 8b, 8c positioned in peripheral areas make up portions of the larger lozenge-shaped areas. Each of the burner port groups 8a has 15 burner ports 7, each of the burner port groups 8b has 10 burner ports 7, and each of the burner port groups 8c has 4 burner ports 7. Therefore, the actual closed burner port percentage is different from the closed burner port percentage (designed value) calculated according to the equation (1). Specifically, the actual closed burner port percentage on the burner plate 3a shown in FIG. 2 is expressed by the following equation (2):

$$\begin{aligned}\text{Closed burner port percentage} &= (\text{closed burner ports 7/the total number of burner ports 7}) \times 100 \\ &= (13/483) \times 100 \\ &= 2.69\ (\%) \qquad \cdots (2)\end{aligned}$$

[0038] On the burner plate 3a shown in FIG. 3, two of the four lozenged burner port groups 8, whose vertexes confront each other in the vertical direction, of each of the burner port group clusters 10 each have four central burner ports 7 closed, providing a closed area 7a. The closed burner port percentage of the burner port group clusters 10 on the burner plate 3a shown in FIG. 3 is calculated according to the equation (3) below.

$$\text{Closed burner port percentage} = (\text{closed burner ports 7/the total number of burner ports 7}) \times 100$$
$$= (4 \times 2)/(36 \times 4) \times 100$$
$$= 5.56\ (\%) \qquad \cdots (3)$$

[0039] On the actual burner plate 3a shown in FIG. 3, burner port groups 8a, 8b, 8c positioned in peripheral areas make up portions of the larger lozenge-shaped areas. Therefore, the actual closed burner port percentage is different from the closed burner port percentage (designed value) calculated according to the equation (3). Specifically, the actual closed burner port percentage on the burner plate 3a shown in FIG. 3 is expressed by the following equation (4):

$$\text{Closed burner port percentage} = (\text{closed burner ports 7/the total number of burner ports 7}) \times 100$$
$$= (27/483) \times 100$$
$$= 5.59\ (\%) \qquad \cdots (4)$$

[0040] The burner plate 3a shown in FIG. 3 may be modified such that two of the four lozenged burner port groups 8, whose vertexes confront each other in the horizontal direction, of each of the burner port group clusters 10, or two of the four lozenged burner port groups 8, which are located adjacent to each other across the gap 9, of each of the burner port group clusters 10, may each have four central burner ports 7 closed.

[0041] On the burner plate 3a shown in FIG. 4, three of the four lozenged burner port groups 8 of each of the burner port group clusters 10 each have four central burner ports 7 closed, providing a closed area 7a. The closed burner port percentage of the burner port group clusters 10 on the burner plate 3a shown in FIG. 4 is calculated according to the equation (5) below.

$$\text{Closed burner port percentage} = (\text{closed burner ports 7/the total number of burner ports 7}) \times 100$$
$$= (4 \times 3)/(36 \times 4) \times 100$$
$$= 8.33\ (\%) \qquad \cdots (5)$$

[0042] On the actual burner plate 3a shown in FIG. 4, burner port groups 8a, 8b, 8c positioned in peripheral areas make up portions of the larger lozenge-shaped areas. Therefore, the actual closed burner port percentage is different from the closed burner port percentage (designed value) calculated according to the equation (5). Specifically, the actual closed burner port percentage on the burner plate 3a shown in FIG. 4 is expressed by the following equation (6):

$$\text{Closed burner port percentage} = (\text{closed burner ports 7/the total number of burner ports 7}) \times 100$$
$$= (32/483) \times 100$$
$$= 6.63\ (\%) \qquad \cdots (6)$$

[0043] The burner plate 3a shown in FIG. 4 may be modified such that any desired three of the four lozenged burner port groups 8 of each of the burner port group clusters 10 may each have four central burner ports 7 closed.

[0044] Other examples in which less than 2 % or more than 9 % of the total number of burner ports 7 are closed will be described below.

[0045] On the conventional burner plate 3b shown in FIG. 5, the four lozenged burner port groups 8 of each of the burner port group clusters 10 do not have any burner ports 7 closed, and hence do not provide any closed area 7a. Accordingly, the closed burner port percentage which is defined as the proportion of closed burner ports 7 in the total number of burner ports 7 which would otherwise be present if no closed burner ports were present is 0 % in terms of both designed and actual values.

[0046] On the comparative burner plate 3c shown in FIG. 6, all of the four lozenged burner port groups 8 of each of the burner port group clusters 10 each have four central burner ports 7 closed, providing a closed area 7a. The closed burner port percentage of the burner port group clusters 10 on the burner plate 3c shown in FIG. 6 is calculated according to the equation (7) below.

$$\text{Closed burner port percentage} = (\text{closed burner ports 7}/\text{the total number of burner ports 7}) \times 100$$
$$= (4 \times 4)/(36 \times 4) \times 100$$
$$= 11.11\ (\%) \quad \cdots (7)$$

[0047] On the actual burner plate 3c shown in FIG. 6, burner port groups 8a, 8b, 8c positioned in peripheral areas make up portions of the larger lozenge-shaped areas. Therefore, the actual closed burner port percentage is different from the closed burner port percentage (designed value) calculated according to the equation (7). Specifically, the actual closed burner port percentage on the burner plate 3c shown in FIG. 6 is expressed by the following equation (8):

$$\text{Closed burner port percentage} = (\text{closed burner ports 7}/\text{the total number of burner ports 7}) \times 100$$
$$= (45/483) \times 100$$
$$= 9.32\ (\%) \quad \cdots (8)$$

[0048] The closed burner port percentages, in terms of both designed and actual values, of the burner plates 3a, 3b, 3c shown in FIGS. 2 through 6 are shown in Table 1 below.

Table 1

		Closed burner port percentage	
		Designed value	Actual value
Conventional Ex.	FIG. 5	0	0
Inventive Ex.	FIG. 2	2.78	2.69
Inventive Ex.	FIG. 3	5.56	5.59
Inventive Ex.	FIG. 4	8.33	6.63
Comparative Ex.	FIG. 6	11.11	9.32

[0049] As described above, the actual values of the closed burner port percentages of the burner plates 3a, 3b, 3c are different from the designed values thereof. Other types of burner plates also have actual values of the closed burner port percentages. However, a study of Table 1 indicates that there are no significant differences between the designed values and the actual values. Therefore, no problem occurs in carrying out the present invention no matter which of the designed values and the actual values may be employed. For the sake of brevity, the closed burner port percentages will hereinafter be described in terms of the designed values.

