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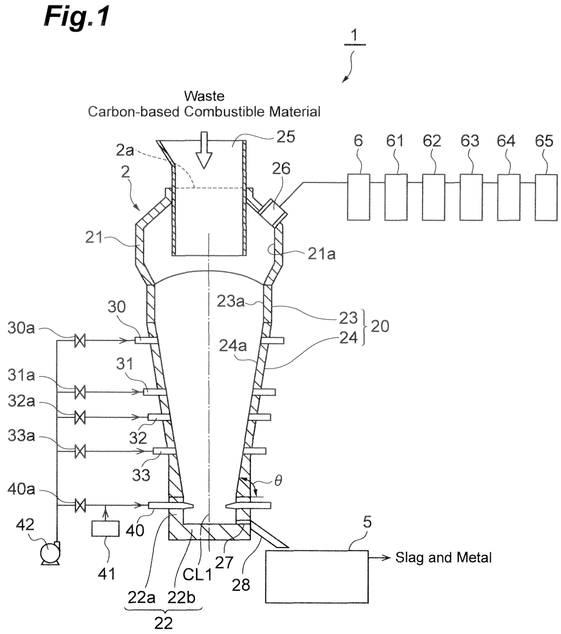
(54) **WASTE MATERIAL MELTING FURNACE**

(57) A waste melting furnace (2) for drying, thermally decomposing, and melting waste comprises a cylindrical main part (20) extending vertically so as to form a space for containing the waste and guide the waste from upside to downside; a melt reservoir part (22), joined to a lower side of the main part along a center axis of the main part (20), for retaining melt generated from the waste; and a gas induction part (21), joined to an upper side of the main part (20) along the center axis of the main part (20), for collecting a gas generated from the waste and guiding the collected gas to an exhaust port (26). The main part (20) has a taper part (24) having an inner cross-sectional area gradually decreasing to the downside. The taper part (24) vertically occupies the largest height in all of parts constituting the main part (20).

Fig.1



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Description

Technical Field

[0001] The present invention relates to a waste melting furnace which dries, thermally decomposes, and melts waste.

Background Art

[0002] An example of methods for processing waste such as general and industrial waste is one melting the waste in an industrial furnace using a carbon-based combustible material such as coke as a melting heat source. Processing the waste by melting can reduce the volume of waste and also recycle burned ashes and noncombustible refuses, which have hitherto been finally disposed as landfills, into slag and metals.

[0003] Known as a method for melting waste is one burning the waste and then melting the resulting burned ashes and noncombustible matters by heating. Attention has recently been focused on a gasification and melting furnace which can burn and gasify combustible matters in waste and melt ashes in the waste in one furnace. The gasification and melting furnace bums and gasifies the combustible matters in the waste by the heat of combustion of a carbon-based combustible material and lets them out and melts the ashes and noncombustible matters remaining in the furnace by heating. That is, the gasification and melting furnace thermally decomposes the waste and melts the ashes and non-combustible matters by heating.

[0004] As a gasification and melting furnace, shaft-type melting furnaces have been known (see, for example, Patent Literatures 1 to 3). Each of the melting furnaces disclosed in Patent Literatures 1 to 3 comprises a cylindrical shaft part (straight barrel part), an inverted truncated cone part (taper part), and a furnace bottom part. The furnace bottom part is provided with a lower tuyere. A gas (combustion-supporting gas) for burning the carbon-based combustible material is blown into the furnace through the lower tuyere. This bums the carbon-based combustible material, thereby producing a high-temperature in-furnace gas, which ascends. Heat exchange occurs between the in-furnace gas and the waste, thereby promoting the drying and thermal decomposition of the waste. The ashes and noncombustible matters accumulate on the furnace bottom part side along the inner face of the taper part, so as to be melted by the heat of combustion of the carbon-based combustible material. The melt is retained on the furnace bottom part and taken out therefrom.

[0005] In each of the melting furnaces disclosed in Patent Literatures 1 and 2, the inverted truncated cone part is further provided with an upper tuyere. Air is blown into the furnace through the upper tuyere. This promotes the drying and thermal decomposition of the waste.

