(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) EP 2 372 243 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
12.09.2018 Bulletin 2018/37

(21) Application number: **09834800.6**

(22) Date of filing: **18.12.2009**

(51) Int Cl.:
F23G 7/08 (2006.01) ***F23M 20/00*** (2014.01)

(86) International application number:
PCT/JP2009/071156

(87) International publication number:
WO 2010/073999 (01.07.2010 Gazette 2010/26)

(54) **GROUND FLARE**

BODENFACKEL

TORCHE EN MILIEU CLOS

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR

(30) Priority: **26.12.2008 JP 2008335055**

(43) Date of publication of application:
05.10.2011 Bulletin 2011/40

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Printed by Jouve, 75001 PARIS (FR)

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Description

Technical Field

[0001] The present invention relates to a ground flare for use in burning a flammable exhaust gas.

Background Art

[0002] Conventionally, processing apparatuses that burn a flammable gas are roughly classified into three types: incinerators, open flare stacks, and ground flare stacks (ground flares).

[0003] An example of a flammable gas to be burned by such processing apparatuses is a gas generated by gasifying coal in an integrated coal gasification combined cycle (IGCC) at the initial activation of the plant, which is a flammable exhaust gas unsuitable for gas turbine fuel. The integrated coal gasification combined cycle is a cycle for generating electricity by gasifying coal serving as a fuel to operate a gas turbine and using the driving force of the gas turbine and exhaust heat from the gas turbine.

[0004] An incinerator (see Fig. 24) is an apparatus that burns a flammable gas with an air blower 2 provided for an incinerator main body 1 formed of a refractory material or the like. In this case, there are problems in that the cost of the refractory material that forms the incinerator main body 1 and the cost of the air blower 2 are high. Reference sign 3 in the drawing denotes a burner, and 4 denotes a chimney.

[0005] An open flare stack (see Fig. 25) is an apparatus that jets fuel into the atmosphere and burns a flammable gas with an ignition device. A fuel exhaust port is generally disposed at a higher position of a flare stack main body 5. Because air for combustion is supplied by natural aspiration from the surroundings, no air blower is needed, and thus, the cost is low. However, flames are exposed, and thus, the problems of occurrence of fire due to radiating the surroundings, noise due to the combustion sound of the flames, and lack of visual harmony due to the fact that the flames can be viewed have been noted.

[0006] As shown in Fig. 26, a ground flare 6 has a configuration such that the lower end of a chimney 7 is open, and one or a plurality of burners 8 for burning a flammable gas are disposed at the lower end of the chimney 7. Since this case needs the chimney 7 and a windbreak 9, the cost is higher than that of the open flare stack. However, the ground flare 6 has the merits that flames are not visible from the outside because they are surrounded by the windbreak 9 and that combustion noise is reduced owing to the chimney.

[0007] An example of the related art for reducing noise due to the chimney has a sound absorbing member at a position in the chimney. (For example, see JP 58-2331 A)

Furthermore, for the ground flare stack, a configuration in which a noise shielding member surrounding a combustion chamber is disposed so as to absorb sound of an air flow introduced to the combustion chamber is disclosed. (For example, see JP 54-45838 A)

[0008] Furthermore, a noise canceling apparatus that reduces noise by canceling noise generated in a flue through which a combustion gas is forcedly exhausted by dynamic noise reduction is disclosed. (For example, see JP 2629410 B)

[0009] US 4137036 B discloses a flare burner with a central combustion chamber that is open at the top for discharging combustion products and is elevated and opened at the bottom for entrance of air for combustion. An acoustical and wind shielding fence is provided outside the bottom of the central combustion chamber over which air passes to enter the bottom of the chamber. The acoustical and wind shielding fence is made from metal and is provided with a lining provided so as to surround and cover the entire peripheral surface of the cylindrical acoustical fence. This acoustical fence is stated to be effective for preventing transmission to the outside of the low-frequency noise attendant on the combustion and of the higher frequency noise attendant on the entry of the gas and air for combustion.

Summary of Invention

Technical Problem

[0010] The conventional ground flare 6 described above has a problem in that surrounding objects resonate and vibrate due to a low-frequency vibration generated from the chimney 7. Conventional measures against the low-frequency vibration in the ground flare 6 are reducing the amount of air to increase the length of flames, changing the flow rate of the burners, and changing the number of burners. However, such conventional low-frequency-vibration control measures have problems in that the amount of unburned gas is increased due to deterioration in combustibility and flames blowing out from the top of the stack due to the increase in the length of the flames.

[0011] Furthermore, a measure for reducing the generated sound pressure by disposing the plurality of burners 8 at different levels to make the flame surfaces, which are vibration sources, nonuniform has a problem in that a burner 8 disposed at a higher position comes into contact with the flames of a lower burner and is damaged.

[0012] Other methods include a method of limiting the chemical heat energy of a gas processed by the ground flare 6 and a method of operating the ground flare 6 only in the daytime, when the noise standards are lax; however, both of them are uneconomical because they limit the operation of the plant.

[0013] Given this background, it is desirable to suppress an increase in the sound pressure level of low-frequency noise and to reduce a low-frequency vibration generated from the ground flare by preventing the resonance of the low-frequency vibration of the ground flare tower and the natural frequency of burner combustion and/or by converting vibrational energy to thermal energy, thereby controlling the low-frequency vibration such that it is below a vibration generation limit for fixtures.

[0014] The present invention is made in consideration of the circumstances described above, and an object thereof is to provide a ground flare in which a low-frequency vibration generated from a ground flare tower, such as a chimney, is properly adjusted to control it below a vibration generation limit for fixtures, thereby preventing surrounding objects from resonating and vibrating.

Solution to Problem

[0015] The present invention employs a ground flare with the features of claim 1 to solve the problems described above.

[0016] A ground flare according to the present invention is a ground flare that burns a flammable exhaust gas with a burner at the lower end of a chimney, in which the lower end of the chimney and the periphery of the burner are surrounded by a windbreak, wherein the low-frequency-noise sound pressure level of a ground flare tower composed of the chimney and the windbreak is reduced by selecting at least changing a natural frequency generated from the ground flare tower.

[0017] With such a ground flare, since the low-frequency-noise sound pressure level of a ground flare tower composed of a chimney and a windbreak is reduced by selecting changing a natural frequency generated from the ground flare tower, a low-frequency vibration generated from the ground flare can be set below a fixture-vibration generation limit.

[0018] In the invention the change of the natural frequency generated from the ground flare tower is achieved by providing a windbreak opening in part of the windbreak and closing the windbreak opening with a non-wall sheet in the form of a soundproof sheet against a low-frequency sound, which allows the generated frequency to be changed higher, thereby decreasing the sound pressure level.

[0019] In this case, preferably, the windbreak opening has a circumferential opening ratio of 50% or higher and a height opening ratio of 70% or higher.

[0020] The sheet surface density of the non-wall sheet may be selected depending on a dominant frequency in front of the windbreak opening.

[0021] In the above aspect, preferably, the change of the natural frequency generated from the ground flare tower is achieved by providing a chimney opening in part of the chimney, which allows the generated frequency to be changed higher, thereby decreasing the sound pressure level.

[0022] In this case, preferably, the chimney opening is a lateral opening provided within a range from 90 °to 360 ° in a circumferential direction. That is, the chimney opening of the present invention should be as large as structural strength permits within the range from 90 °to 360 ° in the circumferential direction.

[0023] Preferably, the heightwise position of the lateral opening is disposed at a portion corresponding to an antinode of a sound pressure mode generated from a resonant frequency.

[0024] Preferably, the opening area ratio of the lateral opening is set to 25% or higher irrespective of its opening shape.

[0025] The lateral opening may be provided at a plurality of positions of the chimney in the heightwise direction.

[0026] In the above aspect, the chimney opening may be one or a plurality of vertical openings that is open in the heightwise direction of the chimney.

[0027] In the above aspect, preferably, an opening concealing member is disposed outside the chimney opening, with a gap therebetween, and the area of a gap formed between the gap and the chimney is set larger than the opening area of the chimney opening, which allows the generated frequency to be changed higher, thereby decreasing the sound pressure level, and moreover, can prevent flames in the chimney from being viewed from the outside through the chimney opening.

[0028] In the above aspect, preferably, the change of the natural frequency generated from the ground flare tower is achieved by setting the burner position ς' of the burner, which is found using [Formula 1], within a range of 2.2 to 3.4 from the inlet of the windbreak with respect to the entire length of a guide including the chimney and the windbreak, which allows the generated frequency to be changed lower, thereby decreasing the sound pressure level.

[0029] In this case, the entire length of the guide should be extended by increasing the length of the chimney and/or the windbreak.

[0030] In the above aspect, preferably, the multiple ground flare towers are achieved by combining towers having different dominant frequencies, which decreases and distributes the sound pressure level at the individual dominant frequencies, thereby decreasing the overall sound pressure level.

[0031] In the above aspect, preferably, the installation of the low-frequency-vibration absorber in the ground flare tower is achieved by hanging a large number of sheets in a noise guide formed between the windbreak and the chimney at an angle of inclination with respect to a vertical direction, which allows the sheets to absorb the vibrational energy of air particles due to noise, thereby reducing the noise.

[0032] Preferably, the angle of inclination in this case is set in a range from 10 ° to 60 °.

[0033] Furthermore, preferably, the sheet is bent at a plurality of locations.

[0034] Furthermore, preferably, a top plate is installed above the inlet of the noise guide.

{Advantageous Effects of Invention}

[0035] According to the present invention described above, a low-frequency vibration generated from a ground flare can be set below a fixture-vibration generation limit, and thus, the surrounding objects can be prevented from resonating and vibrating.

Brief Description of Drawings

[0036]

{Fig. 1} Fig. 1 is a sectional view showing a configuration example as an embodiment of a ground flare according to the present invention.
{Fig. 2} Fig. 2 is a diagram showing the sound pressure level of a low-frequency vibration generated from a ground flare tower.
{Fig. 3} Fig. 3 is a perspective view showing a configuration example of a windbreak opening as a first embodiment (shifting the natural frequency to a higher pitch) of the ground flare according to the present invention.
{Fig. 4A} Fig. 4A is a diagram showing the relationship between the opening ratio of the windbreak opening and a peak sound pressure level, showing the relationship between a circumferential opening ratio and a peak sound pressure level.
{Fig. 4B} Fig. 4B is a diagram showing the relationship between the opening ratio of the windbreak opening and a peak sound pressure level, showing the relationship between a height opening ratio and a peak sound pressure level.
{Fig. 5} Fig. 5 is a diagram showing the relationship between a dominant frequency in front of a windbreak opening and a sheet surface density in a suitable design range of a non-wall sheet.
{Fig. 6} Fig. 6 is a perspective view showing a configuration example of a laterally open chimney opening as a modification of the first embodiment.
{Fig. 7A} Fig. 7A is a diagram showing the definition of the opening area ratio of a laterally open chimney opening, showing the opening area ratio S of a curved, rectangular opening.
{Fig. 7B} Fig. 7B is a diagram showing the definition of the opening area ratio of a laterally open chimney opening, showing the opening area ratio S' of a circular opening.
{Fig. 8A} Fig. 8A is a perspective view showing a configuration example of a laterally open multi-stage chimney opening.
{Fig. 8B} Fig. 8B is a vertical sectional view showing a configuration example of a laterally open multi-stage chimney opening.
{Fig. 9} Fig. 9 is a perspective view showing a configuration example of a vertically open chimney opening.
{Fig. 10A} Fig. 10A is a perspective view showing a configuration example in which an opening concealing member is mounted over a vertically open chimney opening.
{Fig. 10B} Fig. 10B is a cross-sectional view showing a configuration example in which an opening concealing member is mounted over a vertically open chimney opening.
{Fig. 11A} Fig. 11A is a perspective view showing a configuration example in which an opening concealing member is mounted over a laterally open chimney opening.
{Fig. 11B} Fig. 11B is a vertical sectional view showing a configuration example in which an opening concealing member is mounted over a laterally open chimney opening.
{Fig. 12A} Fig. 12A is a cross-sectional view showing a configuration example in which a windbreak is folded back to extend the windbreak length as a second embodiment (shifting the natural frequency to a lower pitch) of the ground flare according to the present invention.
{Fig. 12B} Fig. 12B is a vertical sectional view showing a configuration example in which a windbreak is folded back to extend the windbreak length as a first example (shifting the natural frequency to a lower pitch) of the ground flare serving to explain features of the present invention.
{Fig. 13A} Fig. 13A is a cross-sectional view showing a configuration example in which a windbreak is folded back into two stages to extend the windbreak length as a modification of the first example.
{Fig. 13B} Fig. 13B is a vertical sectional view showing a configuration example in which a windbreak is folded back

into two stages to extend the windbreak length as a modification of the first example.