[0050] Experiments conducted on the burner plates 3a, 3b, 3c shown in FIGS. 3, 5, 6 will be described below.

[0051] The burner plate 3a shown in FIG. 3 was installed in the gas-combusted water heater 1 shown in FIG. 1, and a mixture of a fuel gas and air was supplied to the burner plate 3a for achieving a maximum level of combustion (input: 29.3 kw). The excess air ratio of the mixture was varied, the produced amount of carbon monoxide (%) with respect to the different excess air ratios was measured.

[0052] The measured amounts of carbon monoxide (%) relative to the burner plate 3a shown in FIG. 3 (the closed burner port percentage: 5.56 %) are shown in Table 2 below.

Table 2

Excess air ratio	Produced amount of CO (%)	CO increased or reduced
1.043 (lower limit)	0.2095	reduced
1.063	0.1408	reduced
1.098	0.0794	reduced
1.148	0.0477	reduced
1.177	0.0359	reduced
1.230	0.0242	reduced
1.270	0.0185	reduced
1.318	0.0139	reduced
1.365	0.0111	minimum
1.406	0.0112	increased
1.456	0.0191	increased
1.516	0.0552	increased
1.580 (upper limit)	0.2800	reference level

[0053] The burner plate 3b shown in FIG. 5 was installed in the gas-combusted water heater 1 shown in FIG. 1, and when the excess air ratio of the mixture was varied in the same manner as with the burner plate 3a shown in FIG. 3, the produced amount of carbon monoxide (%) with respect to the different excess air ratios was measured.

[0054] The measured amounts of carbon monoxide (%) relative to the burner plate 3b shown in FIG. 5 (the closed burner port percentage: 0 %) are shown in Table 3 below.

Table 3

Excess air ratio	Produced amount of CO (%)	CO increased or reduced
1.075 (lower limit)	0.1354	reduced
1.095	0.0951	reduced
1.176	0.0412	reduced
1.284	0.0214	reduced
1.351	0.0189	minimum
1.410	0.0381	increased
1.450	0.0647	increased
1.490 (upper limit)	0.2800	reference level

[0055] The burner plate 3c shown in FIG. 6 was installed in the gas-combusted water heater 1 shown in FIG. 1, and when the excess air ratio of the mixture was varied in the same manner as with the burner plate 3a shown in FIG. 3, the produced amount of carbon monoxide (%) with respect to the different excess air ratios was measured.

[0056] The measured amounts of carbon monoxide (%) relative to the burner plate 3c shown in FIG. 6 (the closed burner port percentage: 11.11 %) are shown in Table 4 below.

Table 4

Excess air ratio	Produced amount of CO (%)	CO increased or reduced
1.037 (lower limit)	0.3332	reduced
1.041	0.2531	reduced
1.049	0.1897	reduced
1.054	0.1675	reduced
1.078	0.1075	reduced
1.120	0.0646	reduced
1.169	0.0403	reduced
1.220	0.0270	reduced
1.270	0.0187	reduced
1.310	0.0144	reduced
1.345	0.0116	reduced
1.394	0.0091	minimum
1.438	0.0094	increased
1.483	0.0132	increased
1.529	0.0354	increased
1.630 (upper limit)	0.2800	reference level

[0057] The results given in Tables 2 through 4 are shown in FIG. 7. As can be understood from Tables 2 through 4 and FIG. 7, as the excess air ratio increases from a value a bit higher than 1.0, which is a measurable level, the produced amount of carbon monoxide first tends to decrease. The produced amount of carbon monoxide reaches a minimum level when the excess air ratio is in the range from 1.30 to 1.40, and subsequently increases as the excess air ratio increases.

[0058] The lower limit of the excess air ratio for complete combustion is theoretically of 1.0, but actually of a value slightly higher than 1.0. The actual lower limit of the excess air ratio varies with the closed burner port percentages of the burner plates 3a, 3b, 3c. After having reached the minimum level, the produced amount of carbon monoxide increases as the excess air ratio increases. This is because as the excess air ratio increases, the flames are extended into contact with the fins of the heat exchanger 5 shown in FIG. 1, producing carbon monoxide.

[0059] Then, an upper limit for the excess air ratio was determined from Tables 2 through 4. The upper limit was set to a value of the excess air ratio at the time the produced amount of carbon monoxide reached a predetermined reference level of 0.28 %, for example, after it had been increased from the minimum level. Then, the lower limit was subtracted from the upper limit to determine an excess air ratio allowance with which the produced amount of carbon monoxide was not greater than the reference level. As a result, an excess air ratio allowance of 0.54 was determined with respect to the burner plate 3a shown in FIG. 3, whose closed burner port percentage was 5.56 %. Furthermore, an excess air ratio allowance of 0.42 was determined with respect to the burner plate 3b shown in FIG. 5, whose closed burner port percentage was 0 %, and an excess air ratio allowance of 0.59 was determined with respect to the burner plate 3c shown in FIG. 6, whose closed burner port percentage was 11.11 %.

[0060] Then, excess air ratio allowances with which the produced amount of carbon monoxide was not greater than the reference level were determined with respect to the burner plates 3a shown in FIGS. 2 and 4, whose closed burner port percentages were 2.78 % and 8.33 %, respectively, according to the same process as described above. The relationship between the closed burner port percentages and the excess air ratio allowances with respect to the burner plates 3a, 3b, 3c shown in FIGS. 2 through 6 is shown in Table 5 below.

Table 5

	Closed burner port percentage (%)	Excess air ratio allowance
FIG. 5	0	0.42
FIG. 2	2.78	0.51
FIG. 3	5.56	0.54
FIG. 4	8.33	0.57
FIG. 6	11.11	0.59

[0061] As is clear from Table 5, within a range where the produced amount of carbon monoxide is not greater than the reference level, the excess air ratio allowance is 0.5 or greater when the closed burner port percentage is 2.78 % or greater. As the closed burner port percentage increases, the excess air ratio allowance becomes greater.

