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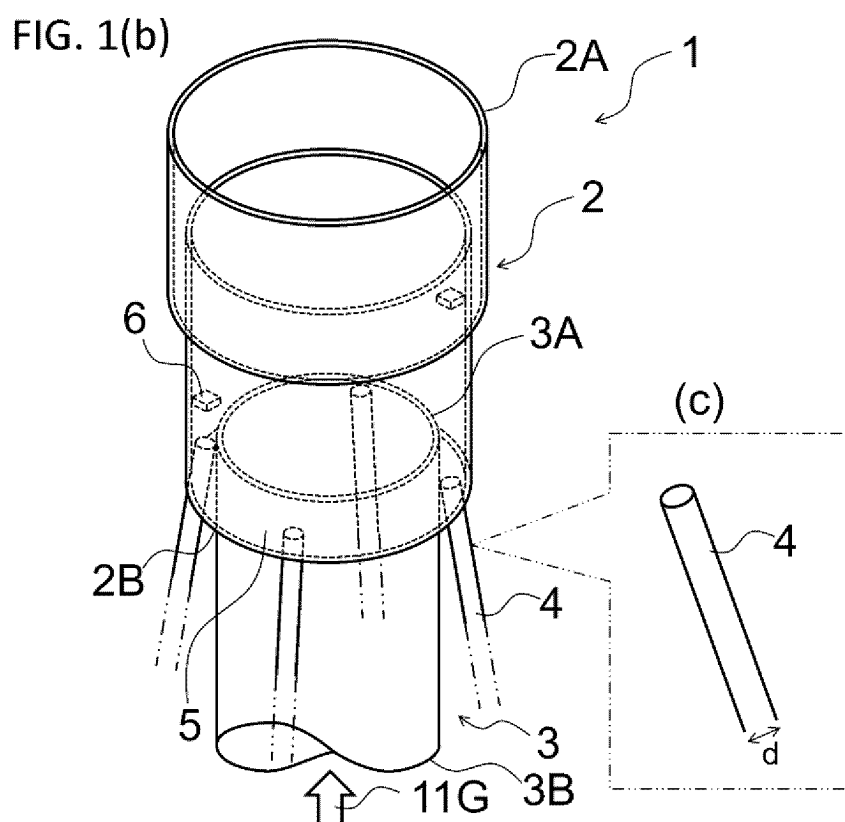
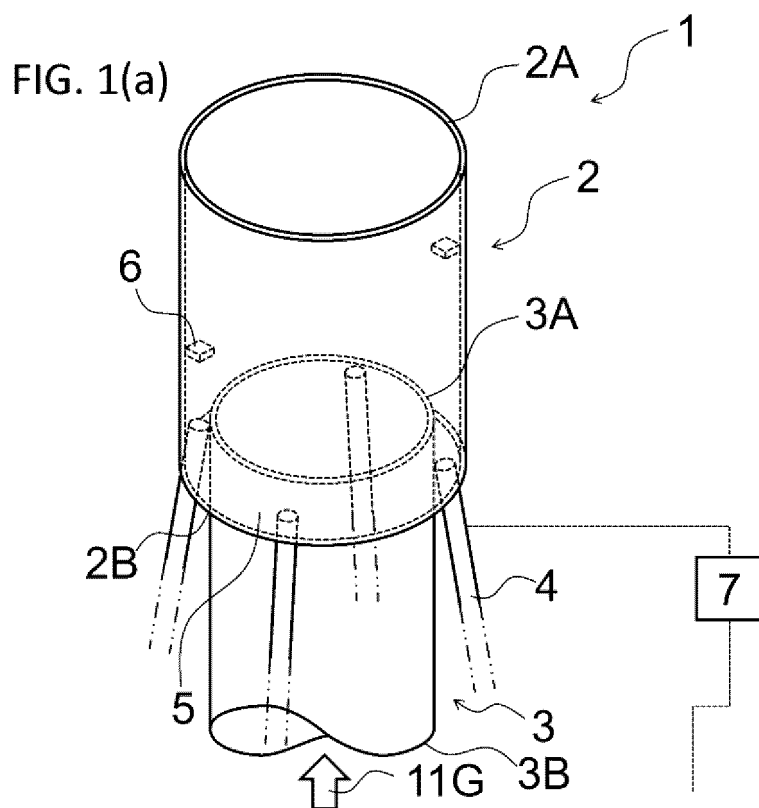
(54) **DEVICE FOR COMBUSTING COKE OVEN EMISSION GASES, METHOD OF COMBUSTING COKE OVEN EMISSION GASES, AND METHOD OF DESIGNING DEVICE FOR COMBUSTING COKE OVEN EMISSION GASES**

(57) Provided is a combustion technology for coke oven emission gas. Specifically, coke oven emission gas is allowed to pass through the inside of a bleeder pipe, and combustion-promoting gas is blown through a blow-in pipe inserted into the gap between the inner wall of a hood and the outer wall of the bleeder pipe, the hood being arranged coaxially with the axis of an end of the bleeder pipe, and having one end that is open to the atmosphere side and the other end enveloping the end of the bleeder pipe, where one or more selected from the gas flow rate M_J [kg/s], the gas flow velocity v_J [m/s], and the gas pressure P_J [Pa] of the combustion-promoting gas is/are adjusted so as to satisfy the Expression:

$$\{M_J/(M_G+M_D)\} \times \{0.5 \times v_J^2 + \gamma/(\gamma-1) \times P_J/\rho_J\} \geq 370000 \times \ln(d) + 2300000$$

(where M_G represents the flow rate [kg/s] of an emission gas in the bleeder pipe, M_D represents the theoretical flow rate [kg/s] of air necessary for the combustion of the emission gas, γ represents the specific heat ratio, ρ_J represents the density [kg/m³] of the combustion-promoting gas, and d represents the inner diameter [m] of the blow-in pipe).

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Description

Technical Field

5 **[0001]** The present invention relates to a combustion apparatus for coke oven emission gas, a combustion method for coke oven emission gas, and a method of designing the combustion apparatus for coke oven emission gas, each capable of enhancing the complete combustion of the coke oven emission gas, and thus reducing the discharge amount of the coke oven emission gas in an incomplete combustion state.

10 Background Art

[0002] Steel mills recover coke oven gas, also known as C gas, which is generated during the process of producing coke. However, if the recovery blower for the coke oven gas stops due to power outages or other trouble, it becomes necessary to discharge the continuously generated coke oven gas from the coke oven. In this situation, the coke oven gas is combusted
15 for detoxification purposes before being discharged. Incomplete combustion during the discharge process would cause black smoke, which has adverse effects on human health. Therefore, it is required to combust the gas completely before its discharge.

[0003] An emission bleeder is widely known as an apparatus for discharging coke oven gas. As shown in FIG. 10, an emission bleeder 1 has a double-pipe structure including a hood 2 that communicates with the atmosphere at its opening
20 located in the upper portion of the drawing, and a bleeder pipe 3 that is enveloped within an end of the hood 2 on the side opposite to the opening of the hood 2 and that communicates with the source of generation of coke oven gas. In a typical conventional emission bleeder 1, combustible gas 11G is fed into the bleeder pipe 3 by pressure, and resulting negative pressure allows oxygen-containing gas (e.g., air) to be drawn into the hood 2 through a gap 5 between the hood 2 and the bleeder pipe 3. Then, the gases are mixed and are ignited by an ignition device 6, so that complete combustion of the
25 combustible gas 11G can be achieved. However, when such a method of drawing in air using negative pressure is used, due to insufficient pressure of the coke oven gas 11G, a sufficient amount of oxygen-containing gas (air) cannot be drawn into the inside of the hood 2 through the gap 5, making it difficult to achieve complete combustion of the coke oven gas 11G. Therefore, a large amount of the coke oven gas 11G is discharged into the atmosphere in an incomplete combustion state, which is problematic.

30 **[0004]** Patent Literature 1 is cited as a document disclosing a technology related to such an emission bleeder. Specifically, Patent Literature 1 discloses adjusting the size, number, and spacing of air passages provided in a hood, for example, to adjust the amount of air to be drawn into the hood and thus improve combustion efficiency.

[0005] Patent Literature 2 is cited as another document that also discloses a technology related to such an emission bleeder. Specifically, Patent Literature 2 discloses improving combustion efficiency by passing air through a bleeder pipe
35 so that combustible gas can be drawn in through a gap between the bleeder pipe and a hood.

[0006] Patent Literature 3 discloses a gas burner-type apparatus for increasing the amount of air in a combustion zone (facilitating the combustion of combustible gas in the atmosphere) that includes a venturi tube and a motive fluid feeding pipe. The apparatus includes a combustion zone that receives the combustible gas via a combustion gas feeding pipe. The end of the feeding pipe is surrounded by multiple devices that inject a motive fluid into the venturi tube located above the
40 combustion zone.

[0007] Patent Literature 4 discloses a flare gas burner for smokeless combustion of waste gas. The flare gas burner includes a device that discharges a high-pressure motive fluid from a manifold into a passage defined by the interior of a deflector and the exterior of a waste gas delivery pipe.

[0008] Patent Literature 5 discloses an apparatus for enhancing combustion with a configuration in which high-pressure
45 air is discharged in the form of a high-velocity jet from a nozzle mounted on a ring manifold surrounding a flare stack at a predetermined distance below a stack outlet, and in which the upper portion of the flare stack is surrounded by an outer shield that is provided with internal guide vanes at the top portion and perforated with air passages 52 at the bottom portion.

[0009] Patent Literature 6 discloses a combustion emission pipe for combustion and emission of unrefined coke oven gas. The combustion emission pipe includes blow-in pipes that jet vapor through the gap between a bleeder pipe and a
50 hood and through the inside of the bleeder pipe.

Citation List

Patent Literature

55 **[0010]**

Patent Literature 1: Japanese Patent Laid-Open No. 2010-236856

Patent Literature 2: Japanese Patent Laid-Open No. 2010-286230

Patent Literature 3: Japanese Translation of PCT International Application Publication No. 2002-534653

Patent Literature 4: U.S. Patent No. 04643669

Patent Literature 5: Japanese Translation of PCT International Application Publication No. 2004-537702

Patent Literature 6: Japanese Patent Laid-Open No. 2020-117623

Summary of Invention

Technical Problem

[0011] However, the conventional technologies have the following problems to be solved.

[0012] The technology disclosed in Patent Literature 1 requires additional components or systems, for example, for controlling the amount of air to be drawn into the hood. This makes the configuration and operation of the apparatus complex, which is problematic. In particular, significant modifications to the hood of the emission bleeder are required.

