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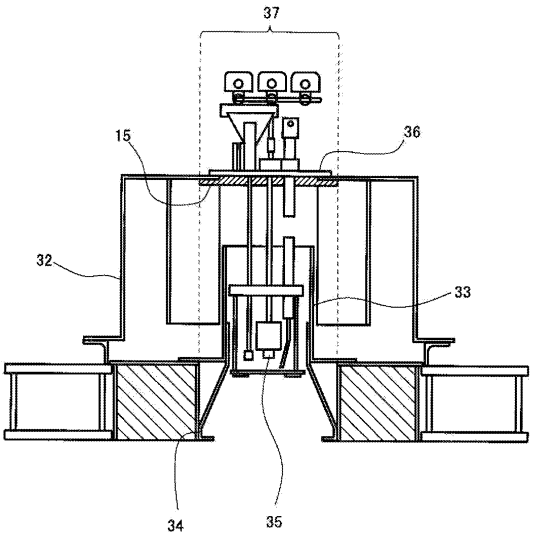
(54) HEAT-RESISTANT FUEL-ACTIVATING SUBSTANCE

(57) A fuel-activating substance comprising a fuel-activating material and having heat resistance imparted thereto. This fuel-activating substance can hence be applied or attached even to parts to be used under such temperature conditions that use with organic resin binders has been impossible, whereby the effect of saving energy in combustion devices is further heightened. The heat-resistant fuel-activating substance is **characterized by** being obtained by melt-mixing 50-150 wt.% metallic thermal spray material with 100 wt.% fuel-activating material of which the spectral emissivity for electromagnetic waves with wavelengths in the range of 3-20 μm is 0.85 or more and making the mixture capable of thermal spraying. Alternatively, 100 wt.% the fuel-activating material and 50-150 wt.% metallic material having a melting point of 420°C or lower may be formed into a sheet through melting. Furthermore, a mixture of 100 wt.% the fuel-activating material and 75-150 wt.% inorganic resin having a heat resistance temperature exceeding 300°C may be formed into a sheet or may be subjected to thermal spraying or applied in a molten state.

Fig. 5



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Description

TECHNICAL FIELD

[0001] The present invention relates to a heat-resistant fuel-activating substance suitable for use in combustion devices such as boilers in which liquid fossil fuels such as heavy oil and kerosene, gas fossil fuels such as LPG and natural gas, and solid fossil fuels such as coal are used as fuels, and enhancing a combustion-activating effect for the combustion therein.

BACKGROUND ART

[0002] Heretofore, various studies have been conducted for the improvement of thermal efficiency at the time of combustion in combustion devices such as boilers. For that purpose, for example, like the invention described in Patent Document 1, there were some proposals to improve burners.
The inventors of the present invention have proposed that combustion efficiency at the time of combustion is improved by activating methane-based molecules in a thermal decomposition region using electromagnetic waves from a fuel-activating substance. That is, methane-based molecules as a kind of active chemical species generated by the thermal decomposition of the fuel during the combustion have an absorption band that absorbs electromagnetic waves with specific electromagnetic wavelengths, specifically around 8 μm (a range approximately 3 to 20 μm). Thus, radiation of the electromagnetic waves in the wavelength region to the methane-based molecules in the thermal decomposition region causes stronger vibration of the methane-based molecules as a kind of active chemical species that are combustion precursors. Thereby, frequency of collision between the methane-based molecules and oxygen molecules in air is enhanced and combustion reactions are accelerated, thus leading to a rise in flame temperature. As a result, combustion efficiency comes closer to that of complete combustion, thus realizing a reduction in the amount of the fuel use. The present inventors have tried to develop a heat-resistant fuel-activating substance that exhibits a high spectral emissivity in such wavelengths.
[0003] For that purpose, focusing on tourmaline having an action of radiating electromagnetic waves, tests of radiating electromagnetic waves from tourmaline to methane-based molecules in a thermal decomposition region were carried out. However, there was no significant effect that enables an improvement in combustion efficiency at the time of combustion.
Based on these findings, the present inventors disclosed an invention described in Patent Document 2. This invention is intended to obtain an energy saving effect by disposing a far infrared ray generator, formed by mixing tourmaline, iron powder and carbon, in a methane gas passageway located before a portion where combustion occurs, thereby activating the fuel.

Patent Literature

[0004]

Patent Document 1: JP 11-1707 A
Patent Document 2: WO 2006/088084 A

SUMMARY OF INVENTION

[0005] After the above prior art, focusing particularly on a spectral emissivity, the present inventors have intensively made an improvement of a fuel-activating substance and found that a flame temperature rise of 100 to 150°C is obtained by using a fuel-activating material in which a spectral emissivity of electromagnetic waves in the above wavelength region becomes 0.85 or more and radiating electromagnetic waves in the relevant wavelength region to methane-based molecules in the thermal decomposition region.
By the way, a conventional fuel-activating substance is prepared by forming an activating material into a sheet using an organic resin such as a urethane resin as a binder, or by forming the activating material into a coating material to be affixed by coating. Therefore, in case the fuel-activating substance is affixed to a place at high temperature of 100°C or more in a combustion device, the binder was sometimes carbonized with a lapse of time, resulting in decrease of a spectral emissivity of the electromagnetic waves from the fuel-activating substance.
[0006] Then, an object of the present invention is that an improved fuel-activating material is used and also heat resistance is imparted to a fuel-activating substance using this fuel-activating material thereby making it possible to affix even under temperature conditions where a conventional fuel-activating substance could not be used, and thus an energy saving effect in various combustion devices is further enhanced.

[0007] The heat-resistant fuel-activating substance according to a first invention among the present invention is formed by melt-mixing 50 to 150% by weight of a metallic thermal spray material with 100% by weight of a fuel-activating material having a spectral emissivity of 0.85 or more for electromagnetic waves with wavelengths in a range of 3 to 20 μm, thereby making the mixture capable of thermal spraying.

Regarding "a spectral emissivity of 0.85 or more for electromagnetic waves with wavelengths in a range of 3 to 20 μm" as stated herein, the relevant wavelength range is a wavelength range of electromagnetic waves, that contributes the most to activation of methane-based molecules in a thermal decomposition region, and is a portion that is referred to as so-called "far infrared rays." This spectral emissivity is a numerical value assumed that an emissivity in the relevant wavelength range of a blackbody is 1, and has significance as a numerical value enough to radiate far infrared rays contributing to activation of methane-based molecules. On this point, the same shall apply in the respective inventions described hereinafter.

[0008] Herein, application of the heat-resistant fuel-activating substance by thermal spraying enables application even to the place having a complicated surface shape.

That is, the heat-resistant fuel-activating substance according to the first invention is applicable to the site to be applied in the combustion device at a temperature within a range from about 100 to 400°C. Herein, it is possible to use, as the metallic thermal spray material, the group of materials having comparatively low melting temperature, for example, copper, aluminum and nickel. In particular, materials having a grain size of 5 to 150 μm are desirable.

When the content of the metallic thermal spray material is less than 50% by weight in addition to 100% by weight of the activating material, adhesion to the site to be applied becomes worse. In contrast, when the content is more than 150% by weight, the spectral emissivity decreases with the decrease of the proportion of the fuel-activating material. Therefore, the content is suitably from 50 to 150% by weight.

[0009] Such a metallic thermal spraying material is mixed with a predetermined fuel-activating material and the obtained mixture is filled in a commercially available thermal spraying apparatus, and then the mixture is thermally sprayed onto a predetermined site to be applied of a burner. A specific place to be thermally sprayed includes a flange portion to which a burner is mounted a combustion device, or the place behind the site where combustion flame occurs inside a combustion device that accommodates the burner. It becomes possible to form a heat-resistant fuel-activating substance as a metal coating layer containing a fuel-activating material as a component on the relevant place with a desired thickness. Moreover, thermal spraying enables application even onto the place having a surface shape with complicated unevenness where it is difficult to affix with a sheet-like material.

The heat-resistant fuel-activating substance according to a second invention among the present invention is formed by melting 50 to 150% by weight of a metallic material having a melting point of 420°C or lower with 100% by weight of a fuel-activating material having a spectral emissivity of 0.85 or more for electromagnetic waves with wavelengths in a range of 3 to 20 μm to be formed into a sheet.

[0010] That is, the heat-resistant fuel-activating substance according to the present second invention is applicable to the site to be applied at a temperature within a range from about 100 to 300°C. Herein, it is possible to use, as a metallic material, metals having a comparatively low melting point, such as lead and zinc.

When the content of the metallic material is less than 50% by weight in addition to 100% by weight of the total amount of the fuel-activating material, it becomes impossible to be formed into a sheet. In contrast, when the content is more than 150% by weight, the spectral emissivity decreases with the decrease of the proportion of the fuel-activating material. Therefore, the content is suitably from 50 to 150% by weight.

Such formation into a sheet enables affixing to a predetermined site to be applied in the vicinity of a burner in a combustion device, for example, a flange portion to which a burner mounted, or the place behind the site where combustion flame occurs inside a combustion device that accommodates the burner.