[0062] The excess air ratio allowance should preferably be 0.5 or greater so as to prevent a large amount of carbon monoxide from being generated when the excess air ratio allowance suffers large variations due to individual gas burner product variations.

[0063] The burner plates 3a, 3b, 3c shown respectively in FIGS. 3, 5, 6 were installed in the gas burner 3 of the gas-combusted water heater 1 shown in FIG. 1, and a mixture of a fuel gas and air was supplied so as to accomplish a maximum level of combustion (input: 29.3 kw). At this time, the excess air ratio of the mixture was varied to check whether combustion resonant sounds were produced due to the combustion of mixtures having respective excess air ratios. Upper and lower limits for the excess air ratio with which no combustion resonant sounds are produced were determined. The determined upper and lower limits are shown in Table 6 and FIG. 8.

Table 6

	Closed burner port percentage (%)	Excess air ratio	
		Upper limit	Lower limit
FIG. 5	0	1.620	1.050
FIG. 3	5.56	1.615	1.055
FIG. 6	11.11	1.400	1.100

[0064] A review of Table 6 indicates that the upper limit for the excess air ratio with which no combustion resonant sounds are produced is lowered as the closed burner port percentage becomes greater. The lower limit for the excess air ratio with which combustion resonant sounds are produced tends to increase as the closed burner port percentage becomes greater.

[0065] FIG. 8 is a histogram showing excess air ratio allowances where no combustion resonant sounds are generated at respective closed burner port percentages, the excess air ratio allowances being represented as regions between the upper and lower limits for the excess air ratio as shown in Table 6. It will be understood from FIG. 8 that the excess air ratio allowance where no combustion resonant sounds are generated is reduced as the closed burner port percentage is increased.

[0066] In Table 6, the lower limits were subtracted from the upper limits to determine excess air ratio allowances where no combustion resonant sounds are generated. As a result, the excess air ratio allowance of 0.56 was calculated for the burner plate 3a shown in FIG. 3 whose closed burner port percentage is 5.56 %. The excess air ratio allowance of 0.57 was calculated for the burner plate 3b shown in FIG. 5 whose closed burner port percentage is 0 %. The excess air ratio allowance of 0.30 was calculated for the burner plate 3c shown in FIG. 6 whose closed burner port percentage is 11.11 %.

[0067] Excess air ratio allowances where no combustion resonant sounds are generated were similarly calculated for the burner plates 3a shown in FIGS. 2 and 4 whose closed burner port percentages are 2.78 % and 8.33 %, respectively. The relationship between the closed burner port percentages and the excess air ratio allowances with respect to the burner plates 3a, 3b, 3c shown in FIGS. 2 through 6 is shown in Table 7 below.

Table 7

	Closed burner port percentage (%)	Excess air ratio allowance
FIG. 5	0	0.57

Table 7 (continued)

	Closed burner port percentage (%)	Excess air ratio allowance
FIG. 2	2.78	0.57
FIG. 3	5.56	0.56
FIG. 4	8.33	0.51
FIG. 6	11.11	0.30

[0068] As is clear from Table 7, insofar as no combustion resonant sounds are generated, the excess air ratio is reduced as the closed burner port percentage is increased. The excess air ratio allowance is less than 0.5 when the closed burner port percentage is 11.11 %. For this reason, the excess air ratio allowance should preferably be set to 0.5 or more.

[0069] The results shown in Tables 5 and 7 are shown in FIG. 9. It can be seen from FIG. 9 that when the closed burner port percentage is in the range of from 2 to 9 %, the produced amount of carbon monoxide is kept to or below the reference level, no combustion resonant sounds are generated, and the excess air ratio allowance is 0.5 or higher.

[0070] A study of FIG. 9 indicates that when the closed burner port percentage is less than 2 %, the excess air ratio allowance where the produced amount of carbon monoxide is kept to or below the reference level is less than 0.5, and that when the closed burner port percentage exceeds 9 %, the excess air ratio allowance where no combustion resonant sounds are generated is less than 0.5.

[0071] In the illustrated embodiment, a plurality of burner ports 7 on each of the burner plates 3a are arranged into a lozenge burner port group 8. However, a plurality of burner ports 7 may be grouped into any of various shapes including a square shape, an elongate rectangular shape, a circular shape, etc.

[0072] Although certain preferred embodiments of the present invention has been shown and described in detail, it should be understood that various changes and modifications may be made therein without departing from the scope of the appended claims.

Claims

1. A burner plate for use in a gas burner for burning a mixture of a fuel gas and air added at a predetermined excess air ratio in total primary combustion to heat a heat exchanger, comprising:

    a heat-resistant plate having a plurality of burner ports defined therein and extending from a surface of the plate to an opposite surface thereof, said burner ports divided into a plurality of burner port groups which are spaced from each other by gaps, said burner port groups including burner port groups each having in a central area thereof as many burner ports closed as effective to limit an extension of flames produced from said burner port groups and suppress combustion resonant sounds generated by vibrations of the flames in coaction with a natural frequency of the gas burner.

2. A burner plate according to claim 1, wherein the closed burner ports are uniformly distributed over said heat-resistant plate.

3. A burner plate according to claim 1, wherein the closed burner ports constitute 2 through 9 % of the total number of the burner ports on said heat-resistant plate.

4. A burner plate according to claim 1, wherein said burner port groups are arranged in a plurality of burner port group clusters each comprising a plurality of burner port groups, said burner port group clusters being repeated in a predetermined pattern, each of said burner port group clusters including a predetermined number of burner port groups each having a predetermined number of burner ports closed in a central area thereof.

5. A burner plate according to claim 4, wherein each of said burner port groups comprises 36 burner ports arranged in six rows and six columns in a lozenge-shaped pattern, each of said burner port group clusters comprising four lozenged burner port groups arranged in a similarly lozenge-shaped area larger than the lozenged burner port groups, said burner port group clusters being kept in a repeated arrangement.