[0013] In addition, Patent Literature 2 has a drawback that requires modification of the entire apparatus to apply its technology to a typical conventional emission bleeder. Specifically, the gas flow is required to be different from the conventional gas flow, such as that air is drawn into the hood by passing the combustible gas through the bleeder pipe.

[0014] Each of the technologies described in Patent Literatures 3 through 6 involves forcibly blowing another gaseous fluid into combustible gas, but does not define either the efficient blowing conditions or the design of the apparatus. In particular, the technology described in Patent Literature 6 involves jetting gas from the center of the bleeder pipe. However, the inventors believe that such a configuration has the disadvantage of requiring high modification costs without achieving sufficient combustion efficiency.

[0015] The present invention has been made in view of the above circumstances, and an object of the present invention is to provide a combustion apparatus for coke oven emission gas, a combustion method for coke oven emission gas, and a method of designing the combustion apparatus for coke oven emission gas, each capable of improving combustion efficiency for combustible gas while reducing the modification cost for an emission bleeder that has been conventionally used.

Solution to Problem

[0016] In view of the above problems, the inventors have conducted intensive studies on the conditions of combustion-promoting gas to be blown into the emission bleeder, and thus arrived at the present invention.

[0017] A combustion apparatus for coke oven emission gas according to the present invention that advantageously solves the above problems, includes

a bleeder pipe having one end that communicates with a portion where the coke oven emission gas is generated and allowing the coke oven emission gas to pass through its inside,
a hood having one end open to an atmosphere side and the other end enveloping the other end of the bleeder pipe, arranged so as to be coaxial with an axis of the other end of the bleeder pipe, and formed of at least one cylinder,
a gas blow-in pipe inserted from below into a gap between an outer wall of the bleeder pipe and an inner wall of the hood, and
a control means for adjusting a blowing condition for combustion-promoting gas to be blown from the gas blow-in pipe, characterized in that
the control means is configured to adjust one or more in combination selected from a gas flow rate M_J [kg/s], a gas flow velocity v_J [m/s], and gas pressure P_J [Pa] of the combustion-promoting gas to be blown through the blow-in pipe so as to satisfy Expression (1) below:

$$\{M_J/(M_G + M_D)\} \times \{0.5 \times v_J^2 + \gamma/(\gamma - 1) \times P_J/\rho_J\} \geq 370000 \times \ln(d) + 2300000 \quad (1),$$

wherein

M_G represents a flow rate [kg/s] of the emission gas in the bleeder pipe,

M_D represents a theoretical flow rate [kg/s] of air necessary for combustion of the emission gas,

γ represents a specific heat ratio,

ρ_J represents a density [kg/m³] of the combustion-promoting gas, and

d represents an inner diameter [m] of the blow-in pipe.

[0018] The combustion apparatus for coke oven emission gas according to the present invention is considered to have more preferable solution means as follows:

- (a) a ratio L/D is between 0.5 and 2.5, inclusive, provided that an inner diameter of the bleeder pipe is D [m] and a distance from the tip of the other end of the bleeder pipe to the tip of the one end of the hood is L [m];
- (b) an angle θ is between 0° and 30° , inclusive, and a value of $W/(d \cdot \cos\theta)$ is in a range of 0.85 to 1.6, inclusive, provided that the gap between the outer wall of the bleeder pipe and the inner wall of the hood is W [m], the inner diameter of the blow-in pipe is d [m], and an angle formed between the bleeder pipe in an axial direction and the blow-in pipe in the axial direction is θ [$^\circ$].

[0019] A combustion method for coke oven emission gas according to the present invention that advantageously solves the above problems includes

allowing coke oven emission gas to pass through the inside of a bleeder pipe having one end that communicates with a portion where the coke oven emission gas is generated,

providing a hood having one end open to an atmosphere side and the other end enveloping the other end of the bleeder pipe, arranged so as to be coaxial with an axis of the other end of the bleeder pipe, and formed of at least one cylinder, and

blowing combustion-promoting gas through a blow-in pipe inserted into a gap between an inner wall of the hood and an outer wall of the bleeder pipe. The method further includes adjusting one or more in combination selected from a gas flow rate M_j [kg/s], a gas flow velocity v_j [m/s], and gas pressure P_j [Pa] of the combustion-promoting gas to be blown through the blow-in pipe so as to satisfy Expression (1) above.

[0020] A method of designing a combustion apparatus for coke oven emission gas according to the present invention that advantageously solves the above problems includes, in designing a combustion apparatus for coke oven emission gas provided with

a bleeder pipe having one end communicating with a portion where the coke oven emission gas is generated and allowing the coke oven emission gas to pass through an inside of the bleeder pipe,

a hood having one end open to an atmosphere side and the other end enveloping the other end of the bleeder pipe, arranged so as to be coaxial with an axis of the other end of the bleeder pipe, and formed of at least one cylinder,

a gas blow-in pipe inserted from below into a gap between an outer wall of the bleeder pipe and an inner wall of the hood, and

a control means for adjusting a blowing condition for combustion-promoting gas to be blown through the gas blow-in pipe,

designing an inner diameter d [m] of the blow-in pipe so as to satisfy Expression (1) above.

[0021] The method of designing a combustion apparatus for coke oven emission gas according to the present invention is considered to have more preferable solution means as follows:

- (c) a ratio L/D is set in a range of 0.5 to 2.5, inclusive, provided that an inner diameter of the bleeder pipe is D [m], and a distance from the tip of the other end of the bleeder pipe to the tip of the one end of the hood is L [m];
- (d) an angle θ is set in a range of 0° to 30° , inclusive, and a value of $W/(d \cdot \cos\theta)$ is set in a range of 0.85 to 1.6, inclusive, provided that the gap between the outer wall of the bleeder pipe and the inner wall of the hood is W [m], the inner diameter of the blow-in pipe is d [m], and an angle formed between the bleeder pipe in an axial direction and the blow-in pipe in the axial direction is θ [$^\circ$].

Advantageous Effects of Invention

[0022] The present invention can promote the complete combustion of coke oven emission gas and thus reduce the amount of emission of the coke oven emission gas in an incomplete combustion state without the need to significantly modify an emission bleeder.

Brief Description of Drawings

[0023]

FIGs. 1(a) to (c) are schematic views showing a combustion apparatus for coke oven emission gas according to an

embodiment of the present invention. FIG. 1(a) represents a case where a hood in the form of a single cylinder is provided; FIG. 1(b) represents a case where a hood in the form of a double cylinder is provided; FIG. 1(c) represents an enlarged view of a blow-in pipe.

FIG. 2 is a view showing a coke oven provided with the combustion apparatus according to the above embodiment.

FIGs. 3(a) and (b) are schematic longitudinal sectional views showing the combustion state of coke oven emission gas that has undergone combustion using the combustion apparatus according to the above embodiment. FIG. 3(a) shows a flow velocity distribution. FIG. 3(b) shows a flow velocity vector and a temperature distribution.

FIGs. 4(a) and 4(b) are schematic longitudinal sectional views showing the combustion state of coke oven emission gas that has undergone combustion using the combustion apparatus according to the above embodiment. FIG. 4(a) shows a pressure distribution when the ratio LID between the inner diameter D of a bleeder pipe and the distance L from the tip end of the bleeder pipe to the open end of the hood is 0.92, and FIG. 4(b) shows a pressure distribution when the ratio LID is 0.25.

FIGs. 5(a) and 5(b) are schematic longitudinal sectional views showing the combustion state of coke oven emission gas that has been combusted using the combustion apparatus according to the above embodiment. FIG. 5(a) shows a gas flow when the ratio LID between the inner diameter D of the bleeder pipe and the distance L from the tip end of the bleeder pipe to the open end of the hood is 0.92, and FIG. 5(b) shows a gas flow when the ratio LID is 0.25.

FIG. 6 is a graph showing the influence of the inner diameter d of the blow-in pipe on the relationship between the value of the left-hand side of Expression (1) and the ratio of the amount of soot generated in a combustion experiment for coke oven emission gas conducted using the combustion apparatus according to the above embodiment.

FIG. 7 is a graph showing the relationship between the ratio LID of the distance L from the tip end of the bleeder pipe to the open end of the hood with respect to the inner diameter D of the bleeder pipe and the ratio of the amount of soot generated in a combustion experiment for coke oven emission gas conducted using the combustion apparatus according to the above embodiment.

FIG. 8 is a schematic longitudinal sectional view showing the gap between the outer wall of the bleeder pipe and the inner wall of the hood, and the tilt angle of the blow-in pipe in the combustion apparatus according to the above embodiment.

FIG. 9 is a graph showing the influence of the gap between the outer wall of the bleeder pipe and the inner wall of the hood and the tilt angle of the blow-in pipe on the ratio of the amount of soot generated in a combustion experiment for coke oven emission gas conducted using the combustion apparatus according to the above embodiment.

FIG. 10 is a schematic view showing a conventional emission bleeder.

FIGs. 11(a1) through (c2) are schematic views showing the relationship between the position of the blow-in pipe and a gas flow. Specifically, FIGs. 11(a1) and 11(a2) each show an example of the conventional emission bleeder, FIGs. 11(b1) and 11(b2) each show an example in which gas is blown into the gap between the outer wall of the bleeder pipe and the inner wall of the hood, and FIGs. 11(c1) and 11(c2) each show an example in which gas is blown from the center of the bleeder pipe.

Description of Embodiments

[0024] Hereinafter, an embodiment of the present invention will be specifically described. Note that the drawings are only schematic and may differ from the actual ones. In addition, the following embodiment only describes examples of an apparatus and a method for embodying the technical idea of the present invention. Thus, the configuration of the present invention is not limited to the embodiments described below. That is, the technical idea of the present invention can be modified in various ways within the technical scope recited in the claims.

[0025] An overview of a coke oven will be described with reference to FIG. 2. A coke oven 11 includes carbonization chambers 12 and combustion chambers 13 that are alternately arranged. In each combustion chamber 13, heat is generated by the combustion of combustion gas. In each carbonization chamber 12, coal is carbonized with the heat generated in the adjacent combustion chambers 13. During the carbonization process of coal, combustible gas called COG gas (hereinafter, C gas), which is a type of combustible gas, is generated. The C gas is composed mainly of H_2 , CO, and various other hydrocarbon gases, for example. FIG. 2 only shows two carbonization chambers 12 and two combustion chambers 13, but in practice, a large number of combinations of carbonization chambers 12 and combustion chambers 13 are provided toward the depth side of the drawing.