[0011] The heat-resistant fuel-activating substance according to the third invention among the present invention is formed by mixing 75 to 150% by weight of an inorganic resin having a heat-resistant temperature exceeding 300°C with 100% by weight of a fuel-activating material having a spectral emissivity of 0.85 or more for electromagnetic waves with wavelengths in a range of 3 to 20 μm.

That is, the heat-resistant fuel-activating substance according to the present third invention is applicable to the site to be applied at a temperature within a range from about 100 to 300°C. Herein, the inorganic resin having a heat-resistant temperature exceeding 300°C does not refer to a resin that is composed only of an organic resin, but refers to a resin in which an inorganic material is partially or entirely used as the component. It is possible to use, for example, a silicone resin, a fluororesin, a water glass and the like, or a material having heat resistance, such as a mixture that is optionally used after mixing among these examples.

[0012] When the content of the inorganic resin is less than 75% by weight in addition to 100% by weight of the total amount of the fuel-activating material, it becomes impossible to be formed into a sheet. In contrast, when the content is more than 150% by weight, the spectral emissivity decreases with the decrease of the proportion of the fuel-activating material. Therefore, the content is suitably from 75 to 150% by weight. The fuel-activating material may contain 0.5 to 1.5% by weight of silicon in 100% by weight of the activating material.

The heat-resistant fuel-activating substance according to the third invention can be formed into a sheet, and can also be thermally sprayed onto the site to be applied in a molten state, or sprayed or coated onto the site to be applied in a mixed state. Formation into a sheet enables application as a sheet to a predetermined site to be applied in the vicinity of a burner in a combustion device, for example, a flange portion to which a burner is mounted, or the place behind the site where combustion flame occurs inside a combustion device that accommodates the burner. It is also possible to conduct thermal spraying after melt-mixing, and to conduct thermal spraying onto the position to form, on the relevant position, a heat-resistant fuel-activating substance that is an inorganic substance coating layer containing the fuel-activating material as a component with a desired thickness.

[0013] It is preferable that the fuel-activating materials in the first invention to the third invention are formed by blending tourmaline, iron powder and carbon in proportions within a range of 30 to 44% by weight, 55 to 69% by weight, and 0.5 to 1.5% by weight, respectively.

Herein, it has already been confirmed by the test of the present applicant that, when the proportion of at least one of the respective components deviates from the range of the above blending ratio, the spectral emissivity of the heat-resistant fuel-activating substance is less than 0.85.

The heat-resistant fuel-activating substance may contain 1.5% by weight or less of silicon in 100% by weight of the activating material. The significance of inclusion of this silicon lies in that, in case the content of carbon had to be decreased, silicon supplements lack of carbon, thus enabling the heat-resistant fuel-activating substance to exhibit the spectral emissivity of 0.85 or more.

[0014] Each of the heat-resistant fuel-activating substances shown above can be used not only in a once-through boiler, a flame-tube smoke-tube boiler and a water-tube boiler (including an industrial boiler and a power station boiler that are equipped with two or more burners), but also in burning appliances equipped with a combustion device that uses combustion flame as a heat source, and a combustion chamber, such as a kiln, a dryer, and a hot and chilled water generator.

The "combustion chamber" as used herein refers to a portion where a fuel blown from a burner quickly undergoes ignition and combustion, and the generated combustible gas undergoes combustion by satisfactory mixing and contacting with air. In addition, the "burner" as used herein refers to a liquid fuel burner, a gas fuel burner and a solid fuel burner, and is specifically as follows.

[0015] The liquid fuel burner atomizes a fuel oil thereby increasing the surface area and accelerates vaporization thereby enabling satisfactory contact with air, thus completing a combustion reaction, and specifically refers to a pressure spraying-type burner, a steam (air) spraying-type burner, a low-pressure air atomizing-type burner, a rotary burner, a gun type burner and the like.

The gas fuel burner often utilizes a diffusion combustion system, and specifically refers to a center-type burner, a ring-type burner, a multispud burner and the like.

The solid fuel burner specifically refers to a burner of a pulverized coal burner combustion system.

[0016] With the constitution of the present invention shown above, it becomes possible to affix a heat-resistant fuel-activating substance onto the place at comparatively high temperature, such as inside of a combustion device, thus making it possible for the electromagnetic waves radiated from this heat-resistant fuel-activating substance to more directly act on combustion flame. As a result, vibration of methane-based molecules as a kind of active chemical species generated by thermal decomposition of a fuel is activated and the combustion is accelerated, thus leading to a rise in flame temperature and stable combustion flame. As a result, it becomes possible to further decrease the amount of the fuel use.

BRIEF DESCRIPTION OF DRAWINGS

[0017]

Fig.1 schematically shows a measuring device used to examine a relationship between the spectral emissivity and the flame temperature in a heat-resistant fuel-activating substance according to the present invention.

Fig.2 schematically shows a flame-tube smoke-tube boiler affixed with a heat-resistant fuel-activating substance as a first embodiment of the present invention.

Fig.3 enlarges a burner portion in Fig.2.

Fig.4 schematically shows a once-through boiler affixed with a heat-resistant fuel-activating substance as a second embodiment of the present invention.

Fig.5 enlarges a burner portion in Fig.4.

Fig.6 schematically shows a water-tube boiler affixed with a heat-resistant fuel-activating substance as a third embodiment of the present invention.

Fig.7 enlarges a burner portion in Fig.6.

DESCRIPTION OF EMBODIMENTS

(1) Verification of Blending ratio of Fuel Activating Material

[0018] The following materials were used as a fuel-activating material.
Tourmaline: Schorl tourmaline, 42 mesh (Adam Kozan Chuo Kenkyusho Co., Ltd.).
Iron powder: RS-200A (POWDER TECH).
Carbon: activated carbon powder (C-AW; 12.011, SHOWA CHEMICAL INDUSTRY CO., LTD.).
The above materials mixed in each blending ratio shown in Table 1 described below was used as the fuel-activating material and an inorganic silicone resin (ES-1002T, Shin-Etsu Chemical Co., Ltd.) as a binder was added thereto. The obtained mixture was kneaded and was thereafter coated on a 2-mm thick aluminized steel sheet so that a thickness of the obtained coating film became 0.6 mm to obtain samples. The obtained samples were subjected to the measurement of the spectral emissivity.

[0019] The spectral emissivity was measured using a Fourier transform infrared spectrophotometer of Shimadzu (IRPrestiga-21 (P/N206-72010), Shimadzu Corporation). Specifically, first, the spectral emissivity was read as 1.0 by a blackbody furnace (at 300°C) and a measuring sample coated with a pseudo-blackbody coating material (spectral emissivity: 0.94) was then placed in a sample furnace. The spectral emissivity was set to 0.94 at a temperature in the sample furnace. Thereafter, each sample was placed in the sample furnace under this condition and the spectral emissivity was measured. The results were also shown in Table 1 below.

[0020]

Table 1

Sample No.	Tourmaline		Iron powder		Carbon		Total	Binder		Spectral emissivity
	g	%	g	%	g	%	g	g	%	
1	150	22.5%	508	76.0%	10	1.5%	668	668	100%	0.77
2	201	30.1%	458	68.6%	9	1.3%	668	668	100%	0.92
3	240	35.9%	420	62.9%	8	1.2%	668	668	100%	0.94
4	293	43.9%	368	55.1%	7	1.0%	668	668	100%	0.89
5	320	47.9%	344.5	51.6%	3.5	0.5%	668	668	100%	0.72
6	308	46.1%	350	52.4%	10	1.5%	668	668	100%	0.78
7	291.5	43.6%	367.5	55.0%	9	1.3%	668	668	100%	0.91
3	240	35.9%	420	62.9%	8	1.2%	668	668	100%	0.94
8	203	30.4%	460	68.9%	5	0.7%	668	668	100%	0.87
9	184	27.5%	480.5	71.9%	3.5	0.5%	668	668	100%	0.70
10	243	36.4%	424	63.5%	1	0.1%	668	668	100%	0.75
11	242.5	36.3%	422	63.2%	3.5	0.5%	668	668	100%	0.90
3	240	35.9%	420	62.9%	8	1.2%	668	668	100%	0.94
12	239	35.8%	419	62.7%	10	1.5%	668	668	100%	0.89
13	236	35.3%	417	62.4%	15	2.2%	668	668	100%	0.74
*Percentages are % by weight based on the total.										

As shown in the above results, the spectral emissivity of Sample No.3, in which the amount of tourmaline in the fuel-activating material was 240 g (35.9% by weight), the amount of iron powder was 420 g (62.9% by weight) and the amount of carbon was 8 g (1.2% by weight), was 0.94, which was considered to be the best mode. Using this sample as a center value, when the blending ratio of tourmaline was 30% by weight or more and 44% by weight or less (from Samples No.