Citation List

Patent Literature

[0006]

Patent Literature 1: Japanese Patent Application Laid-Open No. H08-94036
Patent Literature 2: Japanese Patent Application Laid-Open No. 2011-89672
Patent Literature 3: Japanese Patent Application Laid-Open No. 2002-130632

Summary of Invention

Technical Problem

[0007] In each of the above-mentioned gasification and melting furnaces, however, the burden descent velocity of the waste is not uniform in the furnace but tends to be lower in the vicinity of the furnace wall than in the center part in the furnace. In the furnaces described in Patent Literatures 1 to 3, the burden descent velocity is low in the vicinity of the inner face of the inverted truncated cone part in particular, whereby the waste is apt to stop. In particular, the waste is likely to be caught at the boundary between the inner face of the shaft part and the inner face of the inverted truncated cone part and stop there. When such stagnation occurs, the in-furnace gas may fail to fully extend over a certain part, thereby lowering the efficiency in heat exchange between the waste and the in-furnace gas.

[0008] Thermal decomposition may also occur locally in the part where the waste stops, thereby producing a space. In the melting furnaces disclosed in Patent Literatures 1 and 2, the local thermal decomposition is likely to occur in particular in the vicinity of the upper tuyere, since the air is blown into the inverted truncated cone part through the upper tuyere. When the space produced by the local thermal decomposition forms a flow path for the in-furnace gas, the in-flow gas may blow through the flow path and tends not to extend over parts other than the space (this phenomenon will hereinafter be referred to as "gas blowout"). This may further lower the efficiency in heat exchange between the waste and the in-furnace gas.

[0009] Thermal decomposition residues produced when the space is formed may melt and adhere to the inner face of the furnace. When such adhesion occurs, the waste is more likely to stop. This may further lower the efficiency in heat exchange between the waste and the in-furnace gas.

[0010] When the efficiency in heat exchange between the waste and the in-furnace gas thus decreases, the carbon-based combustible material is consumed in a greater amount in order to compensate for this. Since the carbon-based combustible material derives from fossil fuels in general, the increase in consumption of the carbon-based combustible material is undesirable from the viewpoint of environmental protection. It is therefore an object of the present invention to provide a waste melting furnace which can reduce the consumption of carbon-based combustible materials.

Solution to Problem

[0011] The waste melting furnace in accordance with the present invention is a waste melting furnace for drying, thermally decomposing, and melting waste, the furnace comprising a cylindrical main part extending vertically so as to form a space for containing the waste and guide the waste from upside to downside; a melt reservoir part, joined to a lower side of the main part along a center axis of the main part, for retaining melt generated from the waste; and a gas induction part, joined to an upper side of the main part along the center axis of the main part, for collecting a gas generated from the waste and guiding the collected gas to an exhaust port; wherein the main part has a taper part having an inner cross-sectional area gradually decreasing to the downside; wherein the taper part vertically occupies the whole height of the main part or the largest height in all of parts constituting the main part; and wherein an inner face of the taper part forms an angle of inclination exceeding 75° but less than 90° with a horizontal plane.

[0012] Burning a carbon-based combustible material in a lower part in this waste melting furnace produces a high-temperature in-furnace gas, which ascends. The waste descends against the upward flow of the in-furnace gas. In this process, heat exchange occurs between the in-furnace gas and the waste, thereby promoting the drying and thermal decomposition of the waste. Gases produced by the thermal decomposition of the waste concentrate in the gas induction part and are discharged therefrom. The ashes and noncombustible matters remaining in the furnace accumulate on the bottom part side of the furnace along the inner face of the taper part and are melted by the heat of combustion of the carbon-based combustible material. The melt is retained in the melt reservoir part and taken out therefrom.

[0013] Here, the taper part occupies the largest height in all of the parts constituting the main part. Therefore, the inner face of the taper part forms a greater angle of inclination with the horizontal plane than in the case where the non-tapered straight barrel part occupies the largest height. This allows the waste in the vicinity of the inner face of the taper part to be guided smoothly to the downside. Further, even when the taper part is joined to the lower side of the straight barrel part, the inner face of the taper part tilts moderately with respect to the inner face of the straight barrel part, whereby the waste tends not to stop at the upper end portion of the taper part. When the taper part occupies the largest height, the upper end portion of the taper part is located on the upper side of the main part. The waste reduces its volume by being dried and thermally decomposed as it descends through the main part. The volume reduction also proceeds on the upper side of the main part. When the upper end portion of the taper part is located on the upper side of the main part, the cross-sectional area of the main part becomes smaller from the upper side to downside in conformity to the volume reduction also proceeding on the upper side of the main part. This inhibits spaces from being formed and prevents the gas blowout from occurring. These allow the efficiency in heat exchange between the waste and the in-furnace gas to improve over that in the case where the straight barrel part occupies the largest height. Hence, the consumption of carbon-based combustible materials can be reduced.