FIG.1

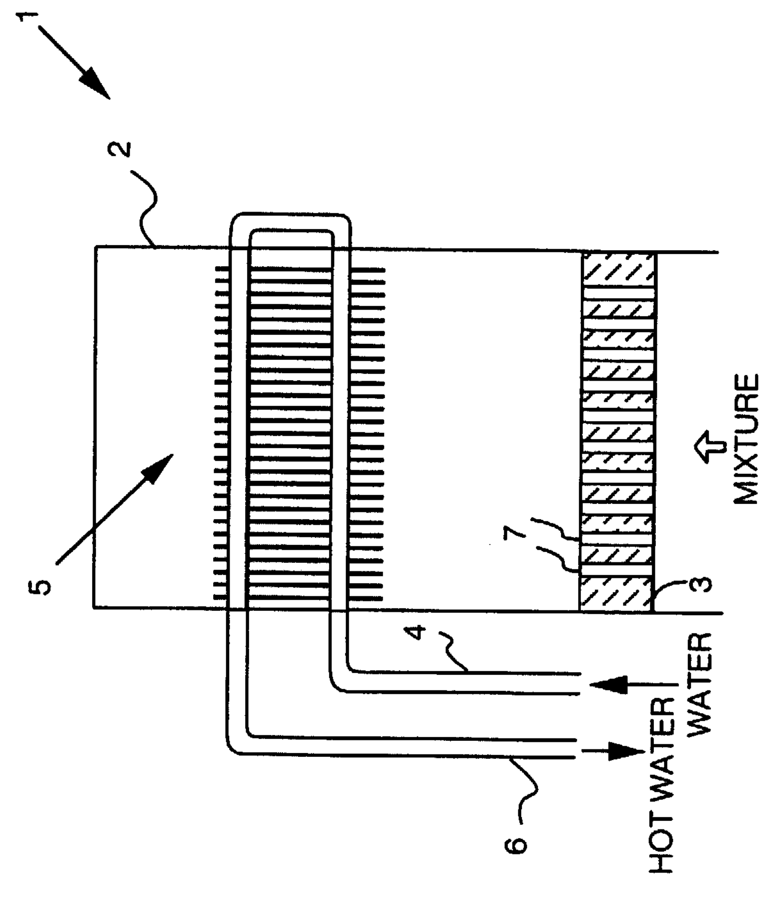


FIG. 2

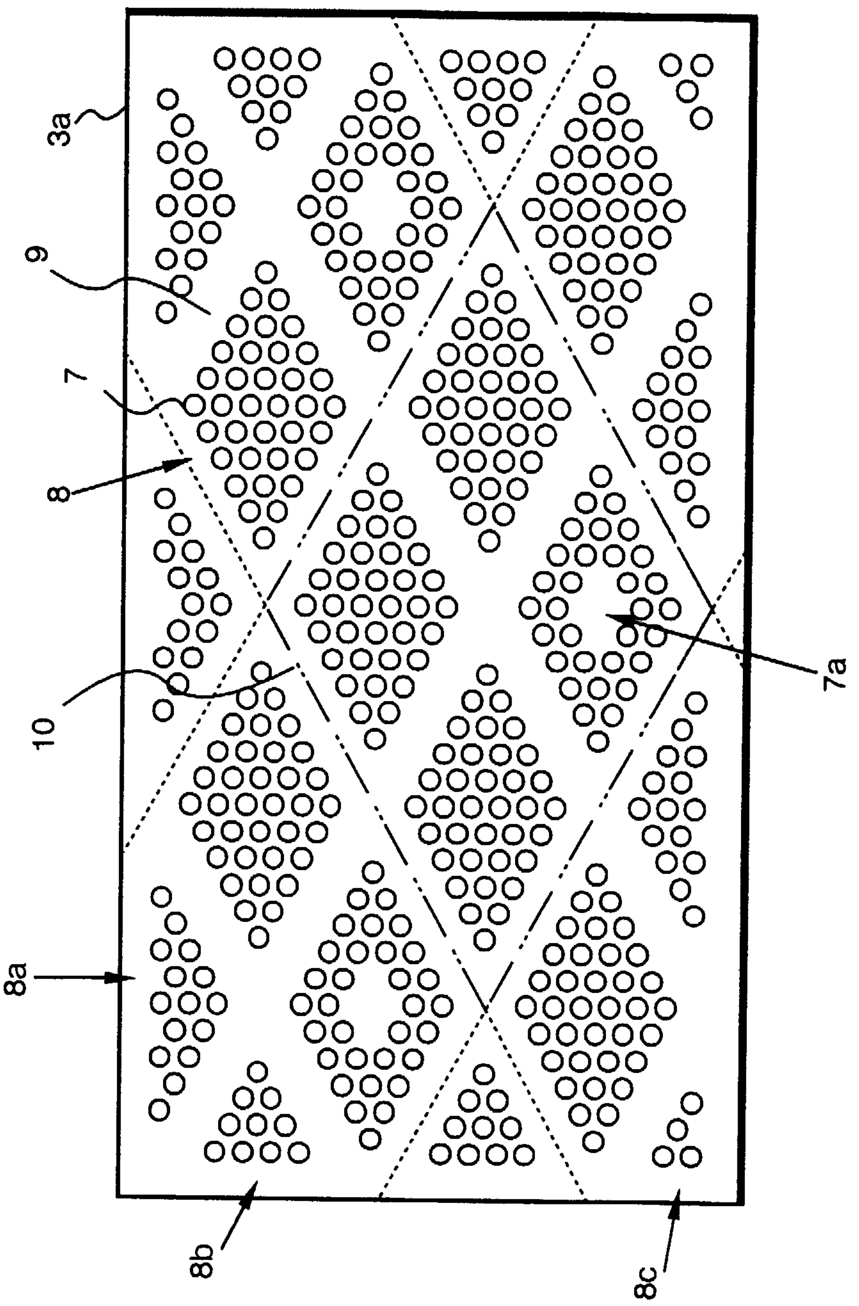


FIG. 3