{Fig. 14A} Fig. 14A is a cross-sectional view showing a configuration example in which lateral extension is combined with the folding of the windbreak to extend the windbreak length as a modification of the first example.

{Fig. 14B} Fig. 14B is a vertical sectional view showing a configuration example in which lateral extension is combined with the folding of the windbreak to extend the windbreak length as a modification of the first example.

{Fig. 15} Fig. 15 is a diagram showing a suitable design range in the relationship between a burner position ζ' and a peak sound pressure level.

{Fig. 16} Fig. 16 is a perspective view showing a configuration example of two separate towers as a second example (multiple towers) of the ground flare serving to explain features of the present invention.

{Fig. 17} Fig. 17 is a perspective view showing a configuration example in which the chimney is separated into three towers as a modification of the second example.

{Fig. 18A} Fig. 18A is a perspective view showing a configuration example in which the interior of the chimney is divided into three towers as a modification of the second example.

{Fig. 18B} Fig. 18B is a cross-sectional view showing a configuration example in which the interior of the chimney is divided into three towers as a modification of the third embodiment.

{Fig. 19} Fig. 19 is a cross-sectional view showing a configuration example in which the interior of a hexagonal-cross-section chimney is divided into three towers.

{Fig. 20} Fig. 20 is an explanatory diagram for overlapping of dominant frequencies when the ground flare is separated into multiple towers.

{Fig. 21} Fig. 21 is a perspective view showing a third example (sound absorber method) of the ground flare serving to explain features of the present invention.

{Fig. 22} Fig. 22 is a front view showing a placement example of sheets (partial of) shown in Fig. 21.

{Fig. 23} Fig. 23 is a front view showing a placement example in which the sheets (partial of) shown in Fig. 21 are bent into a chevron shape.

{Fig. 24} Fig. 24 is a diagram showing a configuration example of an incinerator as an example of a conventional apparatus that burns a flammable gas.

{Fig. 25} Fig. 25 is a diagram showing a configuration example of an open flare stack as an example of a conventional apparatus that burns a flammable gas.

{Fig. 26} Fig. 26 is a diagram showing a conventional example of a ground flare.

Description of Embodiments

[0037] An embodiment of a ground flare according to the present invention will be described hereinbelow based on the drawings.

[0038] A ground flare 10 shown in Fig. 1 is an apparatus for incinerating a flammable gas by burning it with a burner 11 provided at an opening at the lower end of a chimney 20. One or a plurality of burners 11 provided at the lower end of the chimney 20 is surrounded by a windbreak 40. By providing such a windbreak 40, the burners 11 disposed at the lower end of the chimney 20 are not affected by surrounding wind, and flames are not visible from the outside.

[0039] In the thus-configured ground flare 10, the present invention reduces the low-frequency-noise sound pressure level of a ground flare tower composed of the chimney 20 and the windbreak 40 by selecting at least one of changing the natural frequency of a low-frequency sound (noise) generated from the ground flare tower, using multiple ground flare towers composed of the chimney 20 and the windbreak 40, and installing a low-frequency-vibration absorber in the ground flare tower composed of the chimney 20 and the windbreak 40.

[0040] That is, the ground flare 10 of the present invention reduces the low-frequency-noise sound pressure level of the ground flare tower composed of the chimney 20 and the windbreak 40 by selecting at least one of a measure involving changing the natural frequency of a low-frequency sound generated, a measure involving the use of multiple ground flare towers, and a measure involving installing a low-frequency-vibration absorber in the ground flare tower and executing one or a combination of a plurality of the measures.

[0041] Fig. 2 shows the sound pressure level of a low-frequency vibration (noise) generated from the ground flare tower of the foregoing ground flare 10 with a broken line. The horizontal axis in the drawing indicates dominant frequency (Hz), and the vertical axis indicates sound pressure level (dB).

[0042] According to this drawing, the sound pressure level of the low-frequency vibration traces an upward convex curve, which crosses a vibration generation limit for fixtures, indicated by a straight line rising to the right, at two dominant frequencies f1 and f2. Since the vibration generation limit for fixtures is an upper limit of the sound pressure level at which a fixture vibration is generated, it is necessary to set the sound pressure level of the low-frequency vibration to a region lower than the vibration generation limit for fixtures. The sound pressure level before taking any measures, described below, is higher than the vibration generation limit for fixtures.

[0043] Accordingly, the sound pressure level of the low-frequency vibration generated from the ground flare tower of the ground flare 10 has suitable design ranges in both a region where the dominant frequency is lower than f1 and a region where the dominant frequency is higher than f2. Therefore, for the low-frequency vibration generated from the ground flare tower, the sound pressure level of the ground flare tower becomes lower than the fixture-vibration generation limit by decreasing the dominant frequency relative to f1 or increasing the dominant frequency relative to f2. This allows the sound pressure level of the low-frequency vibration generated from the ground flare 10 to be set below the vibration generation limit for fixtures, thereby preventing the surrounding objects from resonating and vibrating.

[0044] Configurations and measures for controlling the low-frequency noise (sound pressure level) of the ground flare 10 below the vibration generation limit for fixtures to fall within a suitable design range by reducing the low-frequency noise will be specifically described.

[0045] The foregoing configurations and measures are roughly classified into the following four.

1) Shifting the natural frequency of a low-frequency sound generated from the ground flare tower to a higher pitch to prevent resonance with the natural frequency of burner combustion.
2) Shifting the natural frequency of a low-frequency sound generated from the ground flare tower to a lower pitch to prevent resonance with the natural frequency of burner combustion.
3) Adopting multiple ground flare towers to produce the effect of reducing a sound pressure due to a decrease in heat quantity processed and setting the natural frequencies of the multiple towers to a frequency other than the natural frequency of the burners and setting the natural frequencies of the plurality of towers to different frequencies.
4) Installing an object (low-frequency-vibration absorber) that absorbs the low-frequency vibration in the tower of the ground flare.

[0046] By executing a single configuration and measure, or an appropriate combination thereof, resonance with the natural frequency of burner combustion and the vibration of an air column in the ground flare can be prevented, and the sound pressure level of a low-frequency noise generated from the ground flare tower can be reduced. Furthermore, the low-frequency-vibration absorber can convert vibrational energy to thermal energy to reduce the sound pressure level of the low-frequency noise.

First Embodiment; Shifting Natural Frequency to Higher Pitch

[0047] An embodiment described below shifts the natural frequency of a low-frequency sound generated from the ground flare tower to a higher pitch to prevent resonance with the natural frequency of burner combustion.

[0048] A ground flare 10A shown in Fig. 3 changes the natural frequency by providing windbreak openings 41 at part of the windbreak 40 and closing the windbreak openings 41 with non-wall sheets 42. That is, after part of the windbreak 40 is cut out to form the windbreak openings 41, the non-wall sheets 42 are mounted over the windbreak openings 41 to close them. The non-wall sheets 42 used here break the wind and prevent an audible sound from leaking out, and also prevent flames from being viewed from the outside through the windbreak openings 41, and should be formed of a material that does not function as a wall against a low-frequency sound.

[0049] The windbreak openings 41 provided by removing part of the windbreak 40 are desirably removed by cutting out plates from the windbreak 40 so as to achieve, for the opening ratios defined below (see Fig. 3), an opening area with a circumferential opening ratio of 50% or higher and a height opening ratio of 70% or higher. The illustrated windbreak openings 41 are curved, rectangular openings disposed at a regular pitch in the circumferential direction.

$$\text{circumferential opening ratio} = n \times w/\pi D \times 100$$

n; the number of windbreak openings
w; the peripheral length of windbreak opening
п; circular constant
D; the diameter of windbreak

$$\text{height opening ratio} = h/H \times 100$$

h; the height of windbreak opening
H; the total height of windbreak

[0050] Figs. 4A and Fig. 4B are diagrams showing the relationship between the opening ratio(%) and the peak sound pressure level (dB).

[0051] For the circumferential opening ratio shown in Fig. 4A, the peak sound pressure level rises as the opening ratio increases from 0, and reaches a peak at an opening ratio of about 20%. After the peak, the peak sound pressure level falls with an increase in the opening ratio, and even when the opening ratio increases to about 50% or higher, the peak sound pressure level changes little. Accordingly, it is desirable that the circumferential opening ratio be set to 50% or higher.

[0052] For the height opening ratio shown in Fig. 4B, the peak sound pressure level falls in the region of an opening ratio from about 0 to 70% as the opening ratio increases. The peak sound pressure level changes little with an increase in opening ratio in a region in which the opening ratio is higher than about 70%. Accordingly, it is desirable that the height opening ratio be set to 70% or higher.

[0053] Furthermore, it is desirable for the windbreak openings 41 that both the circumferential opening ratio and the height opening ratio described above satisfy the conditions.

[0054] The non-wall sheets 42 are soundproof sheets disposed over the windbreak openings 41 so as not to form a wall against a low-frequency sound. The range of a sheet surface density suitable for the non-wall sheets 42 depends on the dominant frequency in front of the windbreak openings, as shown in Fig. 5. That is, the lower the dominant frequency in front of the windbreak openings, the higher the surface density and the heavier the non-wall sheets 42 that need to be selected. In other words, it is desirable to select the sheet surface density of the non-wall sheets 42 from a region below the boundary of the suitable design range shown in Fig. 5.

[0055] This exhibits the characteristic that the dominant frequency increases higher as the surface density of the non-wall sheets 42 decreases, and thus, to obtain the effect of the windbreak openings with the non-wall sheets 42 having a low surface density, it is necessary to select a material with a surface density corresponding to the initial frequency band.

[0056] Here, to increase the dominant frequency from a frequency of 5 Hz by providing a windbreak sheet, it is necessary to select a material lighter than about 3000 g/m^2; to increase the dominant frequency from a frequency of 25 Hz by providing a windbreak sheet, it is necessary to select a material lighter than about 300 g/m^2; and to increase the dominant frequency from a frequency of 80 Hz by providing a windbreak sheet, it is necessary to select a material lighter than about 30 g/m^2.

[0057] Since such a configuration increases the frequency of vibration generated from the ground flare 10A, a point of resonance with the natural frequency of the burners 11 can be avoided.

[0058] Furthermore, since a high-frequency vibration is greatly damped in the chimney 20, the noise level falls. That is, the shift of the natural frequency to the higher pitch described here decreases the sound pressure level of a low-frequency noise while increasing a generated frequency with a configuration in which the windbreak openings 41 are provided at part of the windbreak 40 and closing them with the non-wall sheets 42 to solve the problem of noise reduction of the conventional ground flare 10.

[0059] Next, a modification in which chimney openings are provided at part of the chimney 20, in place of the windbreak openings 41 of the windbreak 40 in the foregoing first embodiment, will be described in Fig. 6. In this modification, chimney openings 21 are provided at part of the chimney 20 to change the natural frequency generated from the ground flare tower, that is, to shift the natural frequency of a low-frequency sound generated from the ground flare tower to a higher pitch, thereby preventing resonance with the natural frequency of burner combustion.

[0060] A ground flare 10B shown in Fig. 6 has laterally open chimney openings 21 provided at appropriate portions of the chimney 20 higher than a position surrounded by the windbreak 40. These chimney openings 21 are provided in the range from 90° to 360° in the circumferential direction of the chimney 20 and are desirably as large as structural strength permits.

[0061] The chimney openings 21 shown in Fig. 6 are set such that the heightwise position of the lateral opening is located at a portion corresponding to the antinode of a sound pressure mode generated from a resonant frequency to efficiently decrease the sound pressure level in the chimney 20.

[0062] The laterally open chimney openings 21 may have openings shaped as round holes or rectangular holes, as shown in Fig. 7A and Fig. 7B, for example, and are not limited to openings of a particular shape. However, it is desirable to set the opening area ratio of the chimney openings 21 to 25% or higher irrespective of the shape of the lateral openings. That is, an opening area ratio S in the case where the chimney openings 21 have a curved, rectangular shape, as shown in Fig. 7A, for example, and an opening area ratio S' in the case where chimney openings 21' are constituted by a large number of circular holes, as shown in Fig. 7B, for example, are set to 25% or higher.

[0063] In the expression that defines the opening area ratio S in Fig. 7A, n is the number of the chimney openings 21, w is the peripheral length of each chimney opening 21, and h is the height of the chimney openings 21, and in the expression that defines the opening area ratio S' in Fig. 7B, n is the number of the chimney openings 21', π is the circular constant, d is the diameter of each chimney opening 21', D' is the diameter of the chimney 20, and h is the height of the chimney openings 21'.

[0064] Although the laterally open chimney openings 21 and 21' described above are provided at only one stage in the heightwise direction of the chimney 20, they may be provided at a plurality of stages in the heightwise direction of the chimney 20, as shown in Fig. 8A and Fig. 8B, for example.