[0026] Each of the carbonization chambers 12 has a riser pipe 14 and a dry main 15 at its upper portion. The riser pipe 14 collects C gas that has risen, and the dry main 15 aggregates the C gas sucked from the plurality of carbonization chambers 12 via the riser pipe 14. An emission bleeder 1 is connected to the dry main 15. The C gas generated in the plurality of carbonization chambers 12 passes through the riser pipe 14 and the dry main 15, and is then discharged to the atmosphere through the emission bleeder 1.

[0027] During regular operation of a plant, C gas generated in each carbonization chamber is sucked and recovered by gas suction equipment (not shown) and then reused as an operation gas for various types of equipment. Meanwhile, in the

event of trouble in a plant, such as a power failure, it would be impossible to sufficiently recover and reuse C gas generated in each carbonization chamber. As a result, it is necessary to discharge the C gas to the atmosphere as coke oven emission gas through the emission bleeder 1.

[0028] As shown in FIG. 1, a combustion apparatus for coke oven gas according to the present embodiment includes the emission bleeder 1 and a control means 7 for controlling a combustion-promoting gas. The emission bleeder 1 includes a hood 2, a bleeder pipe 3, and blow-in pipes 4. Although FIG. 1(a) shows an example in which the hood 2 is a single-wall cylindrical member and FIG. 2(b) shows an example in which the hood is a double-wall cylindrical member, the present invention is not limited thereto. The bleeder pipe 3 communicates with the dry main 15 of the coke oven 11, where C gas 11G is generated, at one end (not shown), which is an end face 3B located in the lower portion of the drawing, allowing the C gas 11G to pass through toward the hood 2. In FIGS. 1(a) and 1(b), the C gas 11G flows from the lower portion toward the upper portion. The hood 2 discharges the C gas 11G, which has been fed from the bleeder pipe 3, to the atmosphere through one end 2A (the upper end) open to the atmosphere. In addition, the other end 3A of the bleeder pipe 3 is enveloped within the hood 2. More specifically, the other end 2B (the lower end face) of the hood 2 is located at a position below the other end 3A (the upper end face) of the bleeder pipe 3 to thus form a region where the bleeder pipe 3 is enveloped within the hood 2. In the region where the bleeder pipe 3 is enveloped within the hood 2, a gap 5 is formed between the inner wall of the hood 2 and the outer wall of the bleeder pipe 3. Note that the inner wall of the hood 2 is provided with an ignition device 6 that first ignites the C gas 11G, which is the coke oven emission gas.

[0029] In the present embodiment, the blow-in pipes 4 are provided, each of which can inject gas (hereinafter referred to as "combustion-promoting gas") in the inside of the hood 2 through the gap 5, which is formed between the bleeder pipe 3 and the hood 2. Each blow-in pipe 4 may be connected to a pump (not shown), for example, to feed a combustion-promoting gas by pressure. When the combustion-promoting gas is blown from the blow-in pipes 4, a flow of not only the combustion-promoting gas but also gas (hereinafter referred to as "associated gas"), such as air, which flows into the gap 5 by being entrained in a region around the combustion-promoting gas due to the effect of the gas viscosity, is generated. The combustion-promoting gas and the associated gas injected into the gap 5 rise along the outer wall of the bleeder pipe 3 and then are mixed with the coke oven emission gas (C gas 11G), which is fed from the inside of the bleeder pipe 3, inside of the hood 2, so that the gasses are stirred and mixed. After these gasses are stirred and mixed, they are ignited by the ignition device 6. The resulting gas discharged from the upper end of the hood 2 is mixed with the outside air and thus combusted so that a flame (not shown) is formed in an upward direction from the upper end face of the bleeder pipe 3. In the present embodiment, the mixed gas of the combustion-promoting gas fed from the blow-in pipes 4, the C gas, and the combustion gas is discharged from the upper end of the hood 2 as a high-speed jet as indicated by a grayscale velocity distribution in FIG. 3(a). In FIG. 3(a), a darker portion indicates a higher velocity. As seen in a velocity vector indicated by the arrow and a temperature distribution indicated in grayscale in FIG. 3(b), when the atmosphere is entrained in the high-speed jet, the coke oven emission gas (C gas), the combustion-promoting gas, and the associated gas are sufficiently stirred. Thus, the complete combustion of the C gas is promoted. In the present embodiment, the control means 7 is provided for adjusting the flow rate, flow velocity, or pressure of the combustion-promoting gas to be blown into the blow-in pipes 4. The control means 7 adjusts the blowing conditions for the combustion-promoting gas based on the information of the composition and flow rate of the C gas so as to promote the complete combustion of the coke oven emission gas.

[0030] The blow-in pipes 4 may be provided at positions where they can inject the combustion-promoting gas into the gap 5, for example, may be provided such that the upper end face of the blow-in pipe 4 is located at a position below the upper end face of the bleeder pipe 3. One or more blow-in pipes 4 may be provided for a combination of the bleeder pipe 3 and the hood 2, and a plurality of blow-in pipes 4 may be provided in the circumferential direction of one bleeder pipe 3. In the present embodiment, it is possible to promote the complete combustion of the C gas, which is the coke oven emission gas, by entraining a sufficient amount of the atmosphere therein as long as the following Expression is satisfied:

$$\{M_J/(M_G + M_D)\} \times \{0.5 \times v_J^2 + \gamma/(\gamma - 1) \times P_J/\rho_J\} \geq 370000 \times \ln(d) + 2300000 \quad (1),$$

= where M_G [kg/s] represents the flow rate of the emission gas in the bleeder, M_D [kg/s] represents the theoretical flow rate of air necessary for the combustion of the emission gas, M_J [kg/s] represents the flow rate of the combustion-promoting gas to be blown through the blow-in pipe, v_J [m/s] represents the flow velocity of the combustion-promoting gas, γ represents the specific heat ratio, P_J [Pa] represents the blowing pressure, ρ_J [kg/m³] represents the gas density, and d [m] represents the inner diameter of the blow-in pipe (see the enlarged view of FIG. 1(c)). When a plurality of blow-in pipes are provided, the left-hand side of Expression (1) above may be set to $\Sigma[M_J \times \{0.5 \times v_J^2 + \gamma/(\gamma - 1) \times P_J/\rho_J\}]/(M_G + M_D)$. Σ represents the sum of the blow-in pipes 4. This is based on the concept that, as long as, at a time when the combustion-promoting gas having the fluid energy defined as $[M_J \times \{0.5 \times v_J^2 + \gamma/(\gamma - 1) \times P_J/\rho_J\}]$ is entrained with the surrounding atmosphere to form a jet of a mixture gas (theoretical amount of air) with an emission gas and air necessary for the complete combustion of the amount of the emission gas, the mixture gas has energy $\{(M_G + M_D) \times E_{ML}\}$ [J] of a given level or higher, the complete combustion of the C gas is promoted and black smoke (the generation of soot) is thus reduced. E_{ML} represents the energy [J/kg] per unit mass. It is assumed that $[M_J \times \{0.5 \times v_J^2 + \gamma/(\gamma - 1) \times P_J/\rho_J\}] \propto \{(M_G + M_D) \times E_{ML}\}$ by assuming that the fluid energy of the

combustion-promoting gas is proportional to the energy necessary for the complete combustion of the C gas. Since ($M_G + M_D$) can be calculated in advance, comparative evaluation was performed on a numerical value, which is obtained by dividing $[M_J \times \{0.5 \times v_J^2 + \gamma/(\gamma-1) \times P_J/\rho_J\}]$ by ($M_G + M_D$), and the amount of soot generated. Then, it was found that the expression can be arranged with the above indices. Since there are a pressure loss due to viscosity and a flow velocity distribution within the jet, E_{ML} cannot be determined theoretically, but the inventors have found that E_{ML} based on the above concept can be expressed as $370000 \times \ln(d) + 2300000$ as described in examples below.

[0031] The combustion-promoting gas is not limited to any particular gas as long as it is gas, but it is preferably incombustible gas to prevent explosion in the hood 2 and incomplete combustion. In particular, among incombustible gases, a mixed gas of one or more selected from air, nitrogen gas, and water vapor is preferably used. Even when nitrogen gas containing no oxygen is adopted as the combustion-promoting gas, it is possible to promote the complete combustion of the C gas because the high-speed jet entrains a sufficient amount of atmosphere (i.e., associated gas), and oxygen contained in the entrained atmosphere thus reacts with the C gas as described above.

[0032] Applying the combustion apparatus for coke oven emission gas of the present embodiment to the coke oven 11 can, even in the event of trouble such as a power outage, promote the complete combustion of C gas generated in and emitted from the carbonization chambers 12, and thus allow the C gas to be discharged into the atmosphere as a less harmful substance, like CO_2 and H_2O . In addition, when the combustion apparatus is applied to the coke oven 11, air is preferably used as gas to be injected through the blow-in pipes 4. When air is used as a combustion-promoting gas in a plant, the combustion-promoting gas can be supplied to the emission bleeder 1 more easily and promptly than when other gases are used, even in an emergency.

[0033] Further, provided that the inner diameter of the bleeder pipe 3 is represented by D [m], and the distance from the tip end (the upper end face 3A) of the bleeder pipe to the tip end (the upper end face 2A) of the hood is represented by L [m], the ratio L/D [-] is preferably set to the range of 0.5 to 2.5, inclusive. As shown by a pressure distribution in FIG. 4(a), when $L/D=0.92$, which falls within the above range, and a high-speed jet of combustion-promoting gas is blown into the hood 2 from the blow-in pipes 4, the high-speed jet generates a sufficient negative-pressure region in the hood 2 at a position above the upper end face 3A of the bleeder pipe 3. The negative pressure causes the atmosphere (air) to be suddenly sucked on the atmosphere side of the upper end face 2A of the hood 2, so that the atmosphere and the coke oven emission gas are stirred and mixed, and thus, oxygen is supplied to the inside of a flame. This can promote the combustion of the C gas, which is the coke oven emission gas.

[0034] Meanwhile, as shown by a pressure distribution in FIG. 4(b), when the ratio $L/D=0.25 < 0.5$ is satisfied, a sufficient negative-pressure region is not formed in the hood 2, reducing the effect of blowing in the combustion-promoting gas. That is, the ratio L/D is preferably 0.5 or more. Meanwhile, if the ratio L/D is too high, an energy loss occurs due to friction between the fluids and due to friction between the fluid and the wall surface resulting from viscosity. Thus, the ratio L/D is preferably set to 2.5 or less.