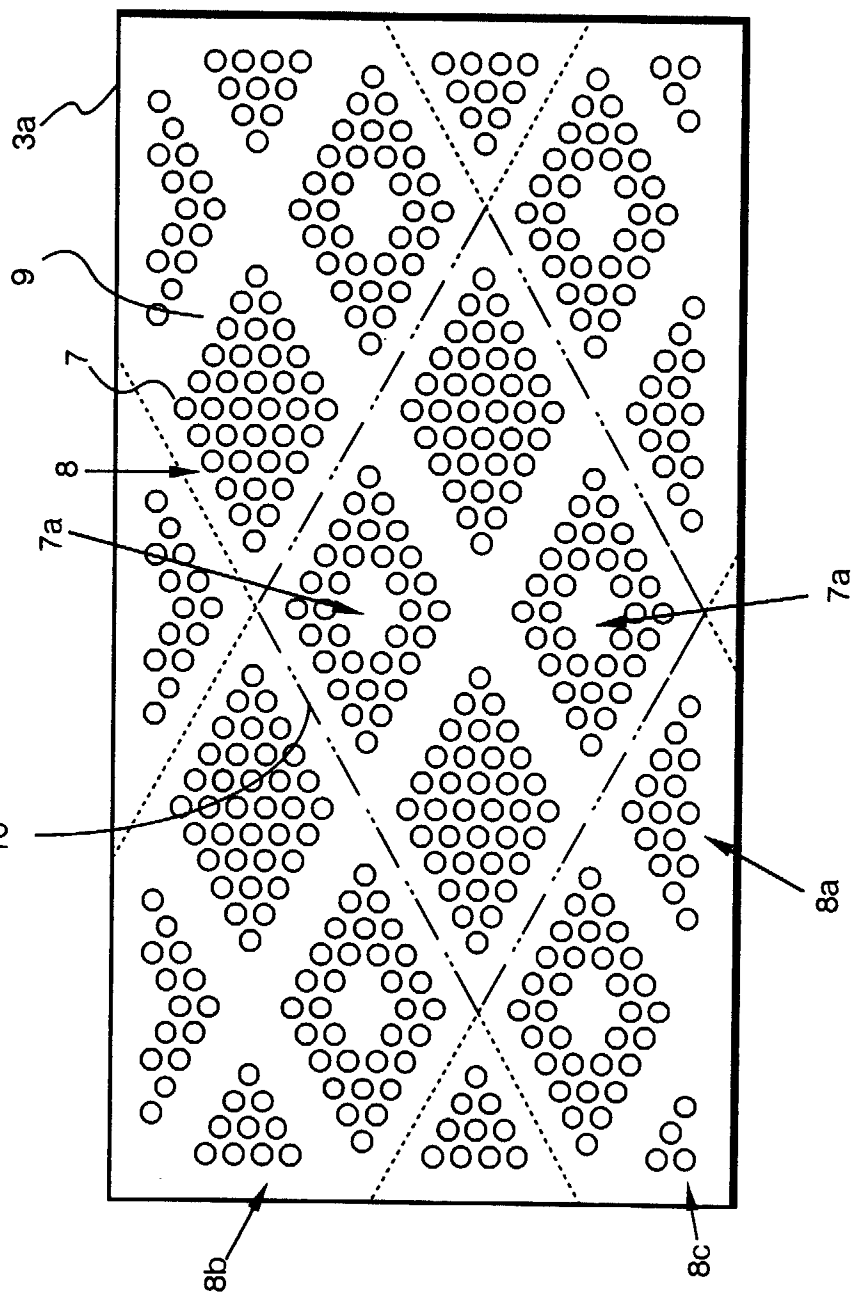


FIG. 4

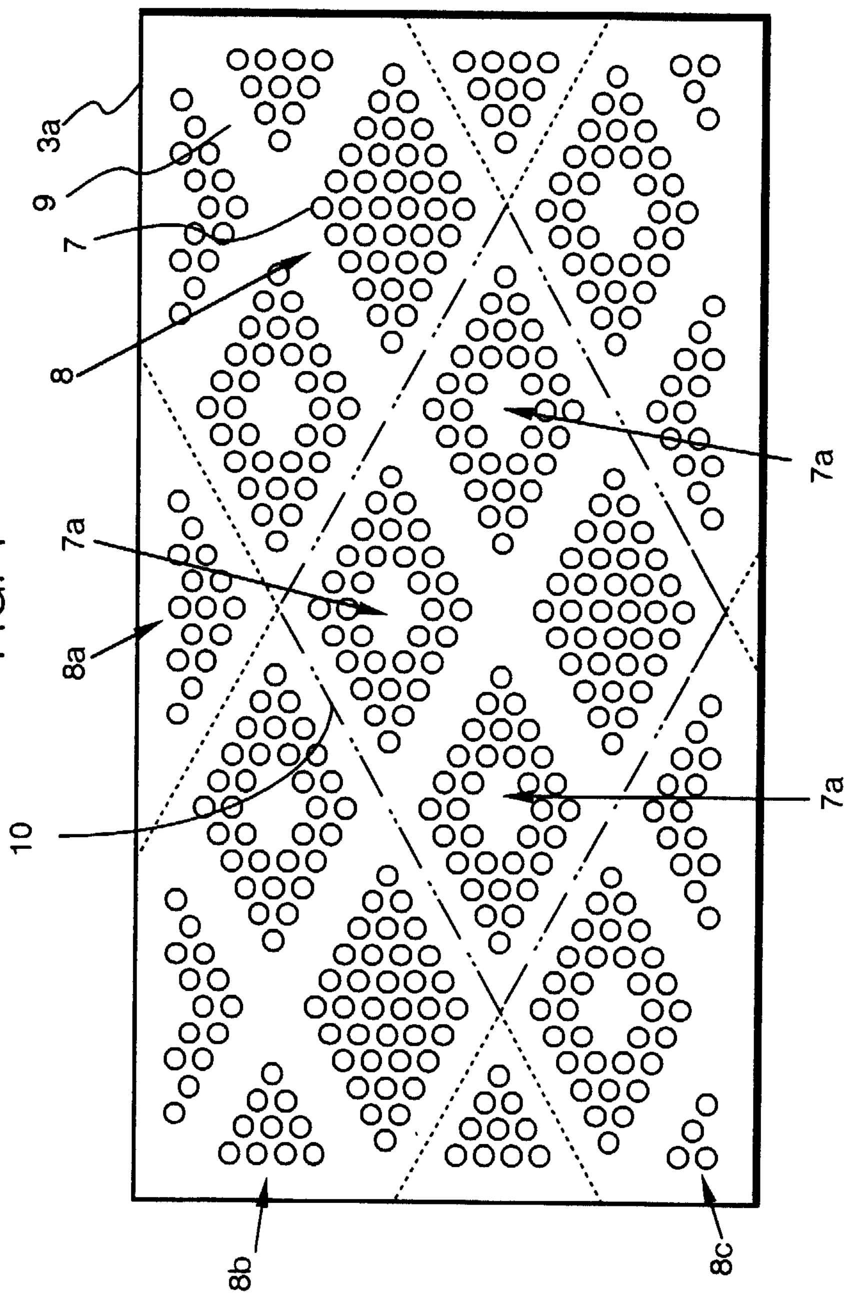


FIG. 5

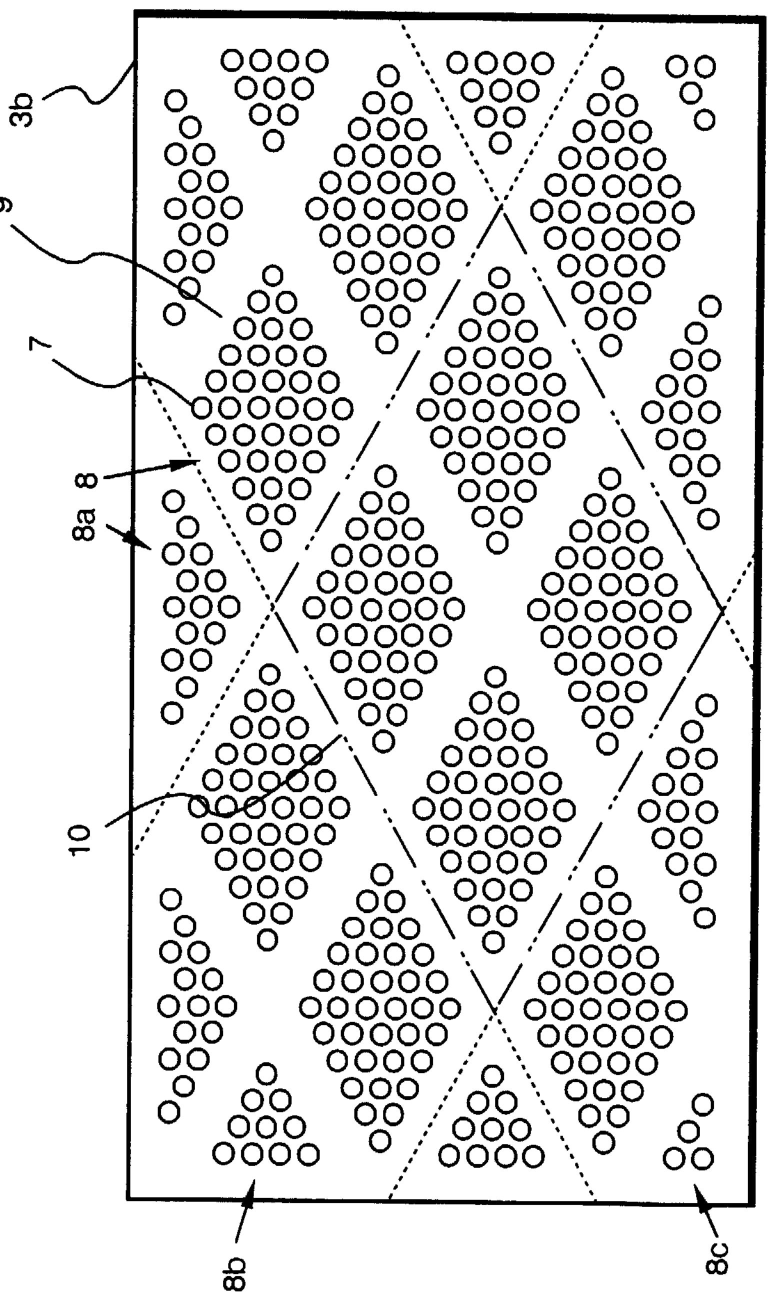