2 and No.4), the blending ratio of iron powder was 55% by weight or more and 69% by weight or less (from Samples No.7 and No.8) and the blending ratio of carbon was 0.5% by weight or more and 1.5% by weight or less (from Samples No.11 and No.12), the spectral emissivity was found to become 0.85 or more.

(2) Heat-Resistant Fuel-Activating Substance formed by Metal Spraying

[0021] Next, an appropriate weight ratio of a binder for metal spraying was examined using the fuel-activating material of Sample No.3, which was considered as the best mode by the results of (1) described above.
Metallizing 29029 as a binder (Eutectic of Japan Ltd.) containing nickel and aluminum as main components in the weight ratio shown in Table 2 below was melt-mixed with 100% by weight of the fuel-activating material of Sample No.3 described above, and then the obtained melt mixture was thermally sprayed onto a 2-mm thick aluminized steel sheet so that a thickness of the obtained coating film became 0.6 mm, using Tero-Dizing System 2000 (Eutectic of Japan Ltd.). With respect to the heat-resistant fuel-activating substance formed by this thermal spraying, the spectral emissivity was measured in the same manner as in (1) described above and also adhesion to the thermal sprayed site was examined. The results were as shown in Table 2 below.
[0022]

Table 2

Sample No.	Tourmaline		Iron powder		Carbon		Total	Binder		Spectral emissivity
	g	%	g	%	g	%	g	g	%	
14	240	35.9%	420	62.9%	8	1.2%	668	300	45%	-
15	240	35.9%	420	62.9%	8	1.2%	668	334	50%	0.91
16	240	35.9%	420	62.9%	8	1.2%	668	668	100%	0.94
17	240	35.9%	420	62.9%	8	1.2%	668	1000	150%	0.90
18	240	35.9%	420	62.9%	8	1.2%	668	1150	172%	0.72
*Percentages are % by weight based on the total.										

As shown in the above results, the spectral emissivity of Sample No.16 in which the weight ratio of the binder compared to 100% by weight of the fuel-activating material is 100% by weight is the highest value of 0.94 and, using this sample as a center value, the spectral emissivity of Sample No.15, in which the weight ratio of the binder is 50% by weight, and that of Sample No.17 in which the weight ratio of the binder is 150% by weight were 0.85 or more. To the contrary, in Sample No.18 in which the weight ratio of the binder is more than 150%, the spectral emissivity was less than 0.85. In Sample No.14 in which the weight ratio of the binder is less than 50% by weight, when the sample was rubbed by hands after thermal spraying onto the steel sheet, the spray coating film was easily peeled off. As a result, it has been found that the sample showed poor adhesion performance as the heat-resistant fuel-activating substance and was not suited for practical use.
[0023] As described above, in the case of forming a heat-resistant fuel-activating substance by mixing with the binder for metal spraying, an appropriate weight ratio of the binder compared to 100% by weight of the fuel-activating material is 50% by weight or more and 150% by weight or less.

(3) Heat-Resistant Fuel-Activating Substance formed as Metal Sheet

[0024] Next, an appropriate weight ratio of a binder for forming into a metal sheet was examined using the fuel-activating material of Sample No.3, which was considered as the best mode by the results of (1) described above.
Lead as a binder in the weight ratio shown in Table 3 below was blended with 100% by weight of the fuel-activating material of Sample No.3 described above, and then the obtained mixture was melted at 350°C and formed into a 1-mm thick sheet. The spectral emissivity of the sheet was measured in the same manner as in (1) described above and also formability as the sheet was examined. The results were as shown in Table 3 below.
[0025]

Table 3

Sample No.	Tourmaline		Iron powder		Carbon		Total	Binder		Spectral emissivity
	g	%	g	%	g	%	g	g	%	
19	240	35.9%	420	62.9%	8	1.2%	668	300	45%	-
20	240	35.9%	420	62.9%	8	1.2%	668	334	50%	0.90
21	240	35.9%	420	62.9%	8	1.2%	668	668	100%	0.94
22	240	35.9%	420	62.9%	8	1.2%	668	1000	150%	0.88
23	240	35.9%	420	62.9%	8	1.2%	668	1150	172%	0.70
*Percentages are % by weight based on the total.										

As shown in the above results, the spectral emissivity of Sample No.21 in which the weight ratio of the binder compared to 100% by weight of the fuel-activating material is 100% by weight is the highest value of 0.94 and, using this sample as a center value, the spectral emissivity of Sample No.20 in which the weight ratio of the binder is 50% by weight, and that of Sample No.22 in which the weight ratio of the binder is 150% by weight were 0.85 or more. To the contrary, in Sample No.23 in which the weight ratio of the binder is more than 150%, the spectral emissivity was less than 0.85. In Sample No.19 in which the weight ratio of the binder is less than 50% by weight, it was impossible to form into a sheet. As a result, it has been found that the sample was not suited for practical use as a heat-resistant fuel-activating substance.

[0026] As described above, in the case of forming a heat-resistant fuel-activating substance by mixing with a metal binder and forming the mixture into a sheet, an appropriate weight ratio of the binder compared to 100% by weight of the fuel-activating material is 50% by weight or more and 150% by weight or less.

(4) Heat-Resistant Fuel-Activating Substance formed as Inorganic Resin Sheet

[0027] Next, in the case of forming into a sheet using the fuel-activating material of Sample No.3, which was considered as the best mode by the results of (1) described above, and using an inorganic resin as a binder, a suitable weight ratio of the binder was examined. The inorganic silicone resin used also in (1) described above as an inorganic resin in the weight ratio shown in Table 3 below was blended with 100% by weight of the fuel-activating material of (1) described above, and then the obtained mixture was kneaded and formed into a 1-mm thick sheet. The spectral emissivity of the sheet was measured in the same manner as in (1) described above and also formability as the sheet was examined. The results were as shown in Table 4 below.

[0028]

Table 4

Sample No.	Tourmaline		Iron powder		Carbon		Total	Binder		Spectral emissivity
	g	%	g	%	g	%	g	g	%	
24	240	35.9%	420	62.9%	8	1.2%	668	470	70%	-
25	240	35.9%	420	62.9%	8	1.2%	668	500	75%	0.91
26	240	35.9%	420	62.9%	8	1.2%	668	688	100%	0.94
27	240	35.9%	420	62.9%	8	1.2%	668	1000	150%	0.90
28	240	35.9%	420	62.9%	8	1.2%	668	1150	172%	0.71
*Percentages are % by weight based on the total.										

As shown in the above results, the spectral emissivity of Sample No.26 in which the weight ratio of the binder compared to 100% by weight of the fuel-activating material is 100% by weight is the highest value of 0.94 and, using this sample as a center value, the spectral emissivity of Sample No.25 in which the weight ratio of the binder is 75% by weight, and that of Sample No.27 in which the weight ratio of the binder is 150% by weight were 0.85 or more. To the contrary, in Sample No.28 in which the weight ratio of the binder is more than 150%, the spectral emissivity was less than 0.85. In Sample No.24 in which the weight ratio of the binder is less than 75% by weight, it was impossible to form into a sheet. As a result, it has been found that the sample was not suited for practical use as a heat-resistant fuel-activating substance.

[0029] As described above, in the case of forming a heat-resistant fuel-activating substance by mixing with an inorganic

resin binder and forming the mixture into a sheet, an appropriate weight ratio of the binder compared to 100% by weight of the fuel-activating material is 75% by weight or more and 150% by weight or less.

(5) Heat-Resistant Fuel-Activating Substance formed As Inorganic Resin Melt Thermal Spraying Sheet

[0030] Next, in the case of forming into a sheet by melting and thermal spraying using the fuel-activating material as Sample No.3, which was considered as the best mode by the results of (1) described above, and using an inorganic resin as a binder, a suitable weight ratio of the binder was examined. The inorganic silicone resin used also in (1) described above as an inorganic resin in the weight ratio shown in Table 3 below was blended with 100% by weight of the fuel-activating material of (1) described above, and then the obtained mixture was melted and thermally sprayed onto a 2-mm thick aluminized steel sheet so that the film thickness became 1 mm. The spectral emissivity of the sheet was measured in the same manner as in (1) described above and also adhesion as the sheet was examined. The results were as shown in Table 5 below.

[0031]

Table 5

Sample No.	Tourmaline		Iron powder		Carbon		Total	Binder		Spectral emissivity
	g	%	g	%	g	%	g	g	%	
29	240	35.9%	420	62.9%	8	1.2%	668	470	70%	-
30	240	35.9%	420	62.9%	8	1.2%	668	500	75%	0.89
31	240	35.9%	420	62.9%	8	1.2%	668	668	100%	0.94
32	240	35.9%	420	62.9%	8	1.2%	668	1000	150%	0.87
33	240	35.9%	420	62.9%	8	1.2%	668	1150	172%	0.72
*Percentages are % by weight based on the total.										