[0035] The mechanism in which the amount of soot generated in the combustion apparatus according to the present embodiment is reduced will be described with reference to FIG. 5 as an example. The flow velocity of a jet FJ blown in from the blow-in pipe 4 is higher than the flow velocity of the C gas FU. Therefore, the C gas FU is first entrained in the jet FJ within the hood 2. When the jet FJ with the C gas FU sufficiently entrained therein comes out of the hood 2, the jet FJ entrains a large amount of the atmosphere FA. This promotes the mixing of the C gas and air, and the C gas is thus expected to be completely combusted. Moreover, the large amount of air causes the combustion temperature to be lowered, thus reducing the generation of soot. In this case, as shown in FIG. 5(a), the hood 2 needs to be kept sufficiently high. When the hood 2 is not sufficiently high as shown in FIG. 5(b), the atmosphere outside the hood will be entrained in the jet FJ before the C gas is sufficiently entrained in the jet FJ, which in turn makes it difficult to sufficiently mix the C gas and air.

[0036] The combustion apparatus for coke oven emission gas according to the present embodiment includes a control means for adjusting one or more selected from the gas flow rate M_J , the gas flow velocity v_J , and the gas pressure P_J of the combustion-promoting gas to be blown in through the blow-in pipe(s) 4 so as to satisfy Expression (1) above based on information on the composition and the amount of the C gas generated grasped in advance, information on a flowmeter provided in the bleeder pipe 3, or information obtained by analyzing the C gas in the bleeder pipe 3. The control means may be configured from a computer, for example.

[0037] The combustion method for coke oven emission gas that uses the combustion apparatus for coke oven emission gas according to the present embodiment includes adjusting one or more in combination selected from the gas flow rate M_J , the gas flow velocity v_J , and the gas pressure P_J of the combustion-promoting gas based on the composition and the amount of the C gas generated.

[0038] The method of designing a combustion apparatus for coke oven emission gas according to the present embodiment includes designing the inner diameter d [m] of the blow-in pipe so as to satisfy Expression (1) above based on the range of the composition of the coke oven emission gas and the transition of the amount of the gas generated, which have been grasped in advance, and on the controllable values of the combustion-promoting gas, such as the gas flow rate range, pressure range, and physical properties. Note that when a plurality of blow-in pipes 4 are used, it is preferable to design the inner diameter d [m] of each blow-in pipe by correcting Expression (1) using the sum of the fluid energy of the

combustion-promoting gas. Note that the gap 5 between the inner wall of the hood 2 and the outer wall of the bleeder pipe is designed such that at least the blow-in pipe(s) 4 can be inserted into the gap 5.

Examples

(Example 1)

[0039] In the present example, the amount of soot generated, which is the main component of black smoke, was attempted to be quantitatively evaluated through simulation. Specifically, NuFD/FrontFlowRed was used as the simulation software to reproduce the combustion of a coke oven gas with each emission bleeder. Then, the condition of a flame (i.e., the flame temperature) was examined, and the amount of soot generated in each of a case where no blow-in pipe is provided (conventional example) and a case where a blow-in pipe is provided (invention example) was examined as the ratio of the amount of soot generated, provided that the amount of soot generated in the conventional example is 1.0. The amount of soot generated is defined as the maximum value of the total amount of soot across horizontal cross-sections in the simulation. The ordinate axis of FIG. 6 represents the ratio ϕ of the maximum value of the maximum amount of soot generated under each blowing condition with respect to the maximum amount of soot generated in the conventional example. The abscissa axis of FIG. 6 represents the left-hand side of Expression (1). This corresponds to a value obtained by dividing the energy of the combustion-promoting gas by the sum of the mass flow rate of the coke oven gas and the mass flow rate of air necessary for the complete combustion of the coke oven gas. FIG. 6 shows that the ratio ϕ of the amount of soot generated decreases after the left-hand side of Expression (1) attains a given value or more for each of the different inner diameters d of the blow-in pipe 4. The ratio ϕ of the amount of soot generated is also approximated to a curve using a sigmoid function. Provided that $\phi = 1 - \{1 / (1 + e^{-\alpha(x-\beta)})\}$, where $\alpha = 5.00005$ and $\beta = 370000 \times \ln(d) + 2300000$, it is found that each plot can be roughly approximated to a curve. Here, β is the inflection point of the function, and is also a point at which ϕ is 0.5, that is, the amount of soot generated is 0.5 with respect to that of the conventional example. This indicates that when Expression (1) above is satisfied, the complete combustion of a C gas is promoted, reducing black smoke (i.e., the generation of soot).

[0040] Next, FIG. 7 shows the simulation results of examining the amount of soot generated by changing the ratio LID variously while fixing the other conditions to $d = 0.01$ [m] and $\{M_J / (M_G + M_D)\} \times \{0.5 \times v_J^2 + \gamma / (\gamma - 1) \times P_J / \rho_J\} = 7.75 \times 10^5$ [J/kg]. From FIG. 7, it is found that the ratio ϕ of the amount of soot generated is minimum when the ratio LID is close to 1. When the ratio LID is less than 1, the amount of soot generated suddenly increases. Meanwhile, when the ratio LID is more than 1, the amount of soot generated moderately increases. When a high-speed jet of a combustion-promoting gas is blown into the hood 2 from the blow-in pipe 4, negative pressure is generated in the hood 2 at a position above the tip end 3A of the bleeder pipe due to the entrainment of the high-speed jet. The negative pressure causes the atmosphere (air) to be suddenly sucked on the atmosphere side of the upper end 2A of the hood 2, so that the atmosphere and the coke oven emission gas are stirred and mixed. This allows oxygen to be supplied to the inside of a flame, and thus can promote the combustion of the C gas that is the coke oven emission gas. As shown in FIG. 4(b), under the condition of $0.5 > L/D$, negative pressure is not sufficiently formed in the hood 2, thus reducing the effect of blowing in the combustion-promoting gas. Meanwhile, when LID is too high, the fluid energy is gradually reduced due to the viscosity between the fluids and the viscosity between the fluid and the wall inside the hood 2. As a result, the effect of entraining the atmosphere at the upper end of the hood is reduced. Therefore, FIG. 7 shows that the ratio LID is preferably in the range of 0.5 to 2.5, inclusive.

(Example 2)

[0041] The influence of the gap W [m] between the outer wall of the bleeder pipe 3 and the inner wall of the hood 2, and the angle θ [°] of the blow-in pipe in the axial direction on the amount of soot generated was examined using simulation software as in Example 1. FIG. 9 shows the results of the amount of soot generated with the inner diameter of the blow-in pipe represented by d [m]. The abscissa axis of FIG. 9 represents $W / (d \cdot \cos\theta)$. The ordinate axis of FIG. 9 represents the ratio of the amount of soot generated as in Example 1. Besides, when the angle θ is too large, the upward motion component decreases while the lateral motion component increases. In such a case, when a jet collides with the bleeder pipe, the jet spreads over a wide range, with the result that the effect of reducing soot through the entrainment of the jet cannot be sufficiently achieved. Thus, the angle θ is preferably in the range of 0° to 30°, inclusive.

[0042] The result shows that a jet can sufficiently entrain the atmosphere and thus promote the complete combustion of a C gas, which is coke oven emission gas, provided that the following two conditions are met: the angle θ is between 0° and 30°, inclusive, and the value of $W / (d \cdot \cos\theta)$ is in the range of 0.85 to 1.6, inclusive.

[0043] When the gap W is too small, a jet from the blow-in pipe 4 cannot sufficiently enter the inside of the hood, causing it to flow out to the atmosphere side. Consequently, the effect of blowing in the jet is reduced. With respect to the gap W , $d \cdot \cos\theta$ is an area obtained by projecting a cross-section of the blow-in pipe onto the gap between the hood and the bleeder pipe. Even $W / (d \cdot \cos\theta)$ of less than 1 is considered to be in the preferable range. This is because the jet flows along the wall

surface while being attracted by the Coanda effect of the jet and the wall surface. FIG. 9 shows that $W/(d \cdot \cos\theta)$ of 0.85 or more allows the entire jet to flow inside the hood, which effectively achieves the effect of reducing the amount of soot generated. Meanwhile, if the gap W is too large, the atmosphere is likely to be sucked in through the gap, reducing the negative-pressure region in the upper portion of the hood and the pressure difference with the surrounding. According to FIG. 9, it can be observed that when $W/(d \cdot \cos\theta)$ is 1.6 or less, the effect of suppressing soot generation can be efficiently achieved.

(Example 3)

[0044] FIG. 11(a1) shows, as a conventional example, a longitudinal section of an emission bleeder that operates without blowing in gas. FIG. 11(b1) shows the arrangement of a blow-in pipe 4 according to the above embodiment as an invention example. FIG. 11(c1), as a comparative example, shows the bleeder pipe 3 with a blow-in pipe 4A arranged in the center. FIGS. 11(a2), 11(b2), and 11(c2) show the results of fluid simulation of the conventional example, the invention example, and the comparative example, respectively. The invention example shows the state where the surrounding atmosphere and the jet are mixed above the hood. Meanwhile, the conventional example and the comparative example have a lower force of drawing in the surrounding atmosphere, compared to the invention example.

[0045] Accordingly, it has been verified through simulation that combustion efficiency for coke oven emission gas can be improved according to the example of the invention.

Industrial Applicability

[0046] The combustion apparatus for coke oven emission gas, the combustion method for coke oven emission gas, and the method of designing the combustion apparatus for coke oven emission gas according to the present invention are each applicable to a case where combustible gas requires complete combustion before being discharged to the atmosphere.