[0065] In the configuration examples of a chimney 20A shown in Fig. 8A and Fig. 8B, truncated-cone-shaped ring members 23 are disposed at a regular pitch in the heightwise direction and are fixed to a plurality of column members 22, and a large number of gaps formed between the upper and lower ring members 23 function as multi-stage chimney openings 21A. In this case, it is also possible to make the chimney openings 21A invisible when the chimney 20A is viewed from the horizontal direction, that is, through which flames are hard to view from the outside, by considering the vertical placement of the ring members 23.

[0066] A chimney 20B shown in Fig. 9 has vertically open chimney openings 21B that open in the heightwise direction of the chimney, unlike the lateral opening described above. In the illustrated configuration example, a pair of substantially C-shaped-cross-section chimney members 24 are used to form two vertically open chimney openings 21B.

[0067] Furthermore, a chimney 20C shown in Fig. 10A and Fig. 10B has a vertically open chimney opening 21C. This chimney opening 21C has an opening concealing member 25 outside the chimney 20C, with a predetermined space therebetween, to prevent flames from being viewed from the outside. The area of a gap formed between the chimney 20C and the opening concealing member 25 is set larger than the opening area of the chimney opening 21C so as not to reduce the low-frequency noise reducing effect. Furthermore, such an opening concealing member 25 can also be disposed over the laterally open chimney openings 21 and so on; for example, as shown in Fig. 11A and Fig. 11B, an opening concealing member 25' can be disposed so as to cover the periphery of the laterally open chimney openings 21. In this case, the area ($Sa \times 2$) of a gap formed between the chimney 20 and the opening concealing member 25' is set larger than the opening area Sb of the chimney openings 21 ($2Sa > Sb$).

[0068] Even with such a configuration in which the chimney openings 21 are provided at the chimney 20 side, the frequency of vibration generated from the ground flare 10B' is as high as with the windbreak openings 41, and thus, the resonant point with the natural frequency of the burner 11 can be avoided.

[0069] Furthermore, since a high-frequency vibration is greatly damped in the chimney 20, the noise level falls. That is, the shift of the natural frequency to the higher pitch described here decreases the sound pressure level of a low-frequency noise while increasing a generated frequency with a configuration in which the chimney openings 21 are provided at part of the chimney 20 to solve the problem of noise reduction of the conventional ground flare 10.

First Example; Shift of Natural Frequency to Lower Pitch

[0070] An example serving to explain features of the invention and described below shifts the natural frequency of a low-frequency sound generated from the ground flare tower to a lower pitch to prevent resonance with the natural frequency of burner combustion. That is, as shown in Fig. 12A to Fig. 15, the windbreak portion is extended to decrease a frequency to be generated, and the sound pressure level of a low-frequency noise is reduced.

[0071] In this method, the burner position ς' of the burners 11, which is found using Fig. 15 and [Formula 1] shown below, falls within a range of 2.2 to 3.4 from the inlet Wi of a windbreak 40A with respect to a length (entire guide length) including the chimney 20 and the windbreak 40A.

[Formula 1]

$$\varsigma' = \left(1 - \frac{L1 + 0.6d_1}{\dfrac{c}{2 \times f}} \right) \times 4$$

L1: chimney height (m)
*d*1: chimney diameter (m)
c: velocity of sound (m/s)
f: measured frequency (Hz)

[0072] In [Formula 1], L1 is chimney height (m), d1 is the diameter of the chimney (m), c is the velocity of sound (m/s), and f is a measured frequency (Hz).

[0073] As shown in Fig. 15, the relationship between the burner position ς' calculated from [Formula 1] and the peak sound pressure level shows that the peak sound pressure level falls after passing through the peak. Accordingly, the suitable design range of the burner position ς' is a region in which the peak sound pressure level is lower than the peak sound pressure level (a peak sound pressure level when ς' = 0) at the inlet Wi (ς' = 2.2 to 3.4).

[0074] To set the burner position ς' in the suitable design range described above, the windbreak length is extended using the windbreak 40A that is formed of the windbreak 40 with a one-stage fold 43, like a ground flare 10D shown in Fig. 12A and Fig. 12B, for example. The windbreak 40A having such a one-stage fold 43 is disposed such that the opening of the inlet Wi of the windbreak 40A is orientated downward.

[0075] Furthermore, the windbreak length may be extended using two-stage folds 43 and 44 (or a plurality of stages having two or more stages) like a windbreak 40B of a ground flare 10E shown in Fig. 13A and Fig. 13B, or alternatively, the fold 43 may be combined with an extension 45, like a windbreak 40C of a ground flare 10F shown in Fig. 14A and Fig. 14B, for example.

[0076] With such a configuration, the frequencies of vibrations generated from the ground flares 10D to 10F are decreased due the extension of the windbreak length and/or the extension of the chimney length. The decrease in frequency can avoid a point of resonance with an object affected by the vibration. Furthermore, the increase in the capacities of the ground flares 10D to 10F increase inside damping, thus decreasing the noise level.

Second Example; Multiple Towers

[0077] An example serving to explain features of the invention and described below adopts multiple ground flare towers and combines towers having different dominant frequencies to reduce the sound pressure level.

This embodiment is provided with two separated ground flares 10a and 10b so as to satisfy the required capacity, as shown in Fig. 16, for example. In this case, the two separated ground flares 10a and 10b are set so that the respective dominant frequencies differ by changing the chimney lengths of chimneys 20a and 20b; the dominant frequency of the ground flare 10b, having a long air column, produces a low-pitched sound, and the dominant frequency of the ground flare 10a, having a short air column, produces a high-pitched sound. That is, the two ground flares 10a and 10b having different primary frequencies are placed side by side. In this example of separation, both the chimney and the windbreak are separated into two. Reference signs 40a and 40b in the drawing denote windbreaks.

[0078] Disposing the two ground flares 10a and 10b having different dominant frequencies side by side in this way prevents their respective sound pressures from overlapping due to a difference in primary frequency, as shown in the lower column in Fig. 20. Accordingly, the respective sound pressure levels are reduced (by about 3 dB) due to the separation into two, and thus, the sound pressure level of ground flares as a whole (10a and 10b) is controlled below a vibration generation limit for fixtures, indicated by the chain dot line in Fig. 20.

[0079] However, if two ground flares having the same dominant frequency are disposed side by side, their respective sound pressures overlap with each other to offset the reduction amounts, as shown in the upper row in Fig. 20, because their primary frequencies are the same. Accordingly, this makes it difficult to control the sound pressure level of the ground flares as a whole (10a and 10b) below the vibration generation limit for fixtures, indicated by a one-dot chain line in the drawing.

[0080] The above-described adoption of multiple ground flare towers is not limited to the separation into two described above; multiple ground flare towers may be formed by separation into three or more towers. In this case, when adopting multiple towers with their respective dominant frequencies set differently, there is no need to uniformly distribute the amount of gas processed. Accordingly, the amount of gas can be appropriately controlled depending on the level of the sound pressure to be output, and thus, the sound pressure level can be reduced in a desired frequency band.

[0081] In the separation example shown in Fig. 17, the windbreak is used in common, and only the chimney is separated into three, that is, 20a, 20b, and 20c. Also in this case, the respective dominant frequencies are set differently using chimneys having different lengths.

In the separation example shown in Fig. 18A and Fig. 18B, the interior of a chimney 20D having a circular cross section is partitioned into three by a partitioning member 26, and the respective dominant frequencies are set differently, for example, by changing the heightwise positions of the chimney openings 21. The cross-sectional shape of the chimney 20D is not limited to the circular cross section; for example, as shown in Fig. 19, the interior of a hexagonal-cross-section chimney 20E may be partitioned into, for example, three, by a partitioning member 26.

Third Example; Sound Absorber Method

[0082] An example serving to explain features of the invention and described below has a low-frequency-vibration absorber in the ground flare tower and absorbs the vibrational energy of air particles due to noise, thereby reducing the noise.

In an example shown in Fig. 21 and Fig. 22, a large number of sheets 60 are hung like bamboo blinds in a noise guide 50 formed between the windbreak 40 and the chimney 20 at an angle of inclination with respect to the vertical direction as a low-frequency-vibration absorber installed in the ground flare tower. The sheets 60 in this case are shaped like a plate, and the angle of inclination at which the sheets 60 are hung is set in the range from 10° to 60° with respect to the vertical direction.

[0083] That is, installing the sheets 60 at an angle prevents a low-frequency noise from traveling straight through gaps formed between the sheets 60 and 60 in the noise guide 50. As a result, the low-frequency noise is reflected by the surfaces of the sheets 60, thereby enhancing the noise reduction effect, and furthermore, preventing a decrease in the amount of air absorbed due to the hanging of the sheets 60. Accordingly, the sheets 60 efficiently absorb the vibrational energy of air particles due to a low-frequency noise, thus allowing the low-frequency noise to be reduced. Although the sheets 60 in this example are shaped like a plate, sheets 61 that are bent once or a plurality of times into a chevron shape may be employed, as shown in Fig. 23, for example. Since such sheets 61 make it more difficult for a low-frequency noise to travel straight through the noise guide 50, the noise reduction effect can be improved by increasing the area of contact with air particles.

[0084] Furthermore, it is desirable to provide a top plate 70 above the inlet of the noise guide 50 described above. This top plate 70 is disposed with a predetermined distance from the inlet (upper opening) of the noise guide 50 so as to cover the inlet of the noise guide 50 in plan view. Installing such a top plate 70 interferes with the straight traveling of a low-frequency noise, thus further enhancing the noise reduction effect.

[0085] Although the foregoing embodiments and first to third examples have a sufficient low-frequency noise reduction effect even independently, an appropriate combination of the embodiment with the examples may be employed depending on the flare stack, as well as its conditions, its installation site, and so on.

Although the embodiment with the combination shown in Fig. 1 employs the chimney openings 21 provided in the chimney 20, the windbreak openings 41 disposed in the windbreak 40, the sheets 60 disposed in the noise guide 50, and the top plate 70 disposed above the inlet of the noise guide 50 together, the present invention is not limited thereto. The windbreak openings 41 are fitted with the non-wall sheets 42, and the outer periphery of the chimney openings 21 is fitted with the opening concealing member 25'.

[0086] Since the ground flare of the present invention reduces the low-frequency-noise sound pressure level of a ground flare tower composed of a chimney and a windbreak by selecting at least one of changing a natural frequency generated from the ground flare tower, using multiple ground flare towers, and installing a low-frequency-vibration absorber in the ground flare tower, as described above, the low-frequency vibration generated from the ground flare can be set below a fixture-vibration generation limit, and thus, the surrounding objects can be prevented from resonating and vibrating.

Reference Sings List

[0087]

10, 10A to 10F ground flare

11 burner

20, 20A to 20E chimney

21, 21A to 21C chimney opening

25, 25' opening concealing member

40, 40A to 40C windbreak

41 windbreak opening

42 non-wall sheets

50 noise guide

60, 61 sheet

70 top plate

Claims

1. A ground flare (10;10A) for burning a flammable exhaust gas, comprising
a ground flare tower including a chimney (20) and a windbreak (40), and
a burner (11) at the lower end of the chimney (20), wherein
the windbreak (40) surrounds the lower end of the chimney (20) and the periphery of the burner (11), **characterized in that** a windbreak opening (41) is provided in part of the windbreak (40), and
the windbreak opening (41) is closed with a soundproof sheet (42) so as to change a natural frequency generated from the ground flare tower, thereby reducing the low-frequency-noise sound pressure level of the ground flare tower to a sound pressure level below a vibration generation limit for fixtures.

2. The ground flare (10A) according to claim 1, wherein the windbreak opening (41) has a circumferential opening ratio of 50% or higher and a height opening ratio of 70% or higher.

3. The ground flare (10A) according to claim 1 or 2, wherein the sheet surface density of the soundproof sheet (42) is selected depending on a dominant frequency in front of the windbreak opening (41) .

4. The ground flare according to claim 1, wherein the change of the natural frequency generated from the ground flare tower is achieved by providing a chimney opening (21;21';21A;21B;21C) in part of the chimney (20;20A;20B;20C).

5. The ground flare according to claim 4, wherein the chimney opening (21;21';21A;21B) is a lateral opening provided within a range from 90° to 360° in a circumferential direction.

6. The ground flare according to claim 5, wherein the heightwise position of the lateral opening (21;21') is disposed at a portion corresponding to an antinode of a sound pressure mode generated from a resonant frequency.

7. The ground flare according to claim 5 or 6, wherein the opening area ratio (S;S') of the lateral opening (21;21') is set to 25% or higher.

8. The ground flare according to claim 5, wherein the lateral opening (21A;21B) is provided at a plurality of positions of the chimney (20A;20B) in the heightwise direction.