FIG. 6

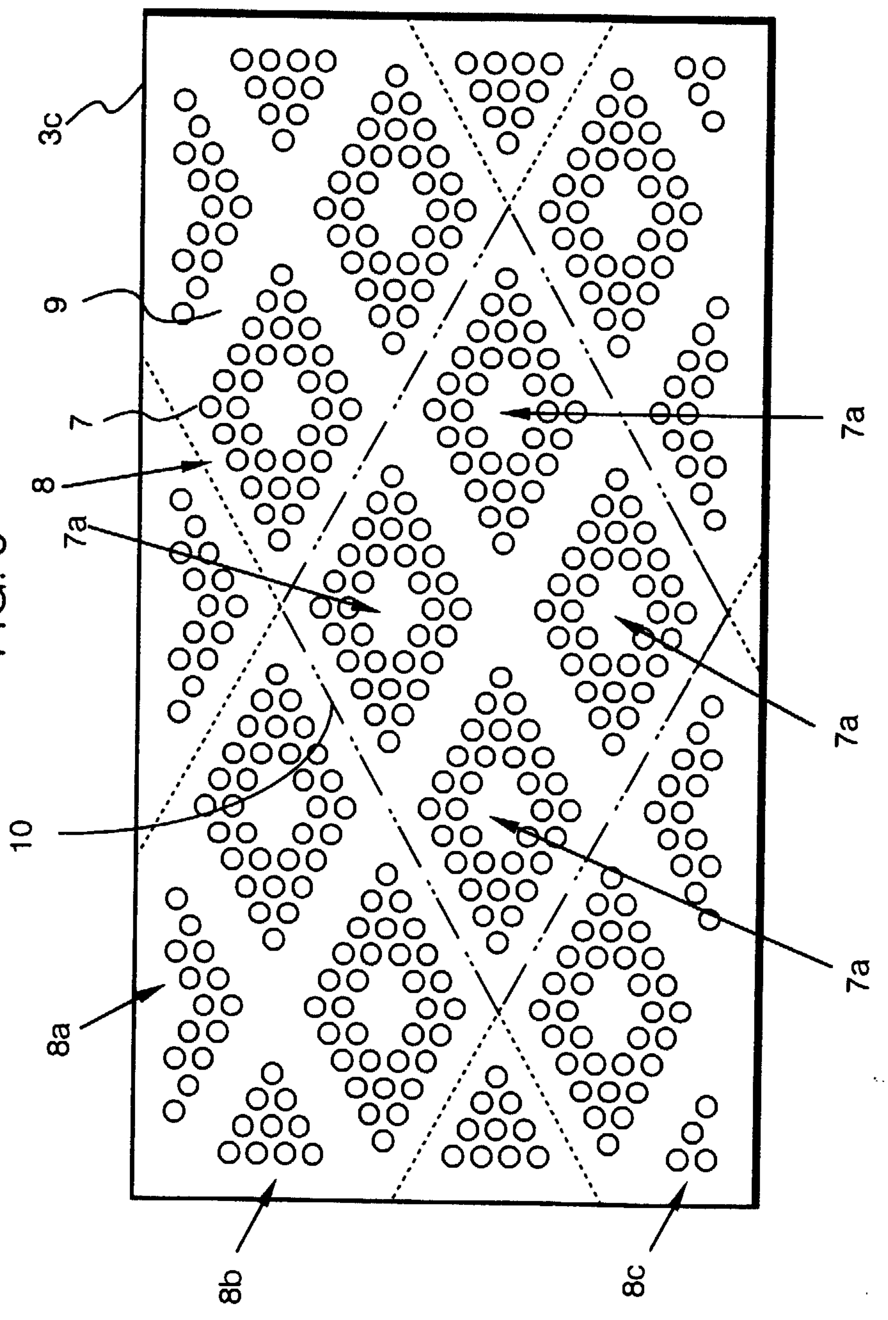
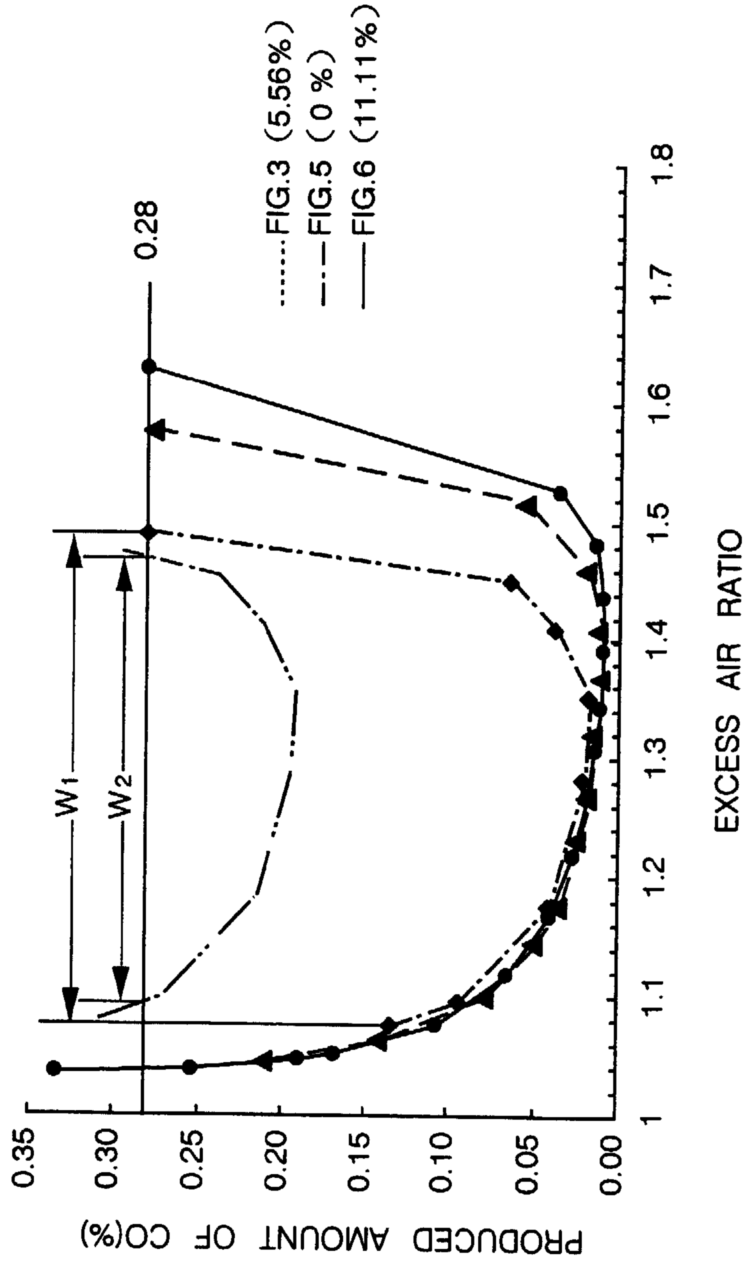


FIG.7



0.28
W1
W2
FIG.3 (5.56%)
FIG.5 (0 %)
FIG.6 (11.11%)
PRODUCED AMOUNT OF CO(%)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
EXCESS AIR RATIO