Reference Signs List

[0047]

- 1 emission bleeder
- 2 hood
- 2A upper end face of hood
- 2B lower end face of hood
- 3 bleeder pipe
- 3A upper end face of bleeder pipe
- 3B end of bleeder pipe on side of coke oven
- 4 blow-in pipe
- 4A blow-in pipe (located in center of bleeder pipe)
- 5 gap (gap between outer wall of bleeder pipe and inner wall of hood)
- 6 ignition device
- 7 control means
- 11 coke oven
- 11G coke oven gas (C gas or combustible gas)
- 12 carbonization chamber
- 13 combustion chamber
- 14 riser pipe
- 15 dry main
- d inner diameter of blow-in pipe
- D diameter of upper end of bleeder pipe
- L distance from upper end of bleeder pipe to open end of hood
- W length of gap between outer wall of bleeder pipe and inner wall of hood
- FJ jet
- FA atmosphere (air)
- FU combustible gas (C gas)

Claims

1. A combustion apparatus for coke oven emission gas comprising

a bleeder pipe having one end that communicates with a portion where the coke oven emission gas is generated and allowing the coke oven emission gas to pass through its inside

a hood having one end open to an atmosphere side and the other end enveloping the other end of the bleeder pipe, arranged so as to be coaxial with an axis of the other end of the bleeder pipe, and formed of at least one cylinder,

a gas blow-in pipe inserted from below into a gap between an outer wall of the bleeder pipe and an inner wall of the hood, and

a control means for adjusting a blowing condition for combustion-promoting gas to be blown from the gas blow-in pipe,

characterized in that

the control means is configured to adjust one or more in combination selected from a gas flow rate M_J [kg/s], a gas flow velocity v_J [m/s], and gas pressure P_J [Pa] of the combustion-promoting gas to be blown through the blow-in pipe so as to satisfy Expression (1) below:

$$\{M_J/(M_G + M_D)\} \times \{0.5 \times v_J^2 + \gamma/(\gamma - 1) \times P_J/\rho_J\} \geq 370000 \times \ln(d) + 2300000 \quad (1),$$

wherein

M_G represents a flow rate [kg/s] of the emission gas in the bleeder pipe,

M_D represents a theoretical flow rate [kg/s] of air necessary for combustion of the emission gas,

γ represents a specific heat ratio,

ρ_J represents a density [kg/m³] of the combustion-promoting gas, and

d represents an inner diameter [m] of the blow-in pipe.

2. The combustion apparatus for coke oven emission gas according to claim 1, wherein a ratio L/D is between 0.5 and 2.5, inclusive, provided that an inner diameter of the bleeder pipe is D [m] and a distance from a tip of the other end of the bleeder pipe to a tip of the one end of the hood is L [m].

3. The combustion apparatus for coke oven emission gas according to claim 1 or 2, wherein an angle θ is between 0° and 30°, inclusive, and a value of $W/(d \cdot \cos\theta)$ is in a range of 0.85 to 1.6, inclusive, provided that the gap between the outer wall of the bleeder pipe and the inner wall of the hood is W [m], the inner diameter of the blow-in pipe is d [m], and an angle formed between the bleeder pipe in an axial direction and the blow-in pipe in the axial direction is θ [°].

4. A combustion method for coke oven emission gas comprising

allowing coke oven emission gas to pass through the inside of a bleeder pipe having one end that communicates with a portion where the coke oven emission gas is generated,

providing a hood having one end open to an atmosphere side and the other end enveloping the other end of the bleeder pipe, arranged so as to be coaxial with an axis of the other end of the bleeder pipe, and formed of at least one cylinder, and

blowing combustion-promoting gas through a blow-in pipe inserted into a gap between an inner wall of the hood and an outer wall of the bleeder pipe,

characterized in that

the method further comprises adjusting one or more in combination selected from a gas flow rate M_J [kg/s], a gas flow velocity v_J [m/s], and gas pressure P_J [Pa] of the combustion-promoting gas to be blown through the blow-in pipe so as to satisfy Expression (1):

$$\{M_J/(M_G + M_D)\} \times \{0.5 \times v_J^2 + \gamma/(\gamma - 1) \times P_J/\rho_J\} \geq 370000 \times \ln(d) + 2300000 \quad (1),$$

wherein

M_G represents a flow rate [kg/s] of the emission gas in the bleeder pipe,

M_D represents a theoretical flow rate [kg/s] of air necessary for combustion of the emission gas,

γ represents a specific heat ratio,

ρ_J represents a density [kg/m³] of the combustion-promoting gas, and

d represents an inner diameter [m] of the blow-in pipe.

5. A method of designing a combustion apparatus for coke oven emission gas comprising

a bleeder pipe having one end that communicates with a portion where the coke oven emission gas is generated and allowing the coke oven emission gas to pass through an inside of the bleeder pipe,
 a hood having one end open to an atmosphere side and the other end enveloping the other end of the bleeder pipe, arranged so as to be coaxial with an axis of the other end of the bleeder pipe, and formed of at least one cylinder,
 a gas blow-in pipe inserted from below into a gap between an outer wall of the bleeder pipe and an inner wall of the hood, and
 a control means for adjusting a blowing condition for combustion-promoting gas to be blown through the gas blow-in pipe,
characterized in that
 the method further comprises designing an inner diameter d [m] of the blow-in pipe so as to satisfy Expression (1):

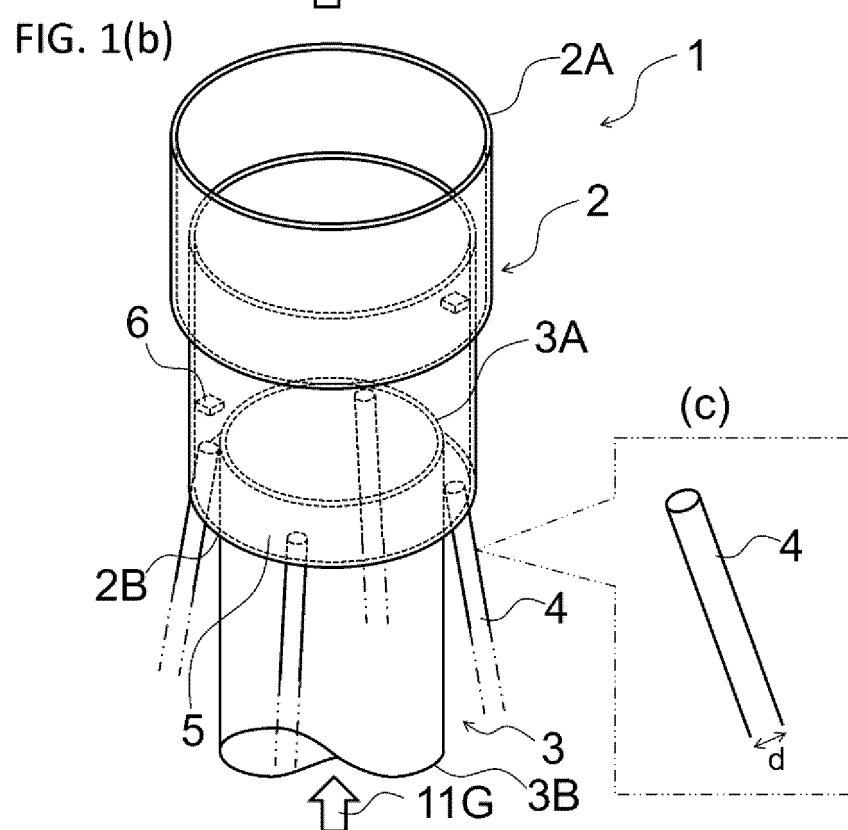
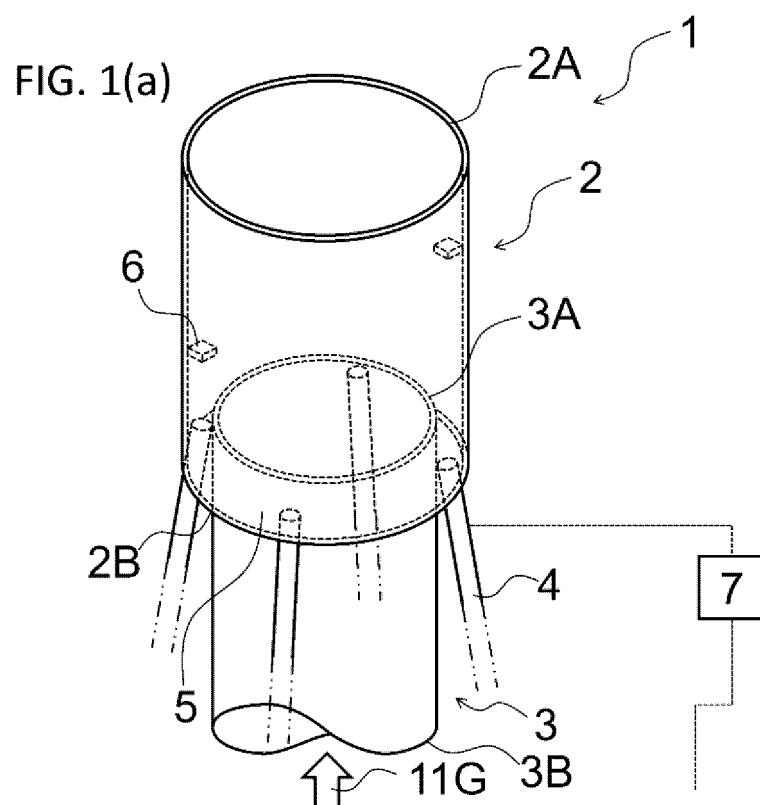
$$\{M_J/(M_G + M_D)\} \times \{0.5 \times v_J^2 + \gamma/(\gamma - 1) \times P_J/\rho_J\} \geq 370000 \times \ln(d) + 2300000 \quad (1),$$

wherein

M_G represents a flow rate [kg/s] of the emission gas in the bleeder pipe,
 M_D represents a theoretical flow rate [kg/s] of air necessary for combustion of the emission gas,
 γ represents a specific heat ratio,
 ρ_J represents a density [kg/m³] of the combustion-promoting gas, and
 d represents an inner diameter [m] of the blow-in pipe.

6. The method of designing a combustion apparatus for coke oven emission gas according to claim 5, wherein a ratio LID is set in a range of 0.5 to 2.5, inclusive, provided that an inner diameter of the bleeder pipe is D [m], and a distance from a tip of the other end of the bleeder pipe to a tip of the one end of the hood is L [m].

7. The method of designing a combustion apparatus for coke oven emission gas according to claim 5 or 6, wherein an angle θ is set in a range of 0° to 30°, inclusive, and a value of $W/(d \cdot \cos\theta)$ is set in a range of 0.85 to 1.6, inclusive, provided that the gap between the outer wall of the bleeder pipe and the inner wall of the hood is W [m], the inner diameter of the blow-in pipe is d [m], and an angle formed between the bleeder pipe in an axial direction and the blow-in pipe in the axial direction is θ [°].