9. The ground flare according to claim 4, wherein the chimney opening (21A;21B) is one or a plurality of vertical openings that is open in the heightwise direction of the chimney (20A;20B).

10. The ground flare according to any of claims 4 to 9, wherein an opening concealing member (25;25') is disposed outside the chimney opening (21C;21), with a gap therebetween, and the area of a gap formed between the gap and the chimney (20C;20) is set larger than the opening area of the chimney opening (21C;21).

11. The ground flare according to claim 1, wherein the change of the natural frequency generated from the ground flare tower is achieved by setting the burner position ζ' of the burner, which is found using the following formula:

$$\zeta' = \left(1 - \frac{L1 + 0.6d1}{\frac{c}{2 \times f}}\right) \times 4 \quad ,$$

within a range of 2.2 to 3.4 from the inlet (Wi) of the windbreak (40A;40B;40C) with respect to the entire length of a guide including the chimney (20) and the windbreak (40A;40B;40C), wherein L1 is the chimney height in m, d1 is the chimney diameter in m, c is the velocity of sound in m/s, and f is the measured frequency in Hz.

12. The ground flare according to claim 11, wherein the entire length of the guide is extended by increasing the length of the chimney (20) and/or the windbreak (40A;40B;40C).

13. The ground flare according to claim 1, wherein multiple ground flare towers (10a,10b;20a-c) are used by combining towers having different dominant frequencies.

14. The ground flare according to claim 1, wherein a low-frequency-vibration absorber is installed in the ground flare

tower by hanging a large number of sheets (60;61) in a noise guide (50) formed between the windbreak (40) and the chimney (20) at an angle of inclination with respect to a vertical direction.

15. The ground flare according to claim 14, wherein the angle of inclination is set in a range from 10° to 60°.

16. The ground flare according to claim 15, wherein the sheets (61) are bent at a plurality of locations.

17. The ground flare according to any of claims 14 to 16, wherein a top plate (70) is installed above the inlet of the noise guide (50).

Patentansprüche

1. Eine Bodenfackel (10;10A) zum Abbrennen eines entflammbaren Abgases, mit
einem Bodenfackelturm, der einen Kamin (20) und einen Windschutz (40) aufweist, und
einem Brenner (11) an dem unteren Ende des Kamins (20), wobei
der Windschutz (40) das untere Ende des Kamins (20) und den Umfang des Brenners (11) umgibt,
dadurch gekennzeichnet,
eine Windschutzöffnung (41) in einem Teil des Windschutzes (40) vorgesehen ist, und
die Windschutzöffnung (41) mit einer Schallschutzlage (42) verschlossen ist, um eine von dem Bodenfackelturm erzeugte Eigenfrequenz zu verändern, um dadurch den Niederfrequenz-Schalldruckpegel des Bodenfackelturms auf einen Schalldruckpegel unter einer Vibrationserzeugungsgrenze für Anbauten zu verringern.

2. Die Bodenfackel (10A) gemäß Anspruch 1, wobei die Windschutzöffnung (41) ein Umfangsöffnungsverhältnis von 50% oder mehr und ein Höhenöffnungsverhältnis von 70% oder mehr besitzt.

3. Die Bodenfackel (10A) gemäß Anspruch 1 oder 2, wobei die Lagenoberflächendichte der Schallschutzlage (42) in Abhängigkeit von einer dominanten Frequenz vor der Windschutzöffnung (41) gewählt ist.

4. Die Bodenfackel gemäß Anspruch 1, wobei die Änderung der Eigenfrequenz, die von dem Bodenfackelturm erzeugt wird, es durch Vorsehen einer Kaminöffnung (21;21';21A;21B;21C) in einem Teil des Kamins (20;20A;20B;20C) erreicht ist.

5. Die Bodenfackel gemäß Anspruch 4, wobei die Kaminöffnung (21;21';21A;21B) eine laterale Öffnung ist, die in einem Bereich von 90° bis 360° in einer Umfangsrichtung vorgesehen ist.

6. Die Bodenfackel gemäß Anspruch 5, wobei die Höhenposition der lateralen Öffnung (21;21') an einem Abschnitt angeordnet ist, der einer Stehwelle bzw. Antinode eines Schalldruckmodus entspricht, der von einer Resonanzfrequenz erzeugt wird.

7. Die Bodenfackel gemäß Anspruch 5 oder 6, wobei das Öffnungsflächenverhältnis (S;S') der lateralen Öffnung (21;21') auf 25% oder mehr eingestellt ist.

8. Die Bodenfackel gemäß Anspruch 5, wobei die laterale Öffnung (21A;21B) an einer Vielzahl von Positionen des Kamins (20A;20B) in der Höhenrichtung vorgesehen ist.

9. Die Bodenfackel gemäß Anspruch 4, wobei die Kaminöffnung (21A;21B) eine oder eine Vielzahl von vertikalen Öffnungen ist, die in der Höhenrichtung des Kamins (20A;20B) geöffnet ist.

10. Die Bodenfackel gemäß einem der Ansprüche 4 bis 9, wobei ein Öffnungs-Verschlusselement (25;25') mit einem Zwischenraum dazwischen außerhalb der Kaminöffnung (21C;21) angeordnet ist, und wobei die Fläche eines Zwischenraums, der zwischen dem Zwischenraum und dem Kamin (20C;20) gebildet ist, größer eingestellt ist als die Öffnungsfläche der Kaminöffnung (21C;21).

11. Die Bodenfackel gemäß Anspruch 1, wobei die Änderung der Eigenfrequenz, die von dem Bodenfackelturm erzeugt wird, erreicht ist durch Einstellen der Brennerposition ζ' des Brenners, die unter Anwendung der folgenden Formel ermittelt ist:

$$\zeta = \left(1 - \frac{L1 + 0.6d1}{\frac{c}{2xf}}\right) x\, 4 \quad ,$$

in einem Bereich von 2,2 bis 3,4 von dem Einlass (Wi) des Windschutzes (40A;40B;40C) bezüglich der Gesamtlänge einer Führung einschließlich dem Kamin (20) und dem Windschutz (40A;40B;40C), wobei L1 die Kaminhöhe in m, d1 der Kamindurchmesser in m, c die Schallgeschwindigkeit in m/s und f die gemessene Frequenz in Hz ist.

12. Die Bodenfackel gemäß Anspruch 11, wobei die Gesamtlänge der Führung durch Vergrößern der Länge des Kamins (20) und/oder des Windschutzes (40A;40B;40C) erweitert ist.

13. Die Bodenfackel gemäß Anspruch 1, wobei mehrere Bodenfackeltürme (10a,10b;20a-c) durch Kombinieren von Türmen mit unterschiedlichen dominanten Frequenzen verwendet sind.

14. Die Bodenfackel gemäß Anspruch 1, wobei ein Niederfrequenz-Vibrationsabsorber in dem Bodenfackelturm durch Abhängen einer großen Anzahl von Lagen (60;61) in einer Schallführung (50) installiert ist, die zwischen dem Windschutz (40) und dem Kamin (20) ausgebildet ist, unter einem Neigungswinkel bezüglich einer vertikalen Richtung.

15. Die Bodenfackel gemäß Anspruch 14, wobei der Neigungswinkel in einem Bereich von 10° bis 60° eingestellt ist.

16. Die Bodenfackel gemäß Anspruch 15, wobei die Lagen (61) an einer Vielzahl von Stellen gebogen sind.

17. Die Bodenfackel gemäß einem der Ansprüche 14 bis 16, wobei eine obere Platte (70) über dem Einlass der Schallführung (50) installiert ist.

Revendications

1. Torche (10; 10A) au sol pour brûler un gaz d'échappement inflammable, comprenant
une tour de torche au sol, comprenant une cheminée (20) et un coupe-vent (40) et
un brûleur (11) au bout inférieur de la cheminée (20), dans lequel
le coupe-vent (40) entoure le bout inférieur de la cheminée (20) et la périphérie du brûleur (11), **caractérisée en ce que**
une ouverture (41) de coupe-vent est prévue dans une partie du coupe-vent (40) et
l'ouverture (41) du coupe-vent est fermée par une feuille (42) d'insonorisation, de manière à changer une fréquence naturelle produite par la tour de torche au sol, en réduisant ainsi le niveau de pression sonore du bruit en basse fréquence de la tour de torche au sol à un niveau de pression sonore en dessous d'une limite de production de vibrations pour des dispositifs de serrage.

2. Torche (10A) au sol suivant la revendication 1, dans laquelle l'ouverture (41) de coupe-vent a un rapport d'ouverture circonférentiel supérieur ou égal à 50% et un rapport d'ouverture en hauteur supérieur ou égal à 70%.

3. Torche (10A) au sol suivant la revendication 1 ou 2, dans laquelle la masse volumique en surface de la feuille (42) d'insonorisation est choisie en fonction d'une fréquence prépondérante en face de l'ouverture (41) du coupe-vent.

4. Torche au sol suivant la revendication 1, dans laquelle le changement de la fréquence naturelle, produit à partir de la tour de la torche au sol, est obtenu en prévoyant une ouverture (21; 21'; 21A; 21B; 21C) de cheminée dans une partie de la cheminée (20; 20A; 20B; 20C).

5. Torche au sol suivant la revendication 4, dans laquelle l'ouverture (21; 21'; 21A; 21B) de la cheminée est une ouverture latérale prévue dans une plage de 90° à 360° dans une direction circonférentielle.

6. Torche au sol suivant la revendication 5, dans laquelle la position en hauteur de l'ouverture (21; 21') latérale est disposée en une partie correspondant à un ventre d'un mode de pression sonore produit à partie d'une fréquence de résonance.

7. Torche au sol suivant la revendication 5 ou 6, dans laquelle le rapport (S; S') de surface d'ouverture de l'ouverture (21; 21') latérale est fixé à 25% ou plus.

8. Torche au sol suivant la revendication 5, dans laquelle l'ouverture (21A; 21B) latérale est prévue en une pluralité de positions de la cheminée (20A; 20B) dans la direction en hauteur.

9. Torche au sol suivant la revendication 4, dans laquelle l'ouverture (21A; 21B) de la cheminée est une ou une pluralité d'ouvertures verticales qui est ouverte dans la direction en hauteur de la cheminée (20A; 20B).

10. Torche au sol suivant l'une quelconque des revendications 4 à 9, dans laquelle un élément (25; 25'), cachant l'ouverture, est disposé à l'extérieur de l'ouverture (21C; 21) de la cheminée avec un intervalle entre eux et la surface d'un intervalle formé entre l'intervalle et la cheminée (20C; 20) est plus grande que la surface de l'ouverture (21C; 21) de la cheminée.

11. Torche au sol suivant la revendication 1, dans laquelle le changement de la fréquence naturelle produite à partir de la tour de la torche au sol est obtenu en fixant la position ζ' du brûleur que l'on trouve en utilisant la formule suivant

$$\zeta' = \left(1 - \frac{L1 + 0{,}6d1}{\frac{c}{2 \times f}}\right) \times 4,$$

dans une plage de 2,2 à 3, 4 à partir de l'entrée (Wi) du coupe-vent (40A; 40B; 40C) par rapport à la longueur totale d'un guide incluant la cheminée (20) et le coupe-vent (40A; 40B; 40C), L1 étant la hauteur de la cheminée en m, d1 étant le diamètre de la cheminée en m, c étant la vitesse du son en m/s et f étant la fréquence mesurée en Hz.

12. Torche au sol suivant la revendication 11, dans laquelle la longueur complète du guide est prolongée en augmentant la longueur de la cheminée (20) et/ou du coupe-vent (40A; 40B; 40C).

13. Torche au sol suivant la revendication 1, dans laquelle de multiples tours (10a, 10b; 20a-c) de torche au sol sont utilisées en combinant des tours ayant des fréquences prépondérantes différentes.

14. Torche au sol suivant la revendication 1, dans laquelle un absorbeur de vibration de basse fréquence est installé dans la tour de torche au sol en suspendant un grand nombre de feuilles (60; 61) dans un guide (50) de bruit formé entre le coupe-vent (40) et la cheminée (20) suivant un angle d'inclinaison par rapport à une direction verticale.

15. Torche au sol suivant la revendication 14, dans laquelle l'angle d'inclinaison est fixé dans une plage de 10° à 60°.

16. Torche au sol suivant la revendication 15, dans laquelle les feuilles (61) sont courbées à une pluralité d'endroits.

17. Torche au sol suivant l'une quelconque des revendications 14 à 16, dans laquelle une plaque (70) de sommet est installée au-dessus de l'entrée du guide (50) de bruit.