As shown in the above results, the spectral emissivity of Sample No.31 in which the weight ratio of the binder compared to 100% by weight of the fuel-activating material is 100% by weight is the highest value of 0.94 and, using this sample as a center value, the spectral emissivity of Sample No.30 in which the weight ratio of the binder is 75% by weight, and that of Sample No.32 in which the weight ratio of the binder is 150% by weight were 0.85 or more. To the contrary, in Sample No.33 in which the weight ratio of the binder is more than 150%, the spectral emissivity was less than 0.85. In Sample No.29 in which the weight ratio of the binder is less than 75% by weight, when the sample was rubbed by hands after thermal spraying onto a steel sheet, the spray coating film was easily peeled off. As a result, it has been found that the sample showed poor adhesion performance as the heat-resistant fuel-activating substance and was not suited for practical use.

[0032] As described above, in the case of forming a heat-resistant fuel-activating substance by subjecting an inorganic resin binder to melting and thermal spraying and forming the melt into a sheet, an appropriate weight ratio of the binder compared to 100% by weight of the fuel-activating material is 75% by weight or more and 150% by weight or less.

(6) Addition of Silicon

[0033] In the case of further adding silicon (silicon powder (Si.14, SHOWA CHEMICAL INDUSTRY CO., LTD.)) to Sample No.11 in which the content of carbon was the lower limit of 0.5% by weight in (1) described above, samples were made under the same conditions as in (1) described above and then subjected to the measurement of the spectral emissivity. The results were as shown in Table 6 below.

[0034]

Table 6

Sample No.	Tourmaline		Iron powder		Carbon		Silicon		Total	Binder		Spectral emissivity
	g	%	g	%	g	%	g	%	g	g	%	
11	242.5	36.3 %	422	63.2 %	3.5	0.5 %	0	0.0 %	668	668	100 %	0.90

(continued)

Sample No.	Tourmaline		Iron powder		Carbon		Silicon		Total	Binder		Spectral emissivity
	g	%	g	%	g	%	g	%	g	g	%	
34	242.5	36.1 %	422	62.9 %	3.5	0.5 %	3.3	0.5 %	671.3	668	100 %	0.92
35	242.5	35.9 %	422	62.5 %	3.5	0.5 %	6.7	1.0 %	674.7	668	99%	0.94
36	242.5	35.8 %	422	62.2 %	3.5	0.5 %	10	1.5 %	678	668	99%	0.91
37	242.5	35.7 %	422	62.1 %	3.5	0.5 %	12	1.8 %	680	668	98%	0.87
*Percentages are % by weight based on the total.												

As shown in the above results, the spectral emissivity of Sample No.11 in which silicon was not added was 0.90, whereas the spectral emissivity was increased to 0.92 in Sample No.34 in which 0.5% by weight of silicon was added. Furthermore, the spectral emissivity was 0.94 in Sample No.35 in which 1.0% by weight of silicon was added and the spectral emissivity was 0.91 in Sample No.36 in which 1.5% by weight of silicon was added. In both samples, the spectral emissivity was increased as compared with the case where silicon was not added. However, the spectral emissivity was rather decreased to 0.87 in Sample No.37 in which the additive percentage of silicon was more than 1.5% by weight (1.8% by weight).

[0035] As described above, when the additive percentage of silicon is 1.5% by weight or less, the significance of supplementing the spectral emissivity was recognized in case the content of carbon is comparatively low.

(7) Continuous Use of Heat-Resistant Fuel-Activating Substance

[0036] Next, an influence of continuous use on the spectral emissivity under a high-temperature environment was examined.

A test piece obtained by coating an aluminum sheet measuring 100 mm × 200 mm × 2 mm in thickness with the heat-resistant fuel-activating substance of Sample No.31 in Table 5 described above was placed on a horizontal steel plate supported by a prop, and then heated by a gas ring to a temperature of 280 to 300°C for 7 hours per day from under the steel plate. After completion of heating, the test piece was subjected to the measurement of the spectral emissivity in the same manner as in (1) described above. This operation was continued for 20 hours with respect to the same test piece.

[0037] As a result, a change with time of the spectral emissivity of the test piece was as shown in Table 7 below.

[0038]

Table 7

Elapsed days	Spectral emissivity
1	0.95
2	0.96
3	0.88
4	0.87
5	0.87
6	0.86
7	0.86
8	0.86
9	0.86
10	0.86
15	0.86

(continued)

Elapsed days	Spectral emissivity
20	0.86

As described above, the spectral emissivity was kept at 0.85 or more over the entire test period.
Over the entire test period, blister, peeling or cracking did not occur in the aluminum sheet coated with the heat-resistant fuel-activating substance.
After the measurement of the spectral emissivity, a peeling test was conducted in a state where the temperature was returned to room temperature. Using a cutter, a lattice-shaped cut reaching an aluminum layer was formed on a surface of a heat-resistant fuel-activating substance at an interval of 5 mm, followed by adhering an adhesive cellophane tape thereonto. The tape was peeled off immediately was observed whether the peeled heat-resistant fuel-activating substance adheres onto the tape or not. As a result, over the entire test period, neither peeling of the heat-resistant fuel-activating substance nor any burr was observed at all.

[0039] Furthermore, an impact resistance test was conducted with respect to tight adhesion. The same aluminum sheet coated with the heat-resistant fuel-activating substance was placed on a floor and a steel ball of 1 kg was dropped thereon three times from a height of 1 m, and then it was observed whether peeling occurs or not. As a result, any peeling of the heat-resistant fuel-activating substance was not observed over the entire test period.
As shown in each observation described above, tight adhesion of the heat-resistant fuel-activating substance onto a material to be coated is extremely satisfactory.
It is additionally noted herein that the observation results with respect to a change of the spectral emissivity and tight adhesion with time were observed in common not only in mode of use of spraying of the inorganic material of (1) described above, but also in all of other modes of use.

(8) Relationship between Spectral Emissivity and Flame Temperature

[0040] With respect to the presence or absence of affixing of the heat-resistant fuel-activating material, and those having different spectral emissivities among heat-resistant fuel-activating substances, various tests were conducted and a change in flame temperature was examined. Specifically, a measuring device 10 as shown in Fig.1 was used. That is, a burner 13 made of a stainless steel tube having an inner diameter of 8.0 mm was connected to a burner connection portion 12 equipped with an air hole 11, and also a fuel pipe 14 protrudes from behind the burner connection portion 12 to halfway of the burner cylinder 13. A heat-resistant fuel-activating substance 15 formed into a sheet using the inorganic resin of (4) described above as a binder was affixed on the portion that was an outer side face of this burner cylinder 13 and was also behind a tip of the fuel pipe 14.

[0041] This measuring apparatus 10 was disposed at room temperature under an atmospheric pressure and a test was conducted. A flow rate of fuel (city gas (13A, 88% of methane)) from the fuel pipe 14 was adjusted to 73 cm/sec and a flow rate of air from the air hole 11 was adjusted to 27 cm/sec. Flame 16 occurring in the burner cylinder 12 as a result of mixing them was videotaped by a high-speed video camera (HPV-1, Shimadzu Corporation) and the obtained video images were analyzed by a dichroic temperature measurement/camera system (Thermera, Nobby Tech. Ltd.) thereby measuring a flame temperature. The results are shown in Table 8 below.

[0042]

Table 8

Test No.	Affixing of heat-resistant fuel-activating substance	Spectral emissivity	Flame temperature (K)
1	Not affixed	-	2158
2	Affixed	0.70	2163
3	Affixed	0.75	2163
4	Affixed	0.80	2172
5	Affixed	0.85	2246
6	Affixed	0.87	2246
7	Affixed	0.90	2258
8	Affixed	0.92	2258
9	Affixed	0.94	2258

As described above, there was a tendency that the flame temperature rose by affixing of the heat-resistant fuel-activating substance, and also the flame temperature rose as the spectral emissivity of the affixed heat-resistant fuel-activating substance became higher. It has also been found that flame temperature rise of 100 K was particularly observed in the test No.1 in which the heat-resistant fuel-activating substance was not affixed, and in the tests Nos. 7 to 9 in which the spectral emissivity was 0.90 or more.
As is also apparent from the test of the heat-resistant fuel-activating substance other than (4) described above, the flame temperature depended on the spectral emissivity.

Embodiments

(1) Test Results in Boiler

[0043] The above heat-resistant fuel-activating substance was affixed in a specific boiler and the energy saving efficiency was verified. Herein, the "energy saving efficiency" was defined as follows.
First, a coefficient obtained by dividing the amount of fuel (unit: liter in the case of liquid fuel, m^3 in the case of gas fuel) used during the test by the amount of water (unit: m^3) used to obtain steam before affixing of the heat-resistant fuel-activating substance was defined as a "fuel use coefficient before affixing" (E_b).
On the other hand, a coefficient obtained by dividing the amount of fuel used during the test by the amount of water used to obtain steam after affixing of the heat-resistant fuel-activating substance is similarly defined as a "fuel use coefficient after affixing" (E_a).
[0044] Then, an energy saving ratio (η) is defined by the following equation:

$$\eta = (Eb - Ea)/Eb \times 100.$$

That is, a ratio (%) of a decrease in amount before and after affixing of the heat-resistant fuel-activating substance of the amount of fuel required to convert 1 cubic meter of water into steam to the amount of fuel required before affixing was the energy saving ratio (η).
This was verified by various kinds of boilers below.