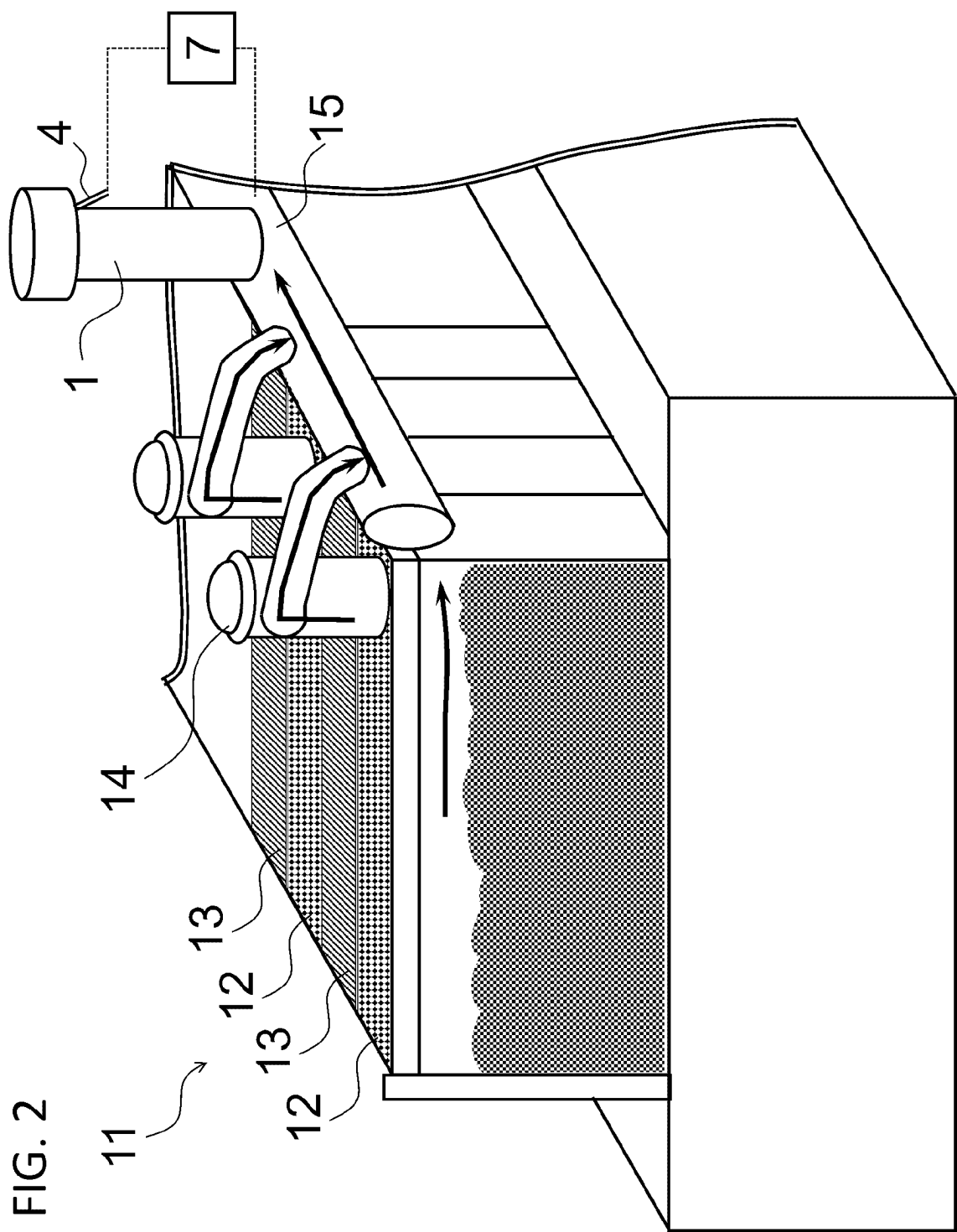


FIG. 3(b) $\longrightarrow$ Flow velocity vector

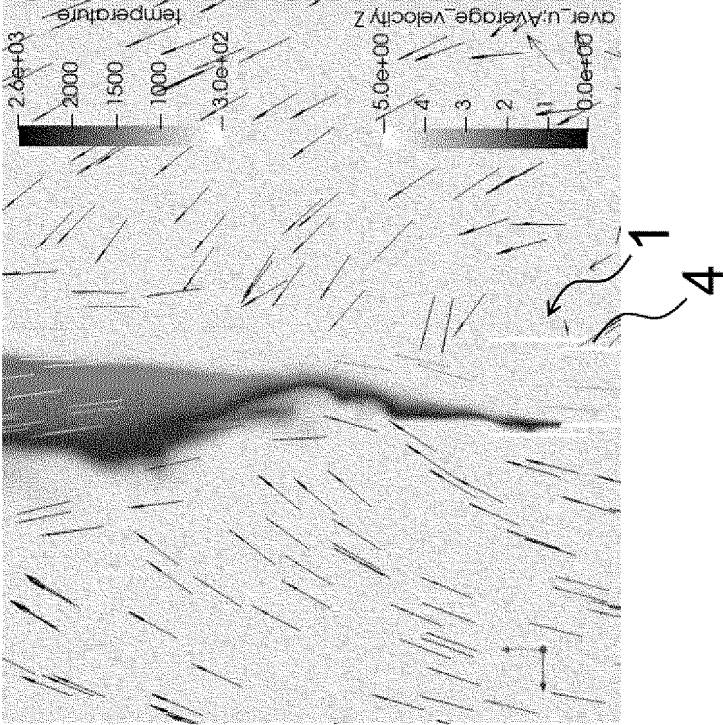


FIG. 3(a)

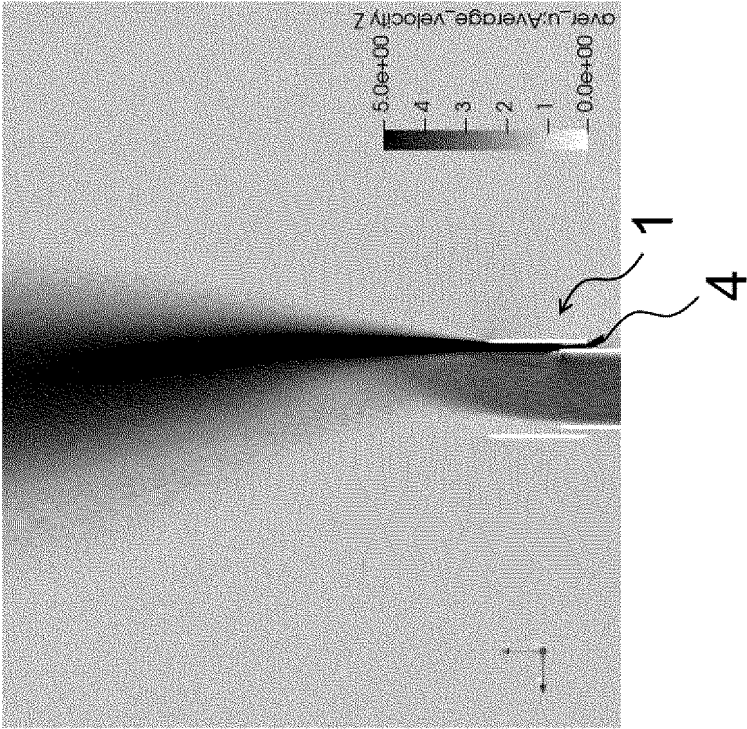
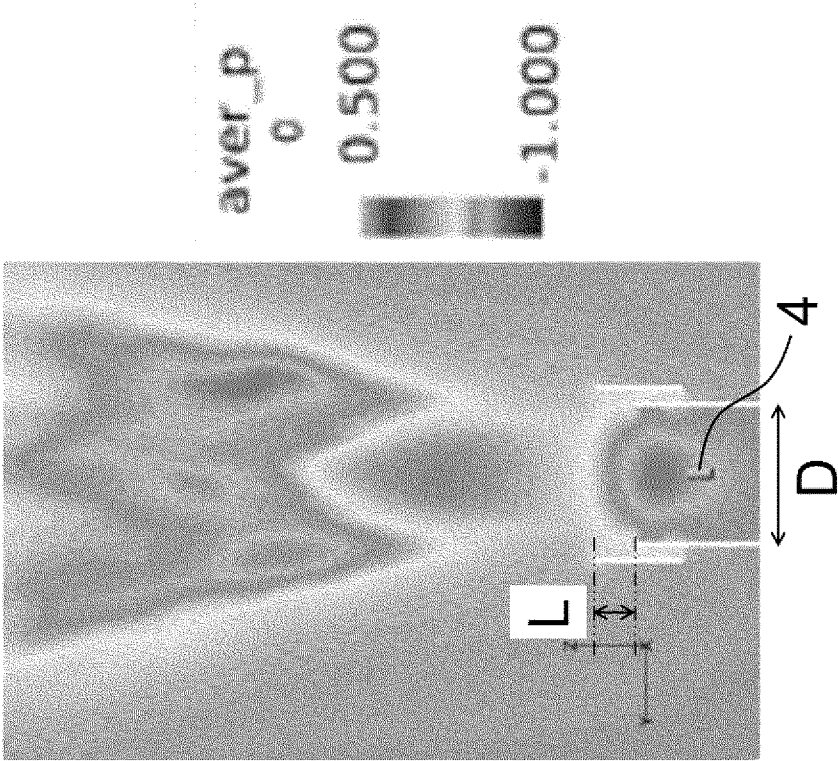


FIG. 4(b) $L/D=0.25$



Negative-pressure region

FIG. 4(a) $L/D=0.92$

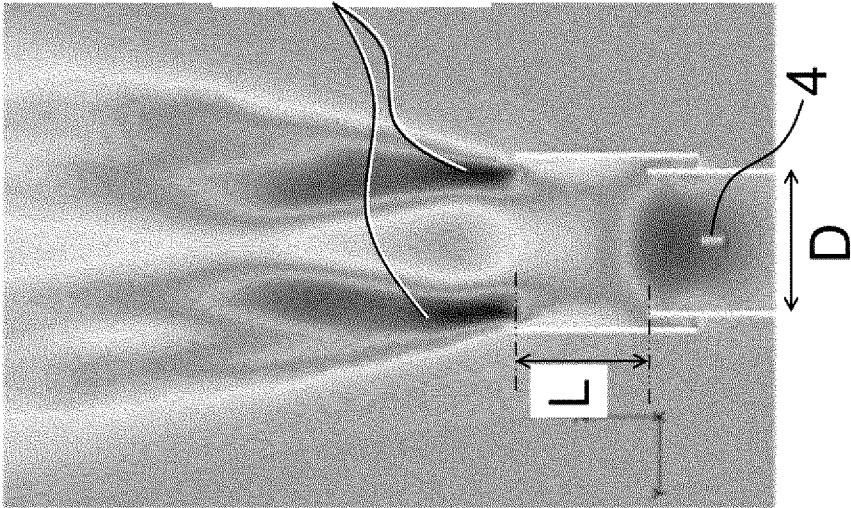


FIG. 5(a)