FIG. 1

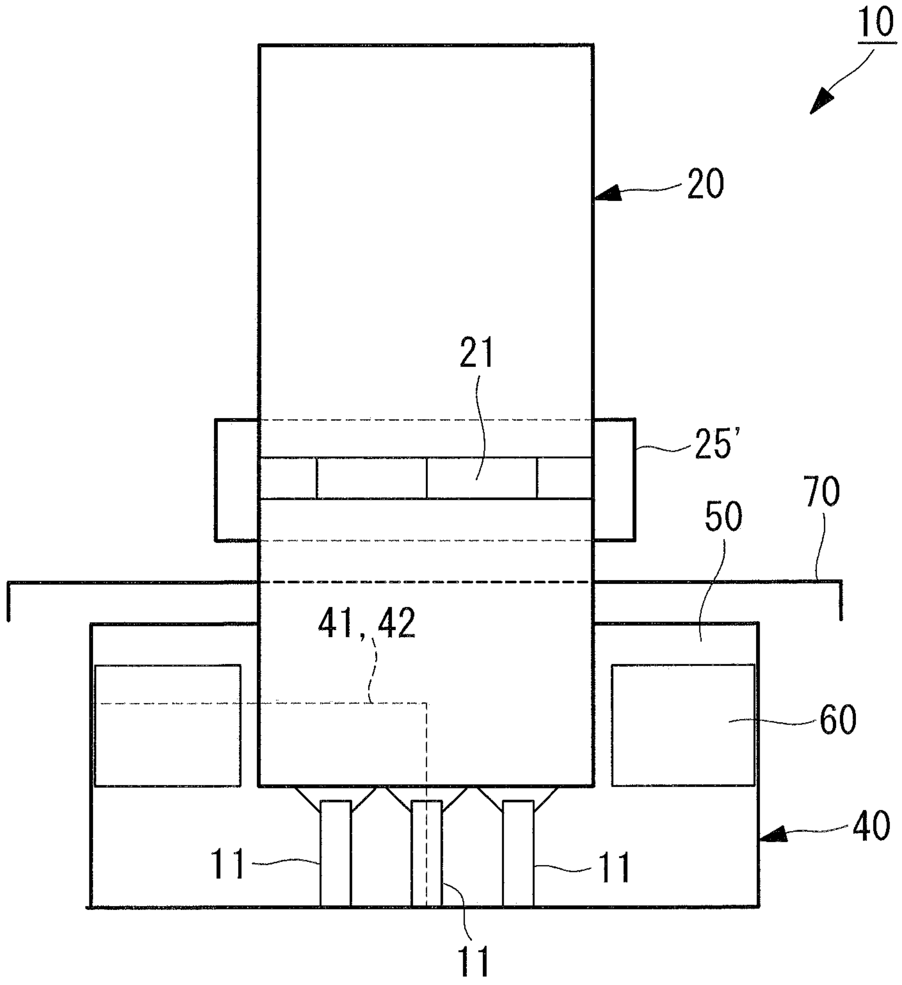


FIG. 2

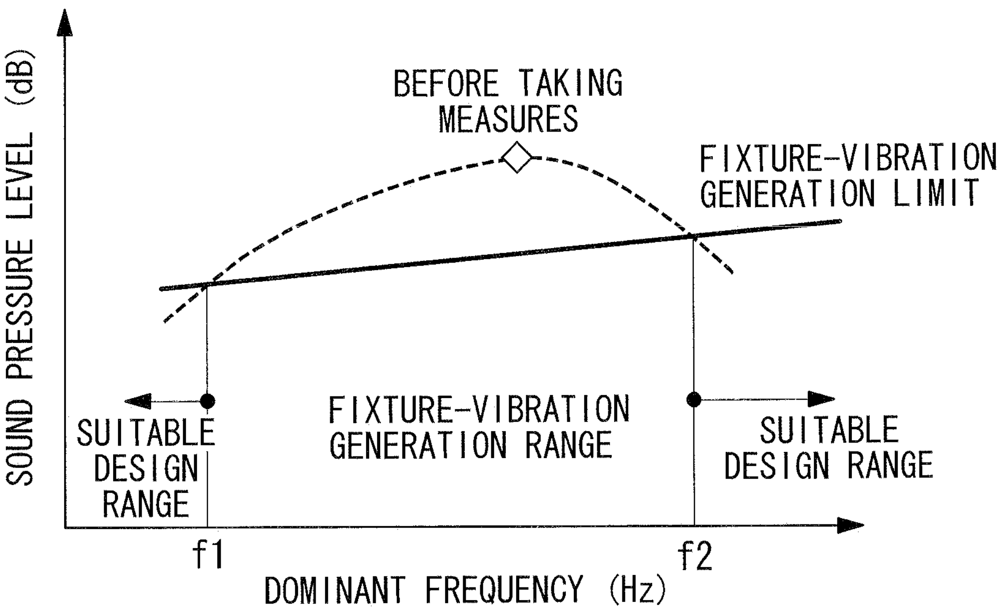

SOUND PRESSURE LEVEL (dB)
BEFORE TAKING MEASURES
FIXTURE-VIBRATION GENERATION LIMIT
SUITABLE DESIGN RANGE
FIXTURE-VIBRATION GENERATION RANGE
SUITABLE DESIGN RANGE
f1
f2
DOMINANT FREQUENCY (Hz)

FIG. 3

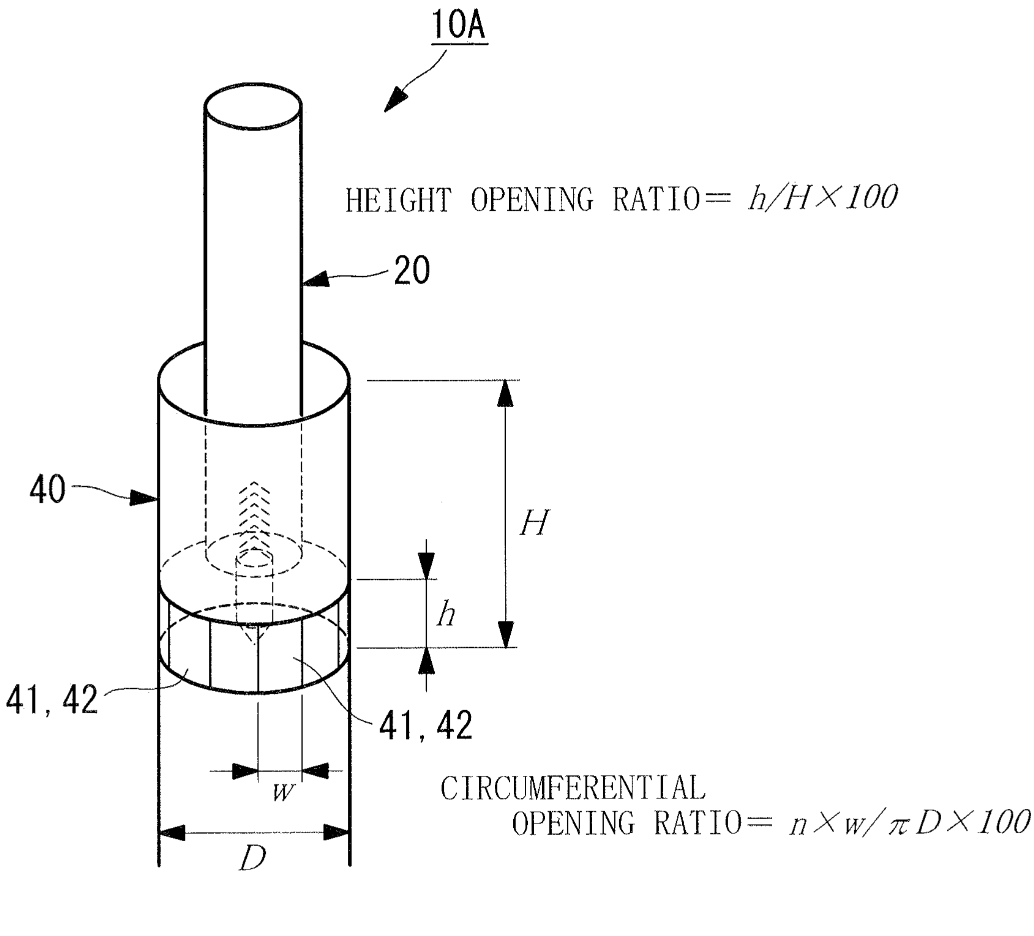

10A
HEIGHT OPENING RATIO= h/H×100
20
40
H
h
41, 42
41, 42
w
CIRCUMFERENTIAL OPENING RATIO= n×w/πD×100
D

FIG. 4A

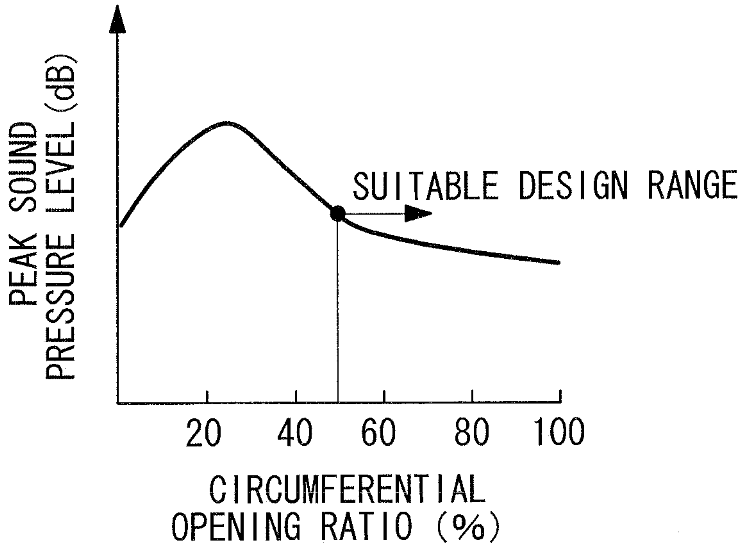

PEAK SOUND
PRESSURE LEVEL (dB)
SUITABLE DESIGN RANGE
20
40
60
80
100
CIRCUMFERENTIAL
OPENING RATIO (%)

FIG. 4B

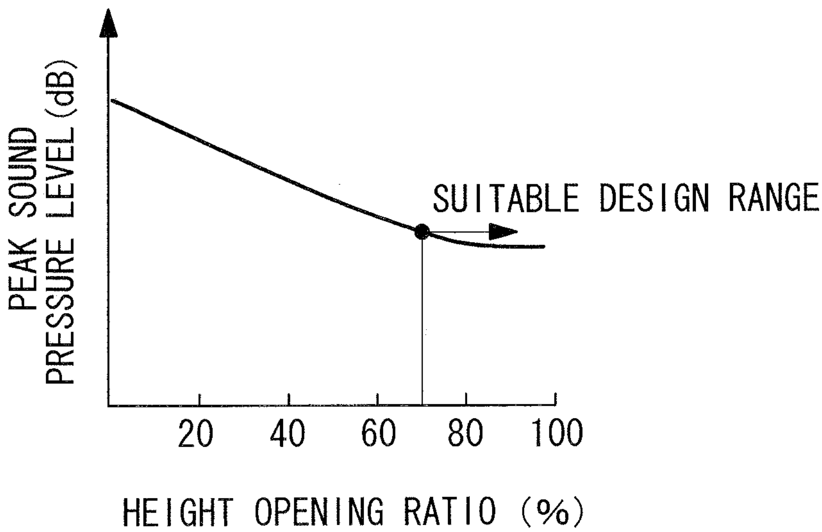

PEAK SOUND
PRESSURE LEVEL (dB)
SUITABLE DESIGN RANGE
20
40
60
80
100
HEIGHT OPENING RATIO (%)

FIG. 5

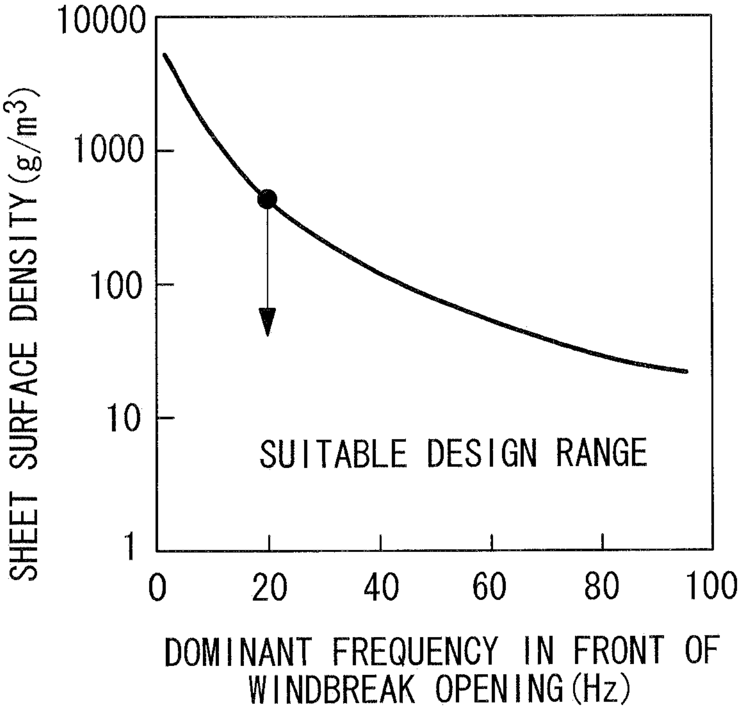

10000
1000
100
10
1
SHEET SURFACE DENSITY (g/m3)
0
20
40
60
80
100
SUITABLE DESIGN RANGE
DOMINANT FREQUENCY IN FRONT OF WINDBREAK OPENING (Hz)