(1-1) First Embodiment

[0045] As the first embodiment, verification was conducted using a flame-tube smoke-tube boiler as a specific boiler. The fuel used in this flame-tube smoke-tube boiler (KMS-16A, IHI PACKAGED BOILER CO., LTD.) was A-heavy oil, the burner used was a gun type burner, the boiler capacity was 8,000 kg/h, and the control method was a proportional control method. Fig.2 is a schematic view of the flame-tube smoke-tube boiler 20, and Fig.3 enlarges a gun type burner portion thereof. A combustion device 22 was attached to one end (left end in Fig.2) of a combustion chamber 28 in a boiler body 21, and a combustion cone 23 enabled a cone maximum diameter portion 24 having the maximum outer diameter to open toward inside the boiler body 21 (rightward in Fig.2, upward in Fig.3), and emitted flame from the tip of gun type burner 25 located in almost the shaft center to a center direction of a combustion chamber 28. A flange 26 that fixed the gun type burner 25 was provided at the rear end of the combustion device 22. Each kind of heat-resistant fuel-activating substances 15 in Table 9 below was affixed onto the inner side face of the flange 26, whose area 27 was 100% of a projected area of the cone maximum diameter portion 24 to the flange 26 (cf. Fig.3), and the fuel use coefficient before and after affixing was calculated and then the energy saving ratio was calculated therefrom. The results were shown in Table 9 below. Regarding the spectral emissivity in the heat-resistant fuel-activating substance, the weight ratio of each binder was appropriately adjusted so as to become each numerical value shown in the table below.
[0046]

Table 9

Method of affixing heat-resistant fuel-activating substance	Spectral emissivity	Fuel use coefficient		Energy saving rate (%)
		Before affixing	After affixing	
Metal spraying	0.90	72.46	68.86	4.97
Metal sheet	0.88	72.40	68.89	4.85
Inorganic resin sheet	0.94	72.30	68.46	5.31

(continued)

Method of affixing heat-resistant fuel-activating substance	Spectral emissivity	Fuel use coefficient		Energy saving rate (%)
		Before affixing	After affixing	
Inorganic resin thermal spray	0.92	72.35	68.62	5.16

As described above, even in each of the affixing methods, if the spectral emissivity was 0.85 or more, a decrease of at least 4.85% or more of the fuel use coefficient before affixing was observed. In particular, even if the heat-resistant fuel-activating substance was different, there was a tendency that the energy saving rate also increased with the increase of the spectral emissivity of the heat-resistant fuel-activating substance. This is assumed that the flame temperature may increase with the increase of the spectral emissivity (cf. item (8) in "BEST MODE FOR CARRYING OUT THE INVENTION").

(1-2) Second Embodiment

[0047] As the second embodiment, verification was conducted using a once-through boiler as a specific boiler. The fuel used in this once-through boiler (STE2001GLM, Nippon Thermoener Co., Ltd.) was LPG, the burner used was a gun type burner, the boiler capacity was 1,667 kg/h, and the control method was a 3-position control method. Fig.4 is a schematic view of the once-through boiler 30, and Fig.5 enlarges a gun type burner portion thereof. A combustion device 32 was attached to one end (upper end in Fig.4) of a combustion chamber 38 in a boiler body 31, and a combustion cone 33 enabled a cone maximum diameter portion 34 having the maximum outer diameter to open toward inside the boiler body 31 (downward in Fig.4 and Fig.5), and emitted flame from the tip of gun type burner 35 located in almost the shaft center to a center direction of a combustion chamber 38. A flange 36 that fixed the gun type burner 35 was provided at the rear end of the combustion device 32. Each kind of heat-resistant fuel-activating substances 15 in Table 10 below was affixed onto the inner side face of the flange 36, whose area 37 was 100% of a projected area of the cone maximum diameter portion to the flange 36, and the fuel use coefficient before and after affixing was calculated and then the energy saving ratio was calculated therefrom. The results were shown in Table 10 below. The heat-resistant fuel-activating substances used herein were respectively the same as those used in the first embodiment.

[0048]

Table 10

Method of affixing heat-resistant fuel-activating substance	Spectral emissivity	Fuel use coefficient		Energy saving rate (%)
		Before affixing	After affixing	
Metal spraying	0.90	27.14	25.80	4.94
Metal sheet	0.88	27.12	25.83	4.76
Inorganic resin sheet	0.94	27.10	25.60	5.54
Inorganic resin thermal spray	0.92	27.15	25.71	5.30

As described above, even in each of the affixing methods, if the spectral emissivity was 0.85 or more, a decrease of at least 4.76% or more of the fuel use coefficient before affixing was observed. In particular, even if the heat-resistant fuel-activating substance was different, similar to the first embodiment described above, there was a tendency that the energy saving rate also increased with the increase of the spectral emissivity of the heat-resistant fuel-activating substance.

(1-3) Third Embodiment

[0049] As the third embodiment, verification was conducted using a water-tube boiler as a specific boiler. The fuel used in this water-tube boiler (SCM-160, IHI Corporation) was C-heavy oil, the burner used was a gun type burner, the boiler capacity was 16,000 kg/h, and the control method was a proportional control method. Fig.6 is a schematic view of the water-tube boiler 40, and Fig.7 enlarges a gun type burner portion thereof. A combustion device 42 was attached to one end (lower end in Fig.6) of a combustion chamber 48 in a boiler body 41, and a combustion cone 43 enabled a cone maximum diameter portion 44 having the maximum outer diameter to open toward inside the boiler body 41 (upward in Fig.6 and Fig.7), and emitted flame from the tip of gun type burner 45 located in almost the shaft center to a center direction of a combustion chamber 48. A flange 46 that fixed the gun type burner 45 was provided at the rear end of the combustion device 42. Each kind of heat-resistant fuel-activating substances 15 in Table 11 below was affixed onto the

inner side face of the flange 46, whose area 47 was 100% of a projected area of the cone maximum diameter portion 44 to the flange 46, and the fuel use coefficient before and after affixing was calculated and then the energy saving ratio was calculated therefrom. The results were shown in Table 11 below. The heat-resistant fuel-activating substances used herein were respectively the same as those used in the first embodiment.

[0050]

Table 11

Method of affixing heat-resistant fuel-activating substance	Spectral emissivity	Fuel use coefficient		Energy saving rate (%)
		Before affixing	After affixing	
Metal spraying	0.90	70.50	68.31	3.11
Metal sheet	0.88	70.52	68.35	3.08
Inorganic resin sheet	0.94	70.38	67.89	3.54
Inorganic resin thermal spray	0.92	70.42	68.05	3.37

As described above, even in each of the affixing methods, if the spectral emissivity was 0.85 or more, a decrease of at least 3% or more of the fuel use coefficient before affixing was observed. In particular, even if the heat-resistant fuel-activating substance was different, similar to the first and second embodiments described above, there was a tendency that the energy saving rate also increased with the increase of the spectral emissivity of the heat-resistant fuel-activating substance.

(2) Others

[0051] It is additionally noted herein that almost the same effects were obtained even in the case of using boilers other than the above respective general-purpose boilers, industrial boilers and using, in addition to the above fuels, biofuel, propane gas and the like as fuels used in the boilers, regardless of the kind.

INDUSTRIAL APPLICABILITY

[0052] The present invention can be utilized not only in a once-through boiler, a flame-tube smoke-tube boiler and a water-tube boiler (including an industrial boiler and a power station boiler that are equipped with two or more burners), but also in burning appliances equipped with a combustion device, such as a kiln and a dryer.

Claims

1. A heat-resistant fuel-activating substance formed by melt-mixing 50 to 150% by weight of a metallic thermal spray material with 100% by weight of a fuel-activating material having a spectral emissivity of 0.85 or more for electromagnetic waves with wavelengths in a range of 3 to 20 μm, thereby making the mixture capable of thermal spraying.

2. A heat-resistant fuel-activating substance formed by melting 50 to 150% by weight of a metallic material having a melting point of 420°C or lower with 100% by weight of a fuel-activating material having a spectral emissivity of 0.85 or more for electromagnetic waves with wavelengths in a range of 3 to 20 μm to be formed into a sheet.

3. A heat-resistant fuel-activating substance formed by mixing 75 to 150% by weight of an inorganic resin having a heat resistance temperature exceeding 300°C with 100% by weight of a fuel-activating material having a spectral emissivity of 0.85 or more for electromagnetic waves with wavelengths in a range of 3 to 20 μm.

4. The heat-resistant fuel-activating substance according to claim 1, 2 or 3, wherein the fuel-activating material is formed by blending tourmaline, iron powder and carbon in proportions within a range of 30 to 44% by weight, 55 to 69% by weight, and 0.5 to 1.5% by weight, respectively.