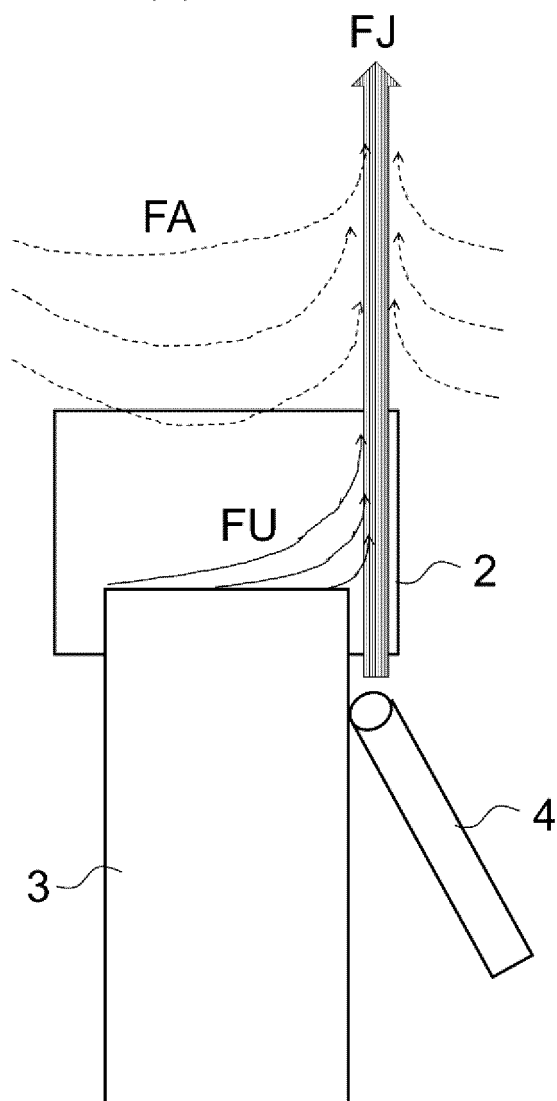


FIG. 5(b)