[0014] Here, the fact that the inner volume of the main part is smaller than that in the case where the straight barrel part occupies the largest height does not adversely affect the efficiency in processing the waste. This is because the efficiency in heat exchange between the waste and the in-furnace gas improves as mentioned above, so that the waste reduces its volume efficiently.

[0015] The inner face of the taper part forms an angle of inclination exceeding 75° but less than 90° with the horizontal plane. This more securely prevents the waste from stagnating. Hence, the efficiency in heat exchange between the waste and the in-furnace gas can further be improved.

[0016] The main part may have a drying region for drying the waste and a thermal decomposition region, placed under the drying region, for thermally decomposing the waste, while a boundary between the drying and thermal decomposition regions may be located in the taper part. In this case, the upper end portion of the taper part is located in the drying region. The above-mentioned volume reduction of the waste also proceeds within the drying region. When the upper end portion of the taper part is located in the drying region, the cross-sectional area of the main part becomes smaller from within the drying region to downside in conformity to the volume reduction also proceeding within the drying region. This can more securely inhibit spaces from occurring.

[0017] The melt reservoir part may be provided with a lower tuyere for feeding an oxygen-enriched gas into the furnace, the taper part may be provided with an upper tuyere for feeding air into the furnace, and at least one upper tuyere may be located in the drying region. In this case, feeding the oxygen-enriched gas into the furnace through the lower tuyere can keep the carbon-based combustible material burning. Feeding the air into the furnace also from the upper tuyere can promote the drying and thermal decomposition of the waste. Here, at least one upper tuyere is located in the drying region. This further promotes the drying of the waste in the drying region. Since the upper end portion of the taper part is located in the drying region as mentioned above, the waste in the drying region descends along the taper part. The waste further reduces its volume as the drying thereof is promoted, whereby the burden descent along the taper part is more smoothened. The waste having reduced its volume by promoting the drying thereof is accumulated at the center by the taper part, whereby spaces are inhibited from being formed. Thus, the fact that the upper end portion of the taper part is located in the drying region cooperates with the fact that the drying region is provided with the upper tuyere, thereby making it possible to promote the drying of the waste while inhibiting spaces from being formed.

[0018] The upper tuyere in the drying region may be located closer to a lower end portion of the drying region between the lower end portion of the drying region and the upper end portion of the taper part. This can more securely inhibit spaces from occurring.

Advantageous Effects of Invention

[0019] The waste melting furnace in accordance with the present invention can reduce the consumption of carbon-based combustible materials.

Brief Description of Drawings

[0020]

Fig. 1 is a schematic view of a waste processing system using the waste melting furnace in accordance with the present invention;
Fig. 2 is a vertical sectional view illustrating the waste melting furnace in Fig. 1;
Fig. 3 is a diagram schematically illustrating drying, thermal decomposition, and melting regions in the waste melting furnace;
Fig. 4 is a set of diagrams illustrating examples and a comparative example;
Fig. 5 is a graph illustrating daily shifts in in-furnace differential pressure;
Fig. 6 is a graph illustrating daily shifts in furnace-top gas temperature;
Fig. 7 is a set of graphs illustrating shifts in middle-furnace gas temperature with time;
Fig. 8 is a chart illustrating results of measurement of the amount of waste processed, coke ratio, in-furnace differential pressure, and furnace-top gas temperature;
Fig. 9 is a set of diagrams illustrating distributions of in-furnace gas flow rate and in-furnace differential pressure in the height direction of the furnace;
Fig. 10 is a chart plotting results of measurement of in-furnace heat exchange temperature and coke ratio;
Fig. 11 is a chart plotting results of measurement of moisture drying capacity per volume and coke ratio;
Fig. 12 is a chart plotting results of measurement of heat transfer efficiency and in-furnace gas flow rate; and
Fig. 13 is a chart plotting results of measurement of gas blowout occurrence time and coke ratio.

Description of Embodiments

[0021] In the following, preferred embodiments of the present invention will be explained in detail with reference to the drawings. In the drawings, the same constituents or those having the same functions will be referred to with the same signs while omitting their overlapping descriptions.