5. The heat-resistant fuel-activating substance according to claim 4, wherein 1.5% by weight or less of silicon is contained in 100% by weight of the fuel-activating material.

Fig. 1

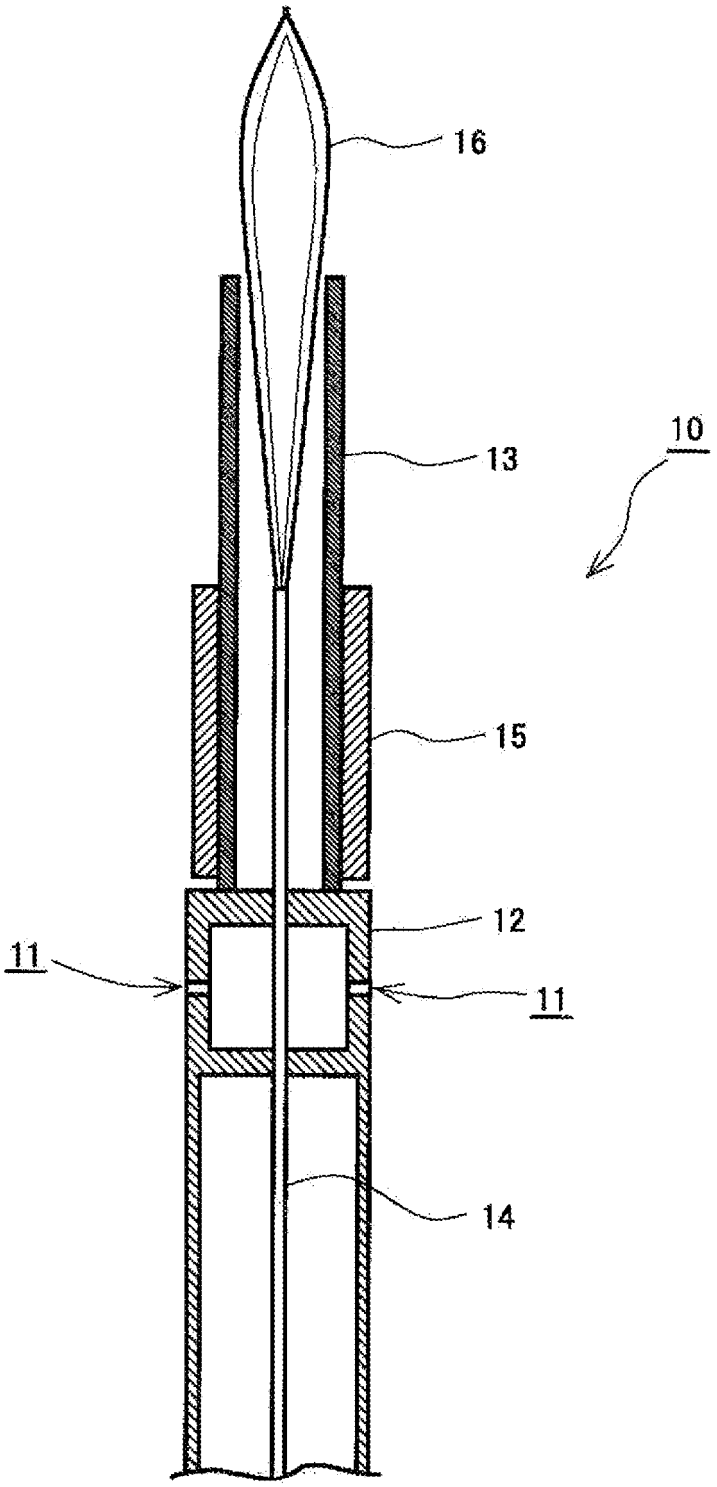


Fig. 2

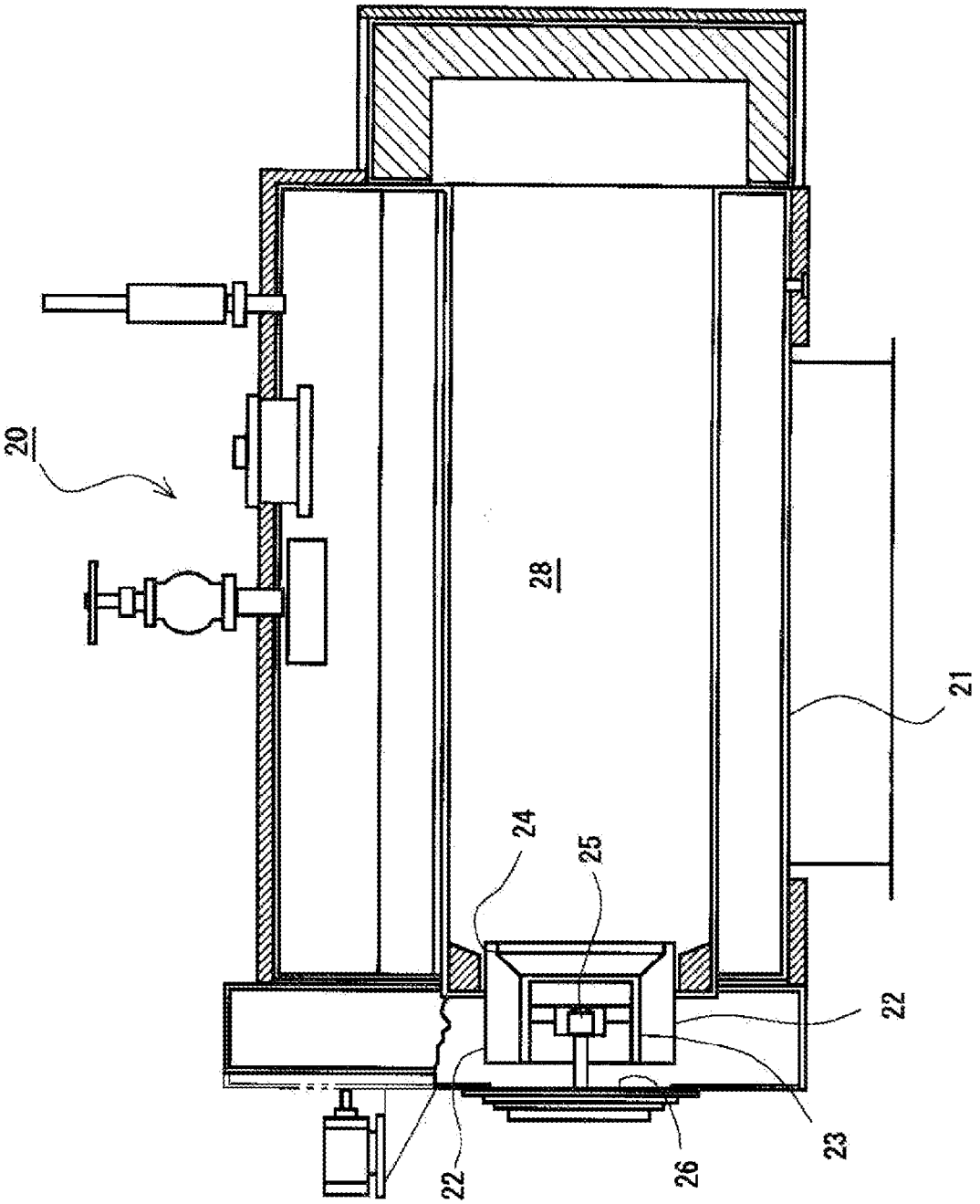


Fig. 3

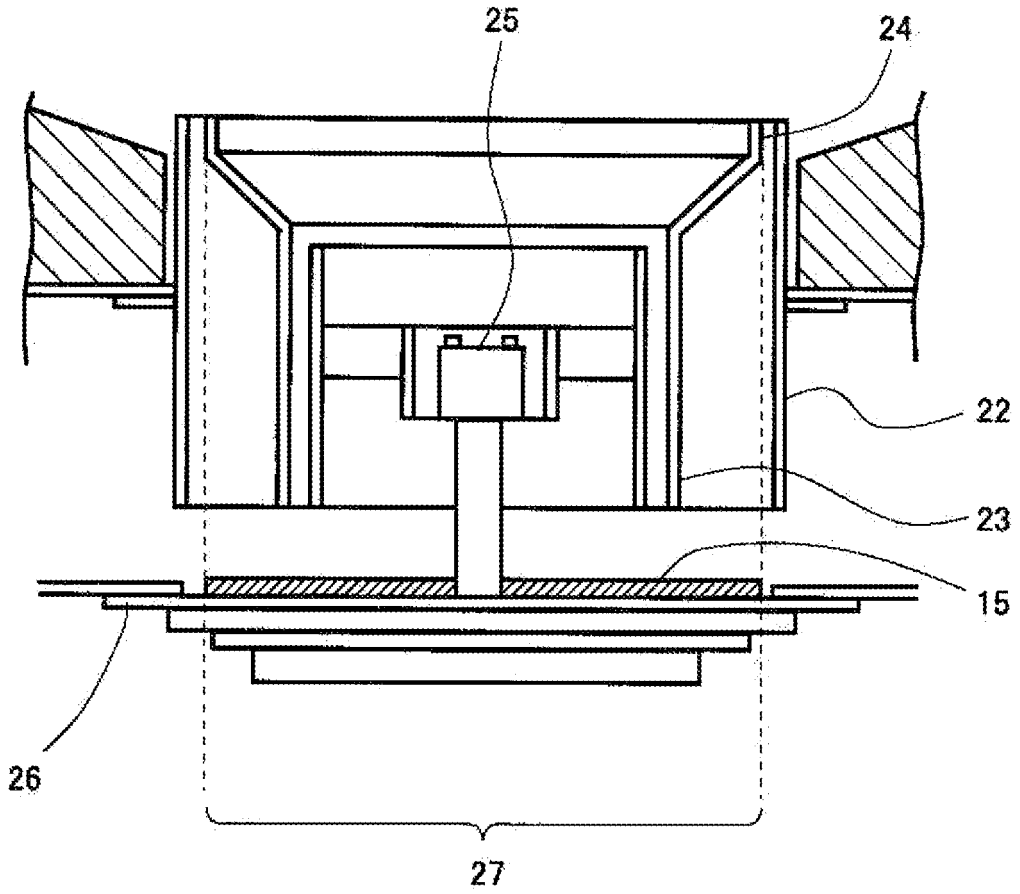


Fig. 4

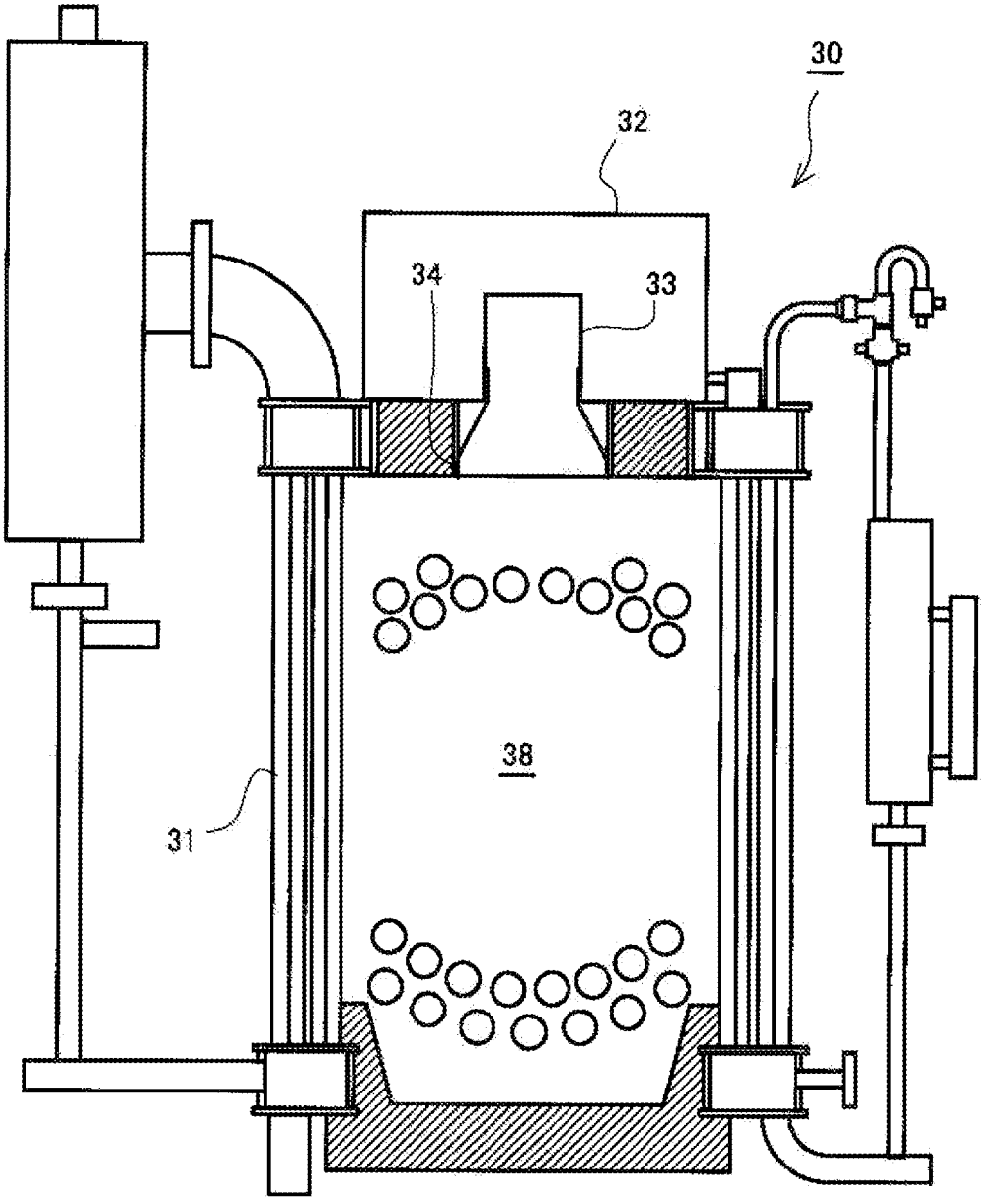


Fig. 5

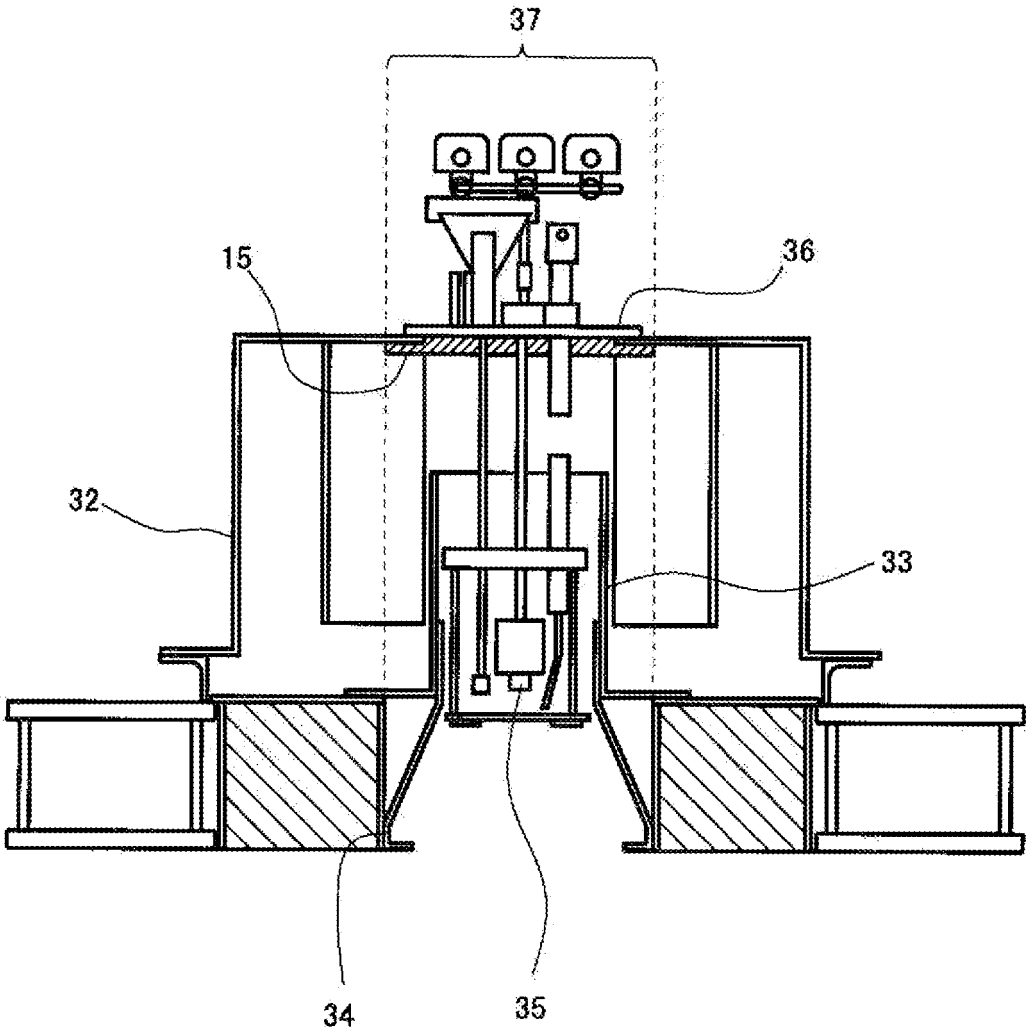


Fig. 6

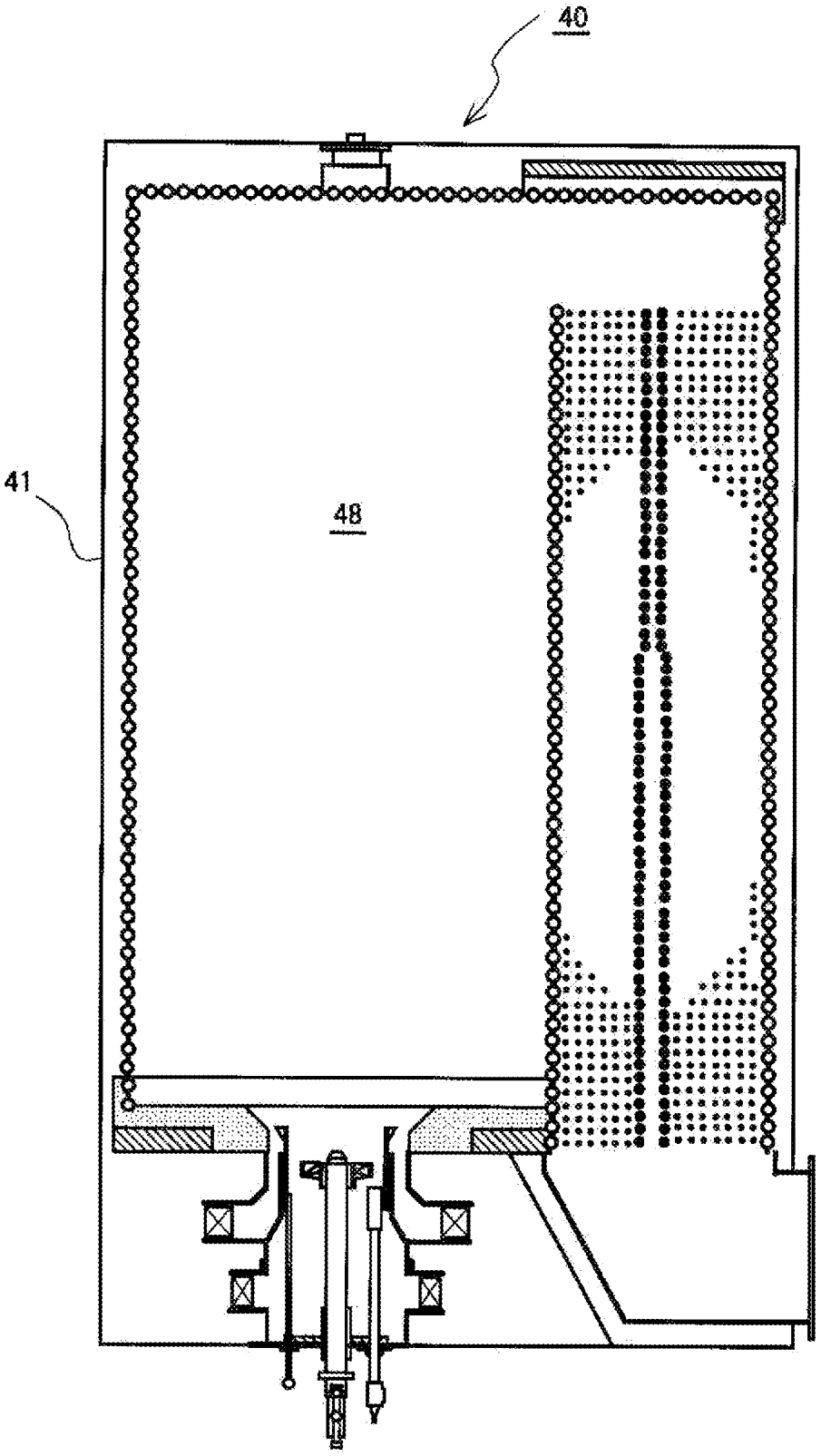
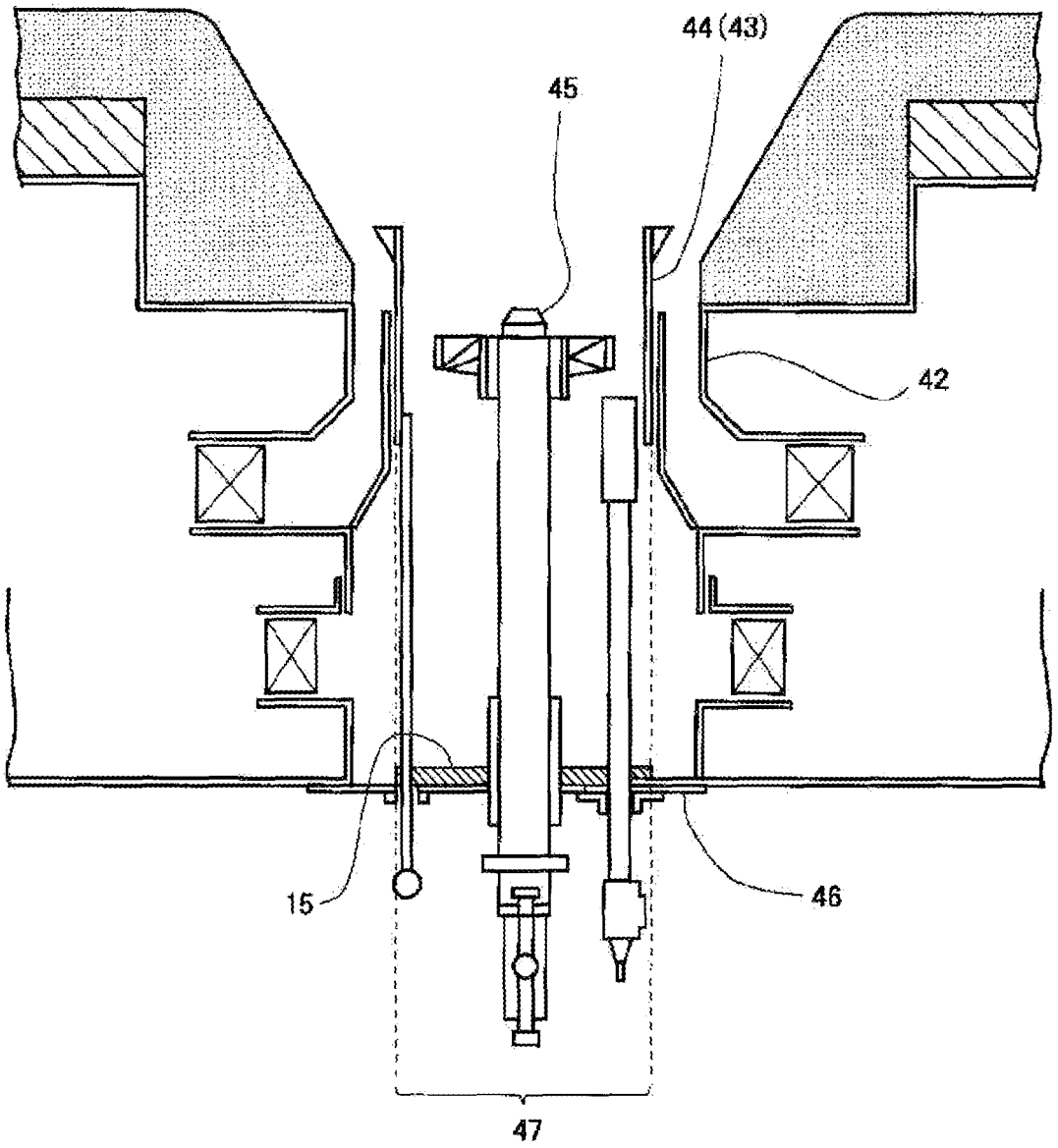


Fig. 7



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004589

A. CLASSIFICATION OF SUBJECT MATTER
F23K5/08(2006.01)i

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)
F23K5/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2009
Kokai Jitsuyo Shinan Koho 1971-2009 Toroku Jitsuyo Shinan Koho 1994-2009

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 Y	JP 3137137 U (Yugen Kaisha Nishikawa Jidosha), 15 November 2007 (15.11.2007), entire text (Family: none)	1,4,5 2,3
Y	JP 3115958 U (Kabushiki Kaisha Hokumon Kensetsu), 24 November 2005 (24.11.2005), claim 1 (Family: none)	2
Y	JP 2001-221109 A (Niles Parts Co., Ltd.), 17 August 2001 (17.08.2001), paragraphs [0008] to [0010] (Family: none)	2

☒ 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	Date of mailing of the international search report
16 October, 2009 (16.10.09)	27 October, 2009 (27.10.09)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004589

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2007-127085 A (Ryoji WATABE), 24 May 2007 (24.05.2007), claims 1, 2 (Family: none)	3
Y	JP 2003-55062 A (Itsuo KUROKAWA), 26 February 2003 (26.02.2003), paragraph [0024] (Family: none)	3

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 11001707 A **[0004]**
- WO 2006088084 A **[0004]**