FIG. 6

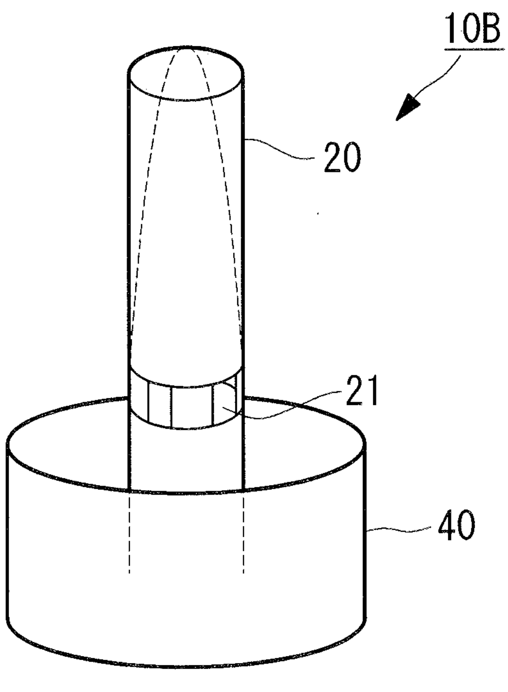

10B
20
21
40

FIG. 7A

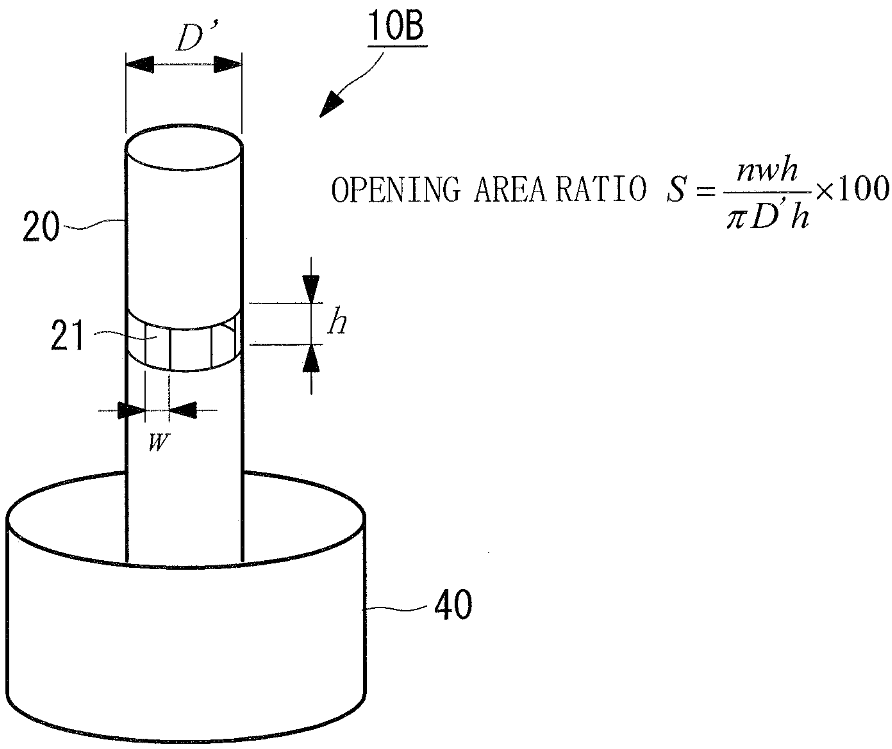

D'
10B
20
21
h
W
40
OPENING AREA RATIO $S = \frac{nwh}{\pi D' h} \times 100$

FIG. 7B

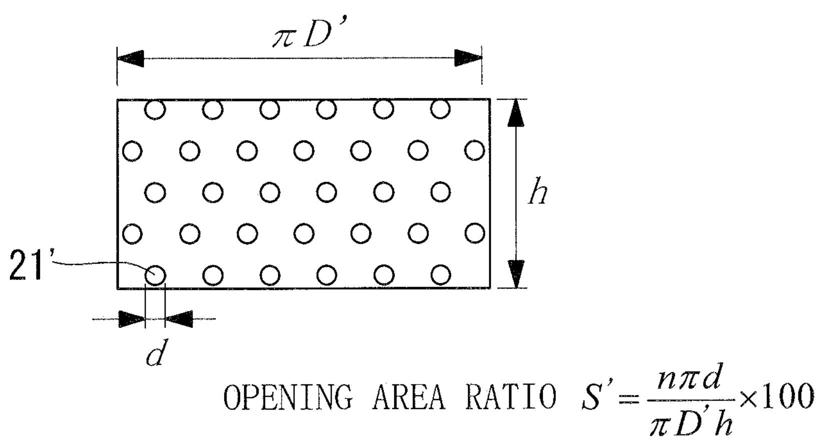

$\pi D'$
h
21'
d
OPENING AREA RATIO $S' = \frac{n\pi d}{\pi D' h} \times 100$

FIG. 8A

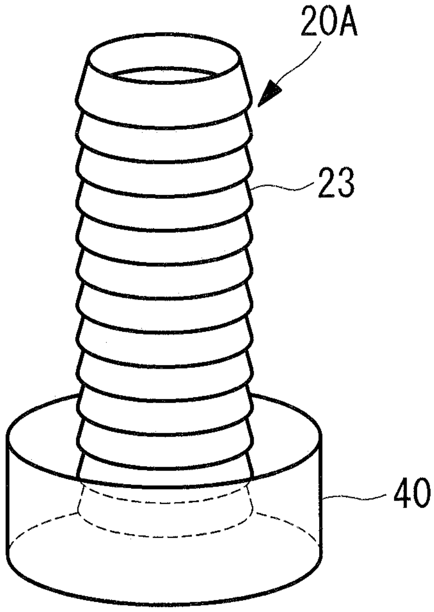


FIG. 8B

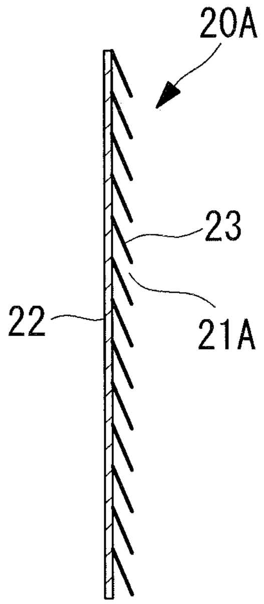


FIG. 9

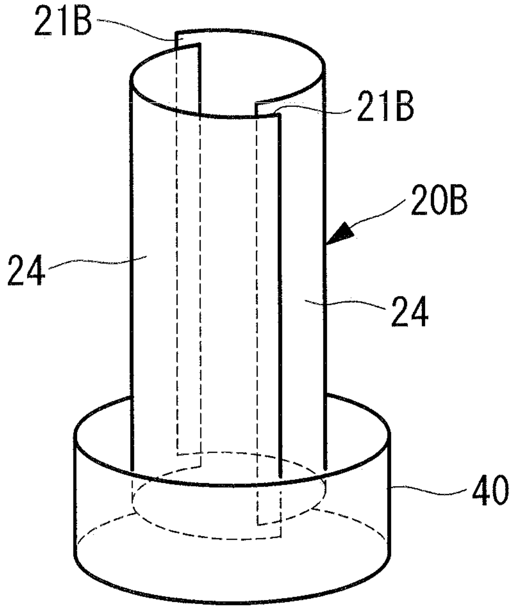


FIG. 10A

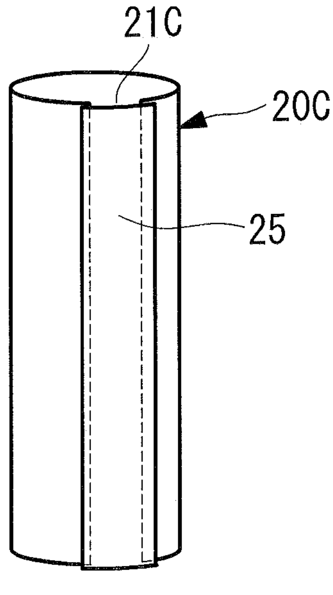


FIG. 10B

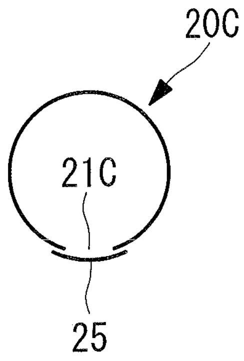


FIG. 11A

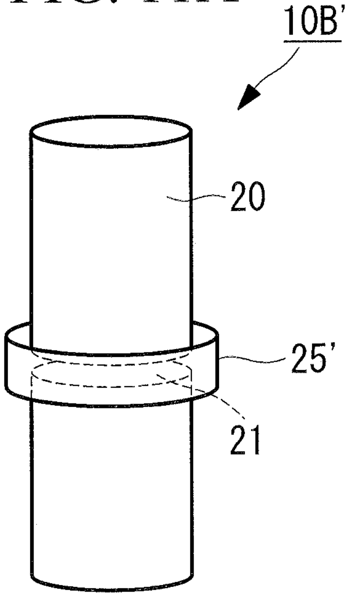


FIG. 11B

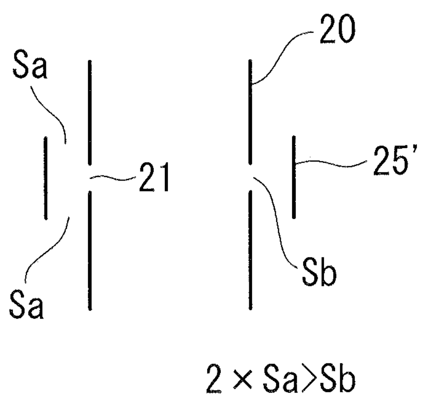


FIG. 12A

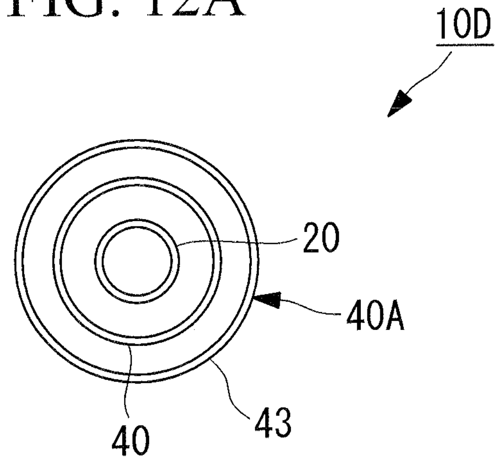


FIG. 12B

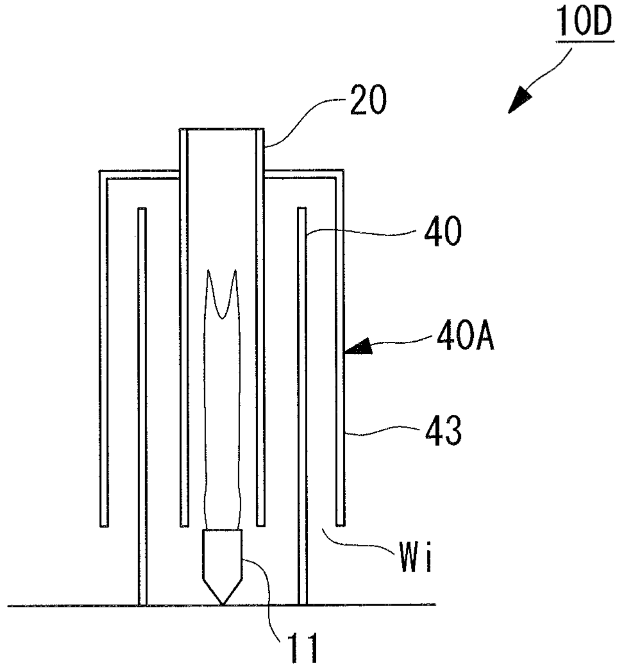


FIG. 13A

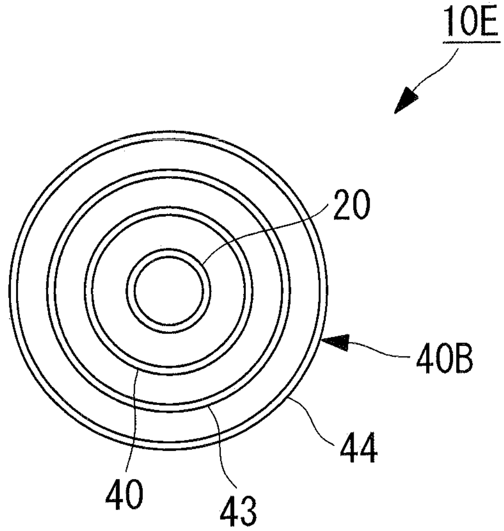


FIG. 13B

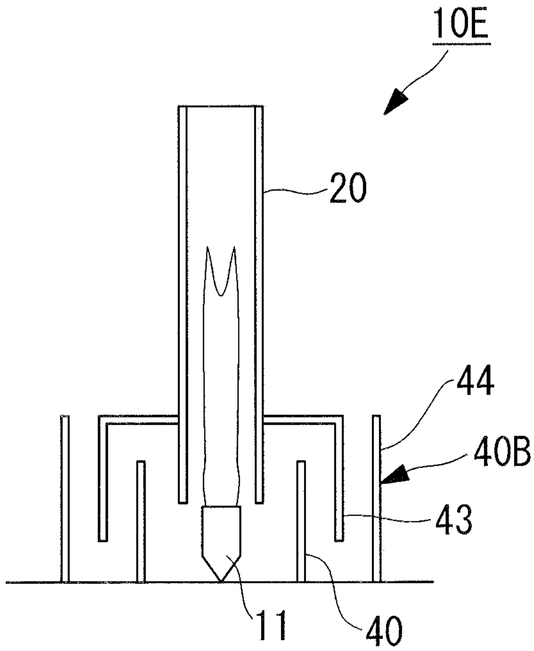


FIG. 14A

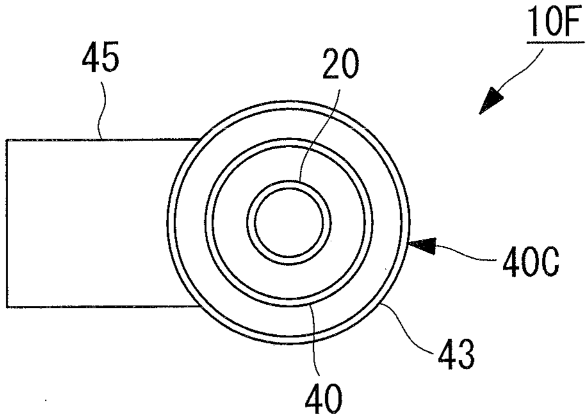


FIG. 14B

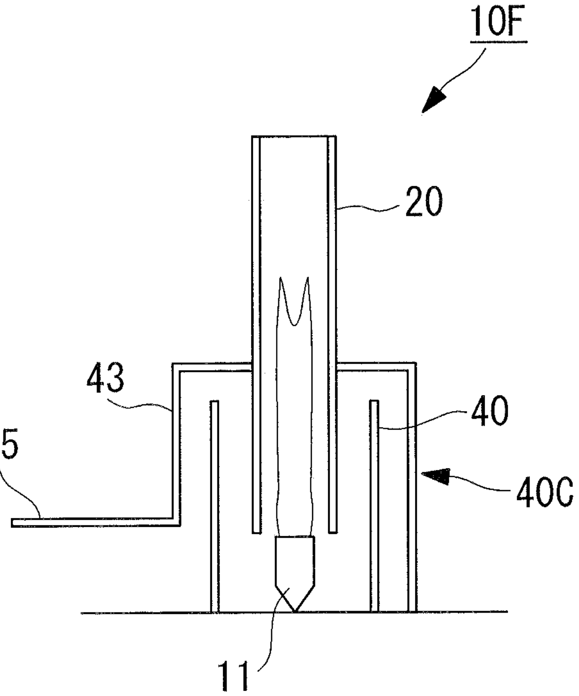
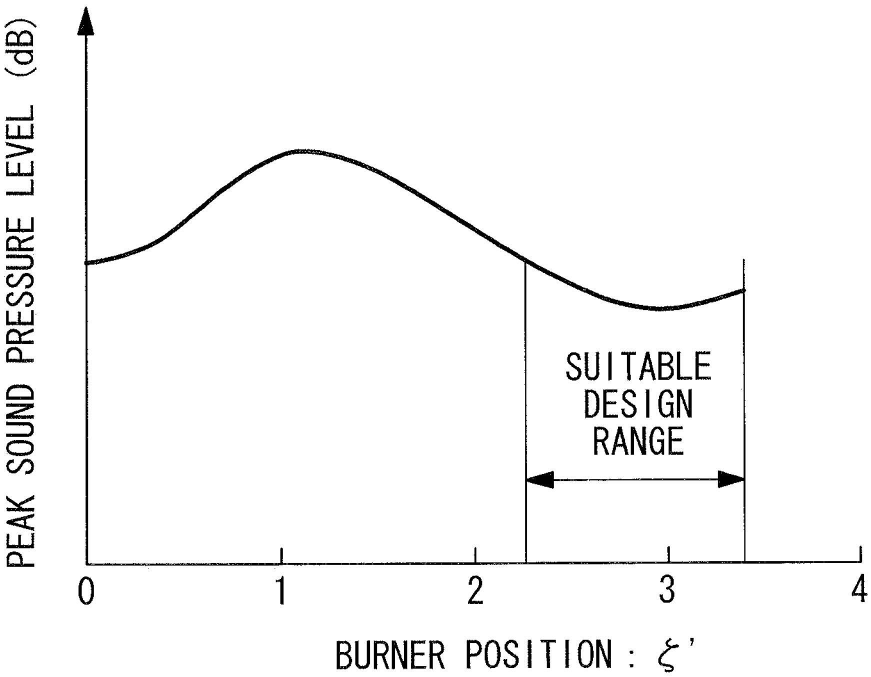


FIG. 15



$$\zeta' = \left(1 - \frac{L1 + 0.6\, d_1}{\frac{c}{2 \times f}} \right) \times 4$$

L1 : CHIMNEY HEIGHT (m)
d_1 : CHIMNEY DIAMETER (m)
c : SOUND VELOCITY (m/s)
f : MEASURED FREQUENCY (Hz)