[0022] As illustrated in Fig. 1, a waste processing system 1 is a system for processing general and industrial waste and comprises a waste melting furnace 2, a granulation pit 5, a combustion chamber 6, a boiler 61, a cooling tower 62, a bag filter 63, a catalytic reaction tower 64, and a chimney 65. In a reducing atmosphere, the waste melting furnace 2 thermally decomposes and gasifies combustible matters in the waste and melts ashes and noncombustible matters. As will be explained later, gases generated from the waste are discharged from the upper part of the waste melting furnace 2, while melt generated from the waste are discharged from the lower part of the waste melting furnace 2.

[0023] The granulation pit 5 granulates, cools, and collects the melt discharged from the waste melting furnace 2. The granulation pit 5 comprises a casing for retaining cooling water and a scraper conveyor (not depicted) for taking out the cooled products granulated and cooled within the casing. The combustion chamber 6 and boiler 61 are connected to the upper part of the waste melting furnace 2 through an exhaust duct, so as to collect thermal energy from exhaust gases of the waste melting furnace 2. The cooling tower 62, bag filter 63, and catalytic reaction tower 64 are connected to the downstream side of the boiler 61, so as to detoxify the exhaust gases. The chimney 65 discharges the detoxified exhaust gases.

[0024] The waste melting furnace 2 is formed by a refractory material and the like, examples of which include bricks, SiC, and alumina. The waste melting furnace 2 comprises a vertically extending cylindrical main part 20 centered at a vertical axis CL1, a gas induction part 21 joined to the upper side of the main part 20, and a melt reservoir part 22 joined to the lower side of the main part 20. The main part 20 forms a space for containing the waste and guides them from upside to downside. The gas induction part 21 collects gases generated from the waste within the main part 20 and guides the collected gases to the exhaust duct. The melt reservoir part 22 retains the melt generated from the waste within the main part 20.

[0025] The main part 20 is constituted by a straight barrel part 23 having a fixed inner cross-sectional area and a taper part 24, joined to the lower side of the straight barrel part 23, having an inner cross-sectional area gradually decreasing to the downside. The straight barrel part 23 has a cylindrical inner face 23a, while the taper part 24 has an inner face 24a of an inverted truncated cone. The inner diameter of the upper end portion of the taper part 24 is equal to that of the straight barrel part 23.

[0026] The height H2 of the taper part 24 is greater than the height H3 of the straight barrel part 23 (see Fig. 3). That is, the taper part 24 occupies the largest height in all of the parts constituting the main part 20. Therefore, the inner face 24a of the taper part 24 forms a greater angle of inclination θ with a horizontal plane than in the case where the straight barrel part 23 occupies the largest height. The angle of inclination θ is more than 75° but less than 90°. More preferably, it is at least 80° but less than 90°.

[0027] The inner diameter and height of the main part 20 are determined according to volumes necessary for a drying region 70 and a thermal decomposition region 71 which will be explained later, for example. The volume necessary for the drying region 70 is a volume in which the total amount of moisture contained in the waste put into the waste melting furnace 2 per hour (i.e., input moisture amount) can be dried, assuming that the amount of moisture dried per hour is 50 to 150 $kg/m^3 \cdot h$, for example. The volume necessary for the thermal decomposition region 71 is a volume in which the amount of carbon contained in the waste and coke put into the waste melting furnace 2 per hour can be gasified, assuming that the amount of gasification per hour is 50 to 150 $kg/m^3 \cdot h$, for example.

[0028] The melt reservoir part 22 has a cylindrical side wall part 22a centered at the axis CL1 and a bottom part 22b closing the lower end portion of the side wall part 22a. The upper end portion of the side wall part 22a is connected to the lower end portion of the taper part 24. The inner diameter of the side wall part 22a is equal to that of the lower end portion of the taper part 24. A tap hole 27 for discharging the melt retained in the melt reservoir part 22 is formed in the lower end portion of the side wall part 22a. The tap hole 27 is provided with an opening and closing mechanism (not depicted) through which the melt are discharged intermittently. Disposed on the outside of the tap hole 27 is a melt chute 28 extending obliquely downward from the side wall part 22a. The melt chute 28 sends the melt to the granulation pit 5.

[0029] The gas induction part 21 exhibits a cylindrical form centered at the axis CL1. The lower end portion of the gas induction part 21 is connected to the upper end portion of the straight barrel part 23 of the main part 20. The inner diameter of the lower end portion of the gas induction part 21 is equal to that of the straight barrel part 23. The vertical middle portion of the gas induction part 21 bulges radially. Hence, the gas induction part 21