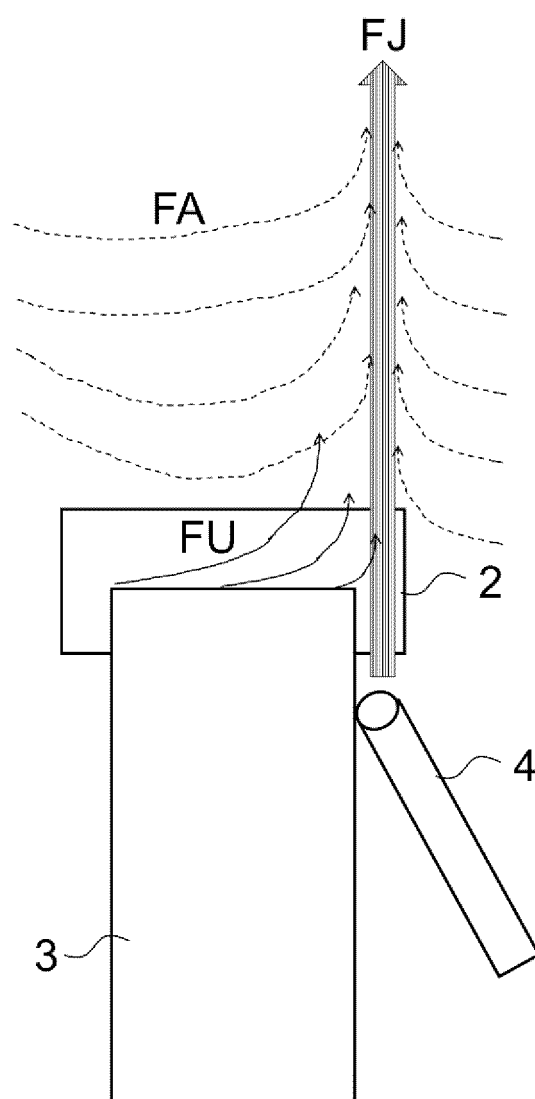


FIG. 6

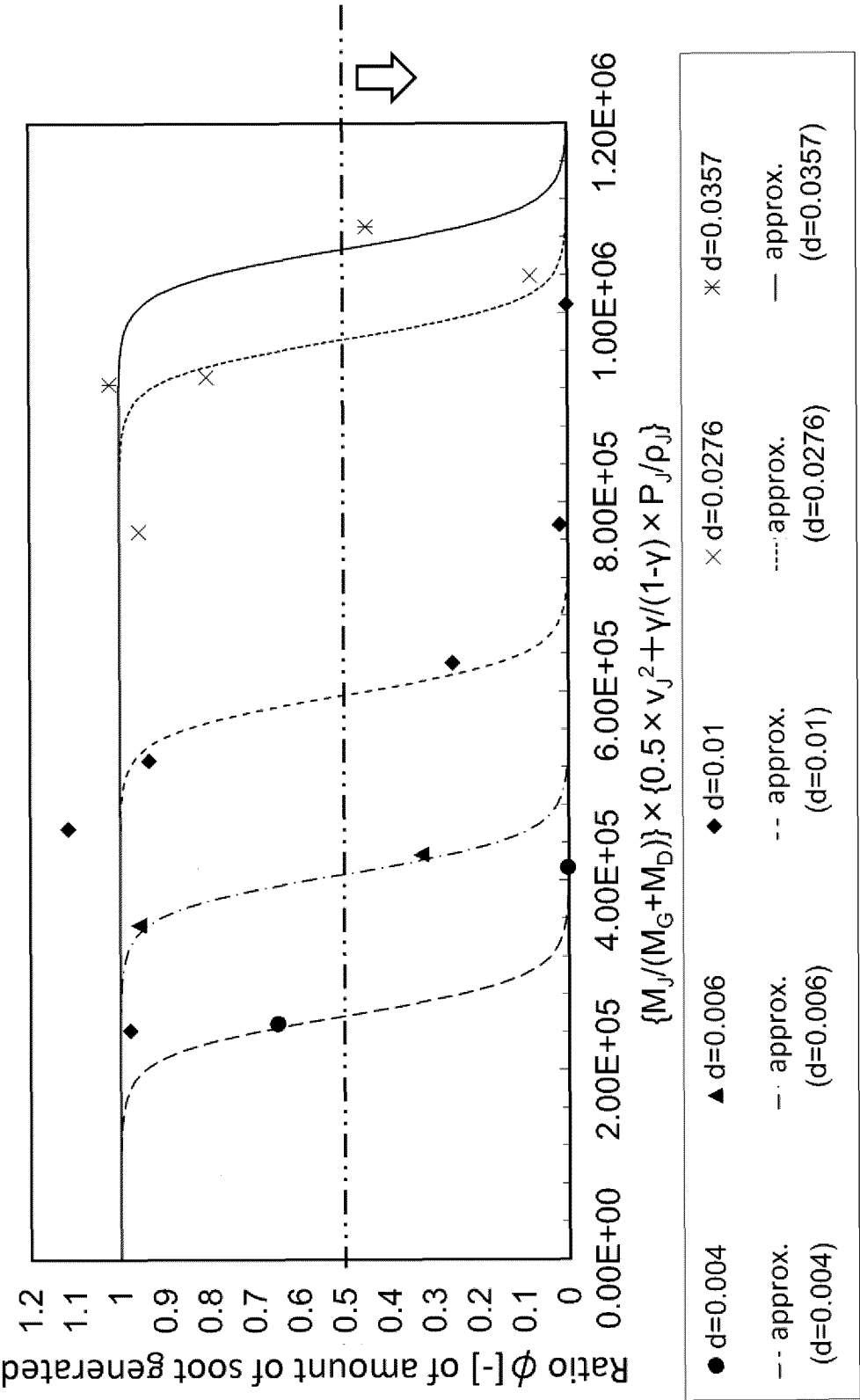


FIG. 7

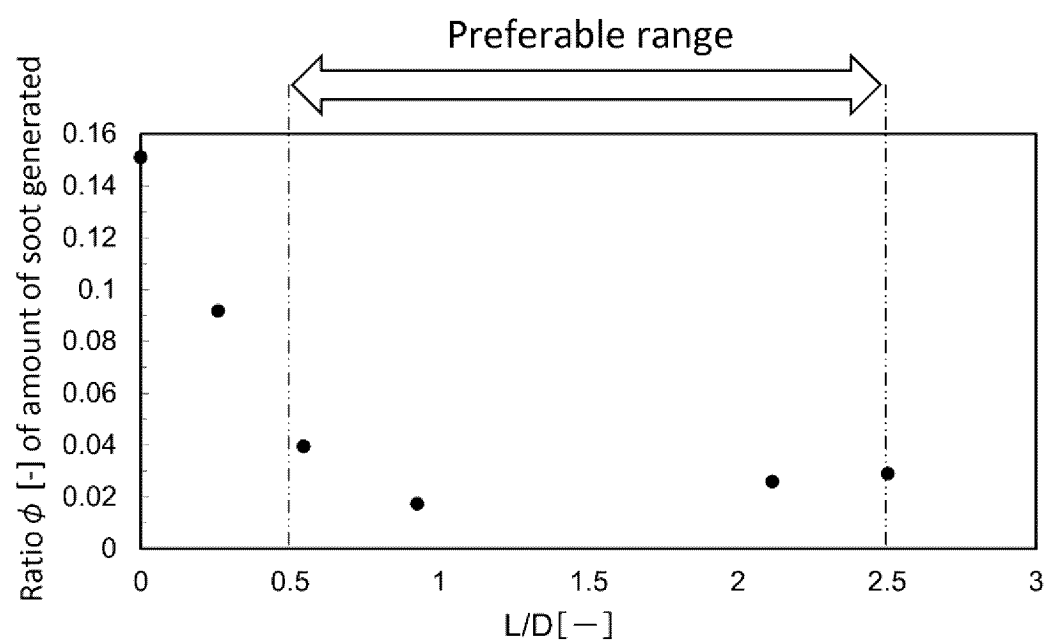


FIG. 8

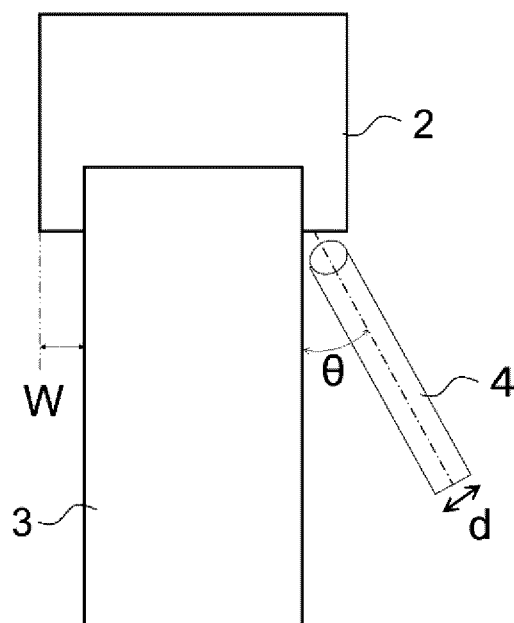


FIG. 9

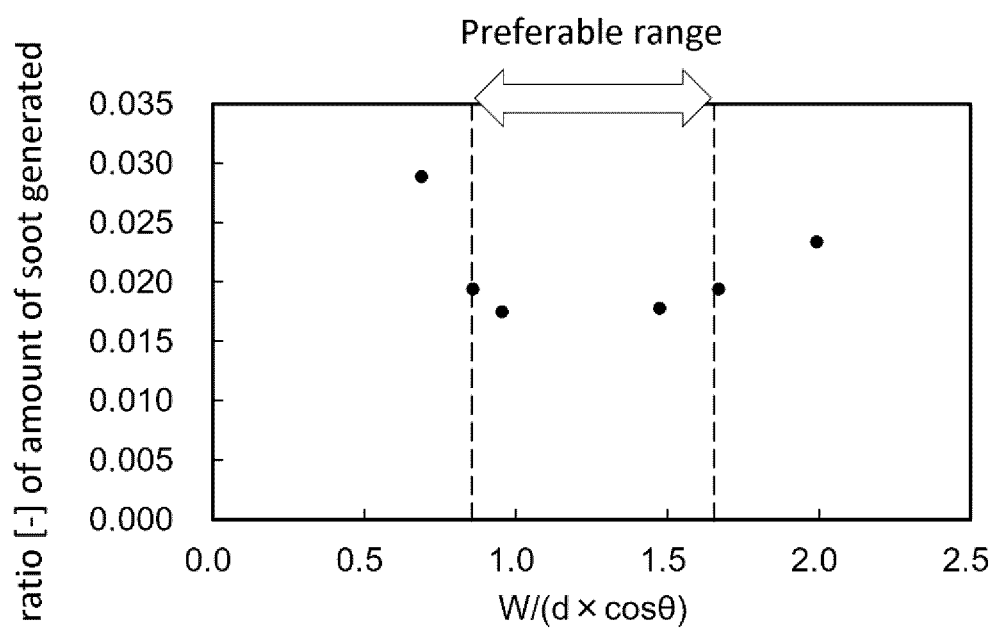
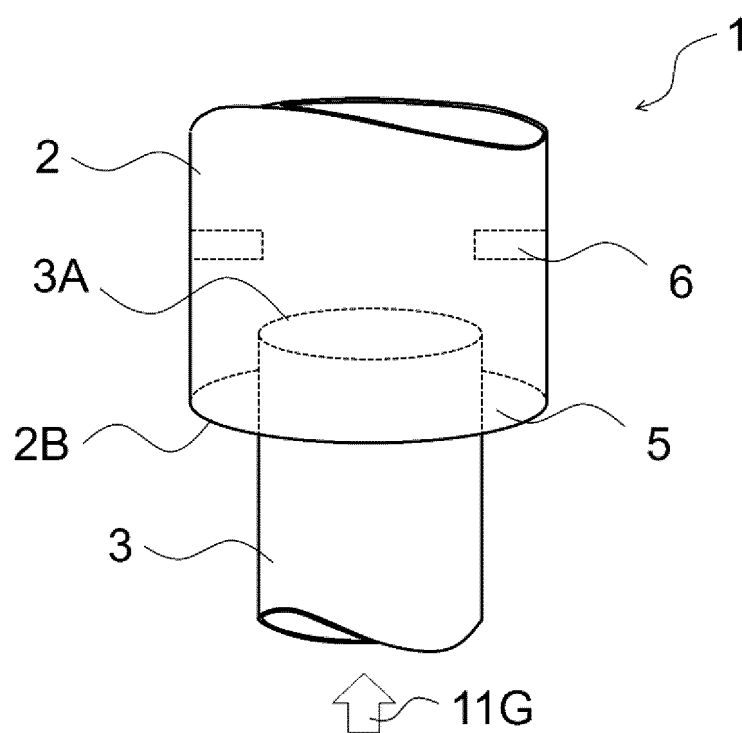


FIG. 10



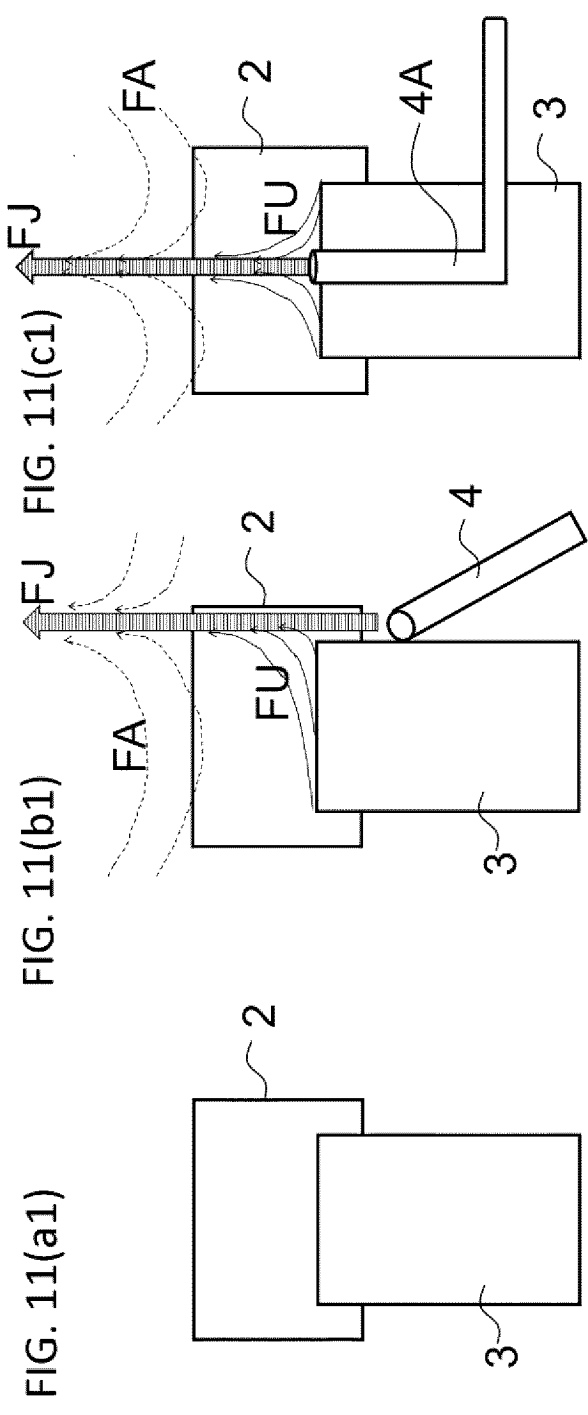
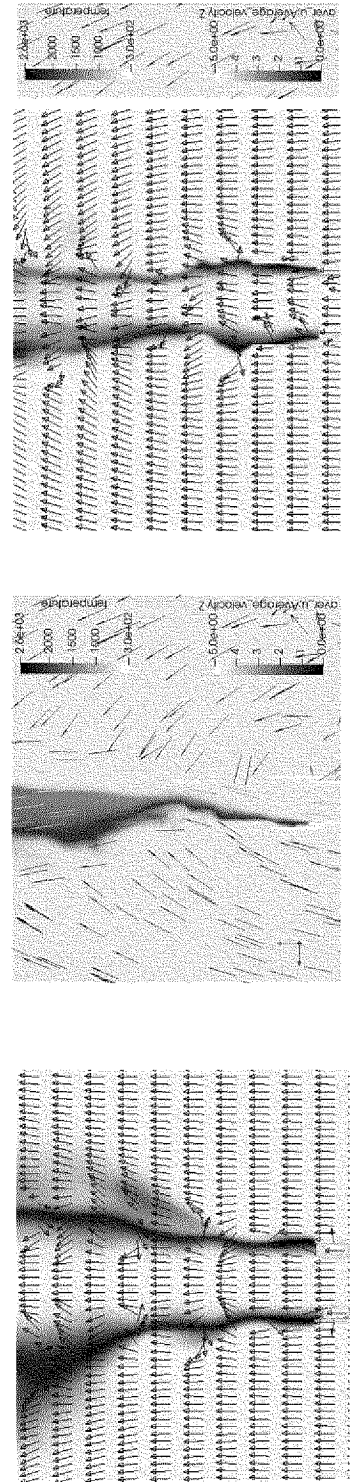


FIG. 11(a1)

FIG. 11(b1)

FIG. 11(c1)



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/043090

A. CLASSIFICATION OF SUBJECT MATTER

F23G 7/08(2006.01)i; *F23G 7/06*(2006.01)i

FI: F23G7/08 Z; F23G7/06 C

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F23G7/08; F23G7/06

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

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2023
 Registered utility model specifications of Japan 1996-2023
 Published registered utility model applications of Japan 1994-2023

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2020-117623 A (NIPPON STEEL CORP.) 06 August 2020 (2020-08-06) paragraphs [0044]-[0056], [0073]-[0079], fig. 6	1-7
X	JP 2017-96615 A (JFE STEEL CORP.) 01 June 2017 (2017-06-01) paragraphs [0014]-[0026], fig. 2	1-7

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

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Date of the actual completion of the international search

02 February 2023

Date of mailing of the international search report

14 February 2023

Name and mailing address of the ISA/JP

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Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/043090

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP	2020-117623	A	06 August 2020	(Family: none)	
JP	2017-96615	A	01 June 2017	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

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