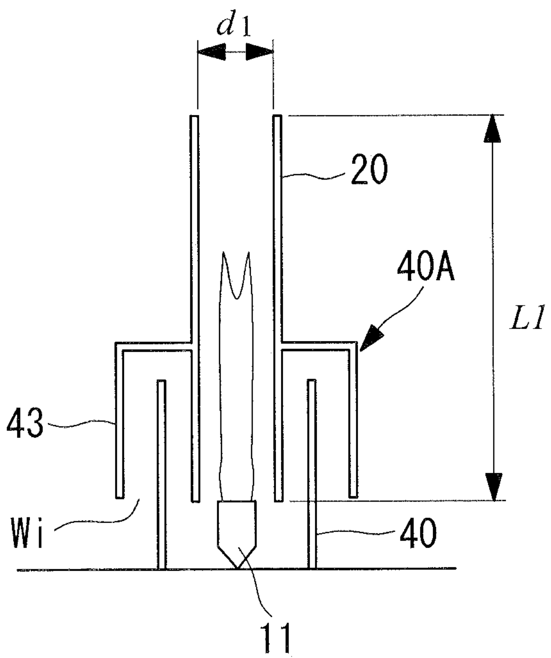


FIG. 16

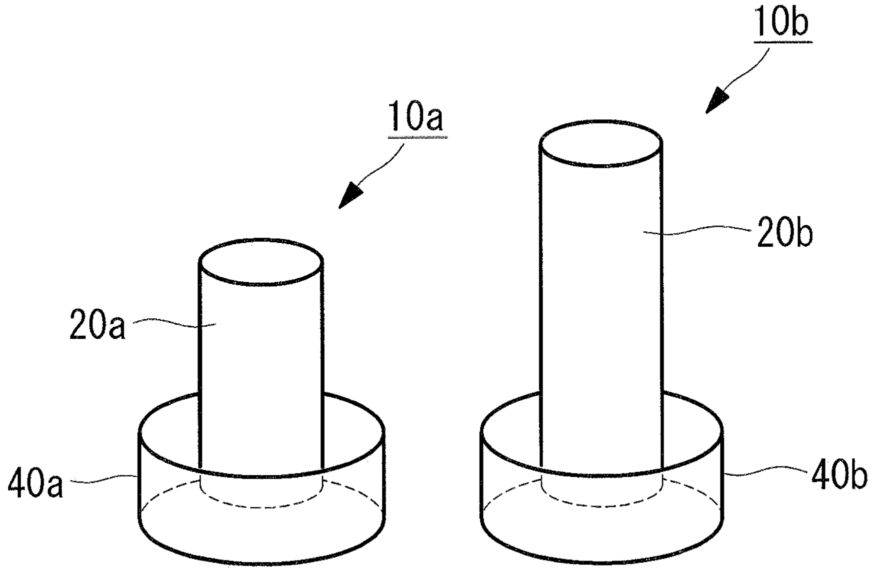


FIG. 17

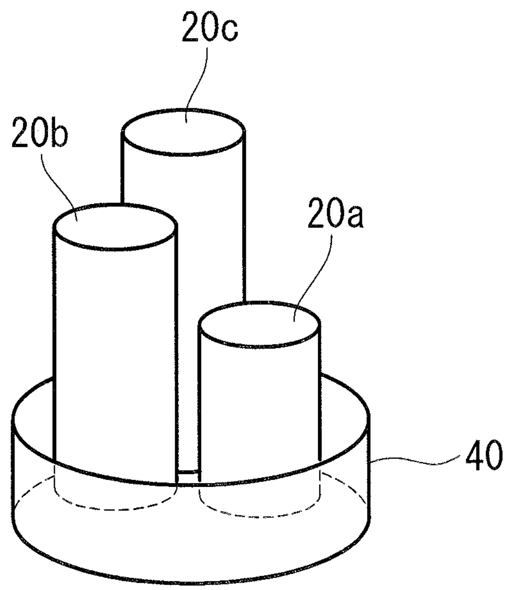


FIG. 18A

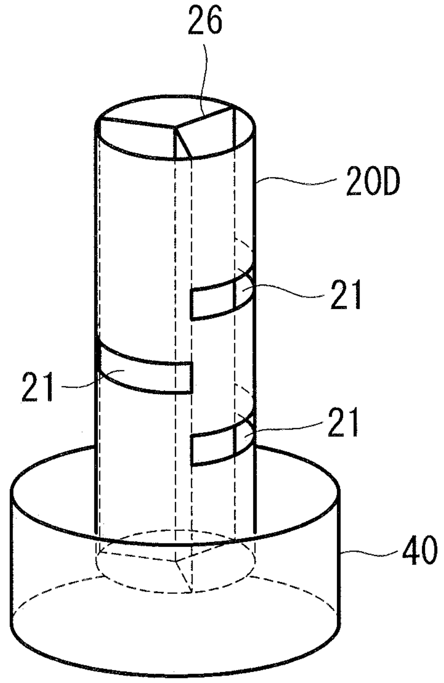


FIG. 18B

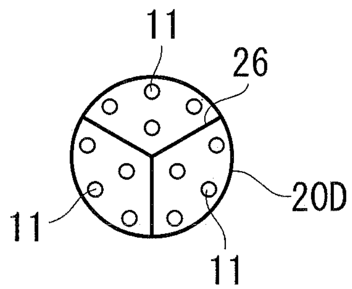


FIG. 19

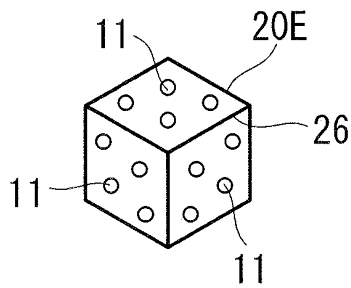


FIG. 20

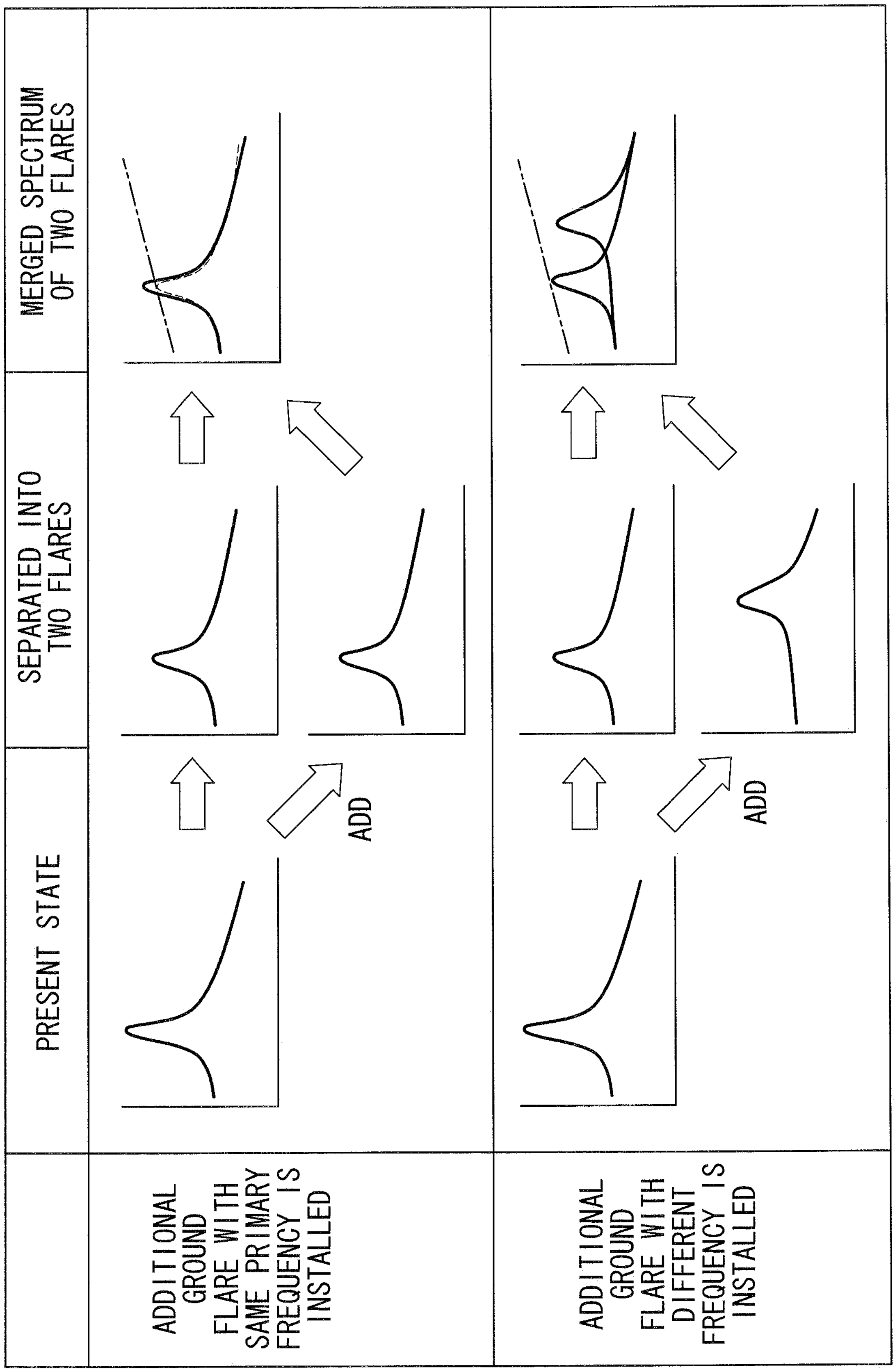

PRESENT STATE
SEPARATED INTO TWO FLARES
MERGED SPECTRUM OF TWO FLARES
ADDITIONAL GROUND FLARE WITH SAME PRIMARY FREQUENCY IS INSTALLED
ADD