FIG. 8

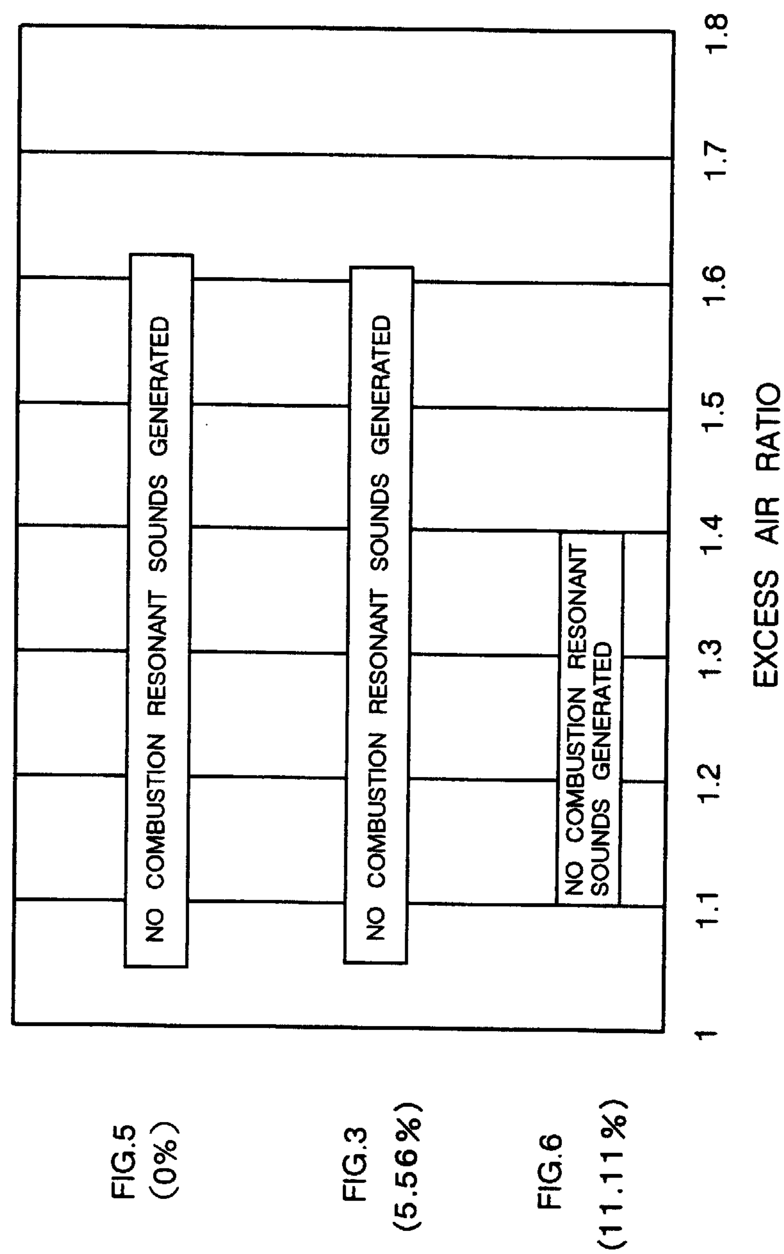
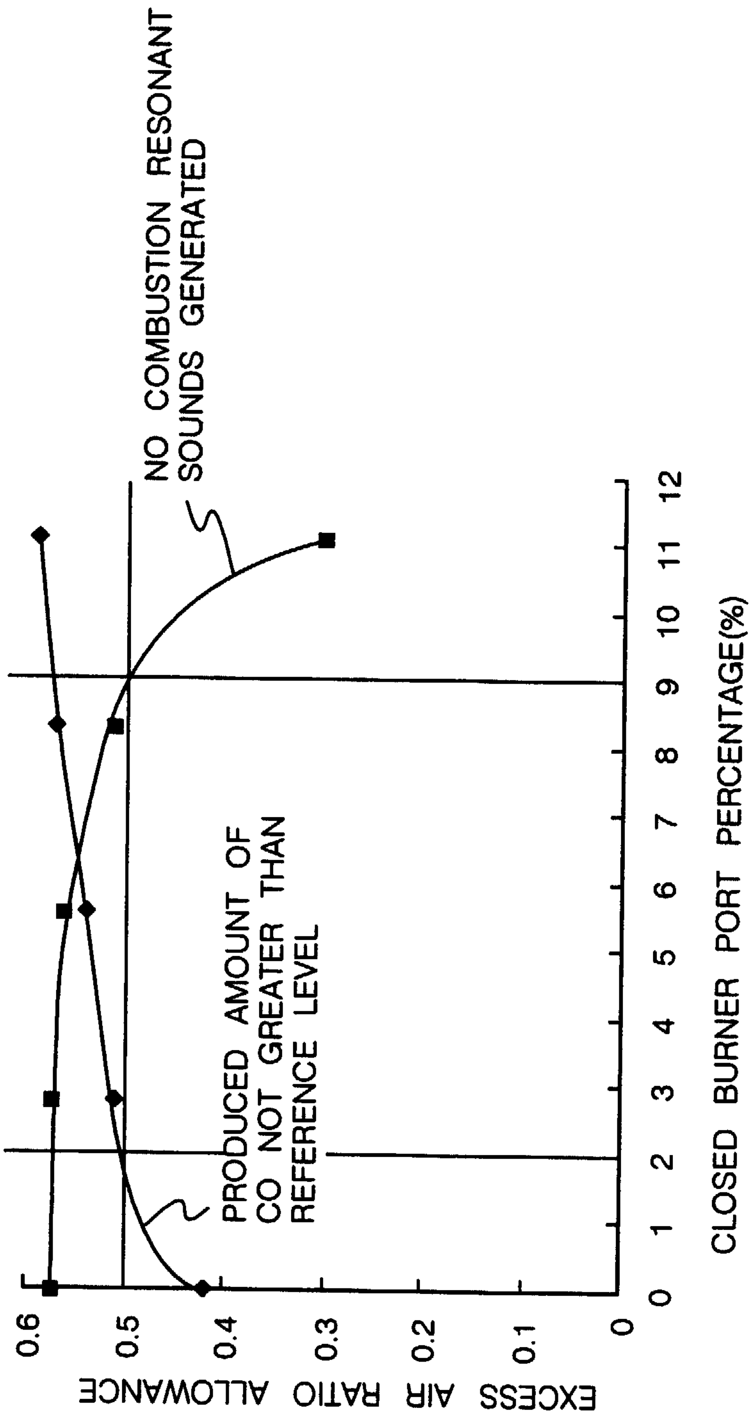


FIG.5 (0%)
FIG.3 (5.56%)
FIG.6 (11.11%)
NO COMBUSTION RESONANT SOUNDS GENERATED
NO COMBUSTION RESONANT SOUNDS GENERATED
NO COMBUSTION RESONANT SOUNDS GENERATED
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
EXCESS AIR RATIO

FIG.9


NO COMBUSTION RESONANT
SOUNDS GENERATED
PRODUCED AMOUNT OF
CO NOT GREATER THAN
REFERENCE LEVEL
EXCESS AIR RATIO ALLOWANCE
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10 11 12
CLOSED BURNER PORT PERCENTAGE(%)