ADDITIONAL GROUND FLARE WITH DIFFERENT FREQUENCY IS INSTALLED
ADD

FIG. 21

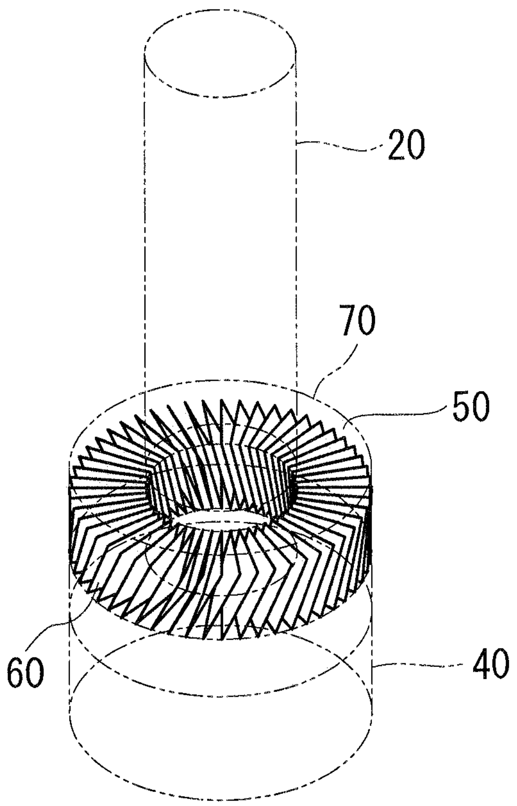


FIG. 22

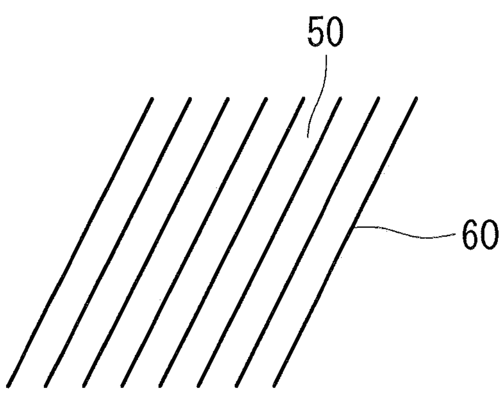


FIG. 23

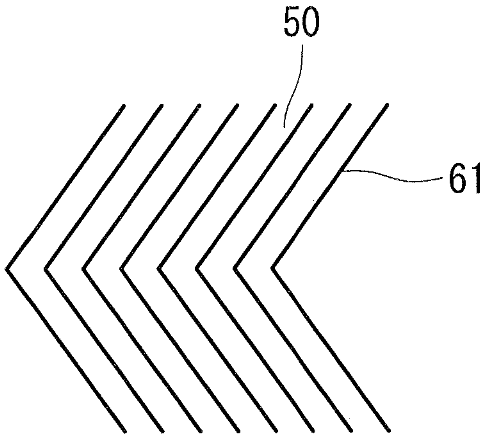


FIG. 24

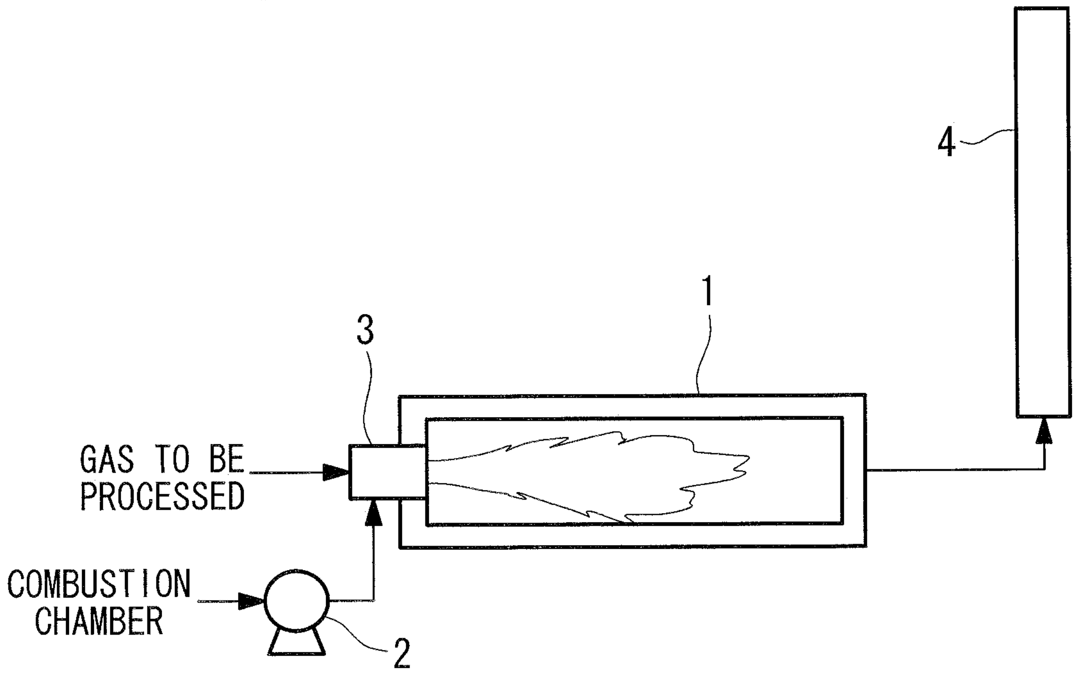


FIG. 25

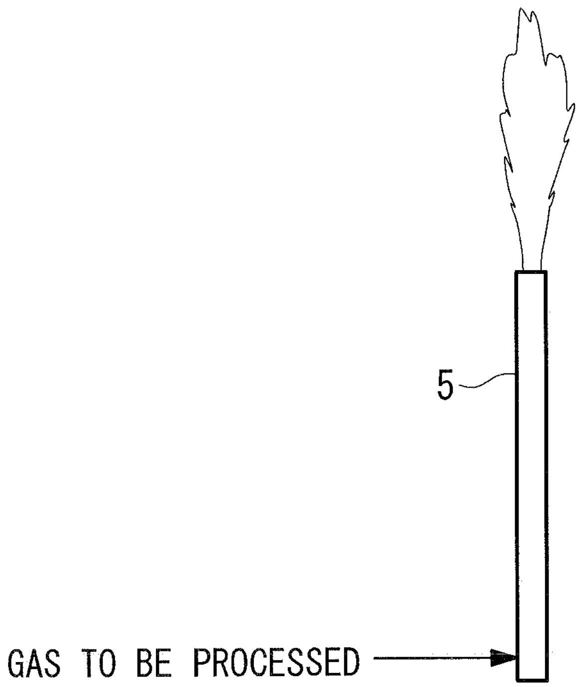
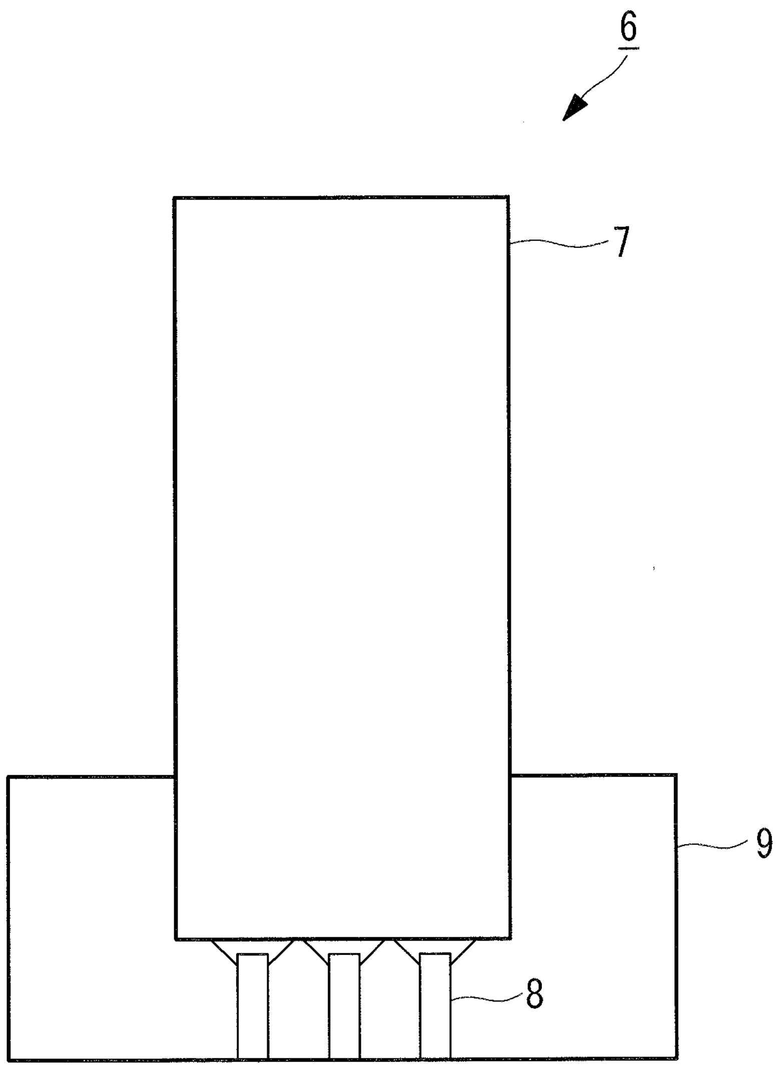


FIG. 26



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 58002331 A **[0007]**
- JP 54045838 A **[0007]**
- JP 2629410 B **[0008]**
- US 4137036 B **[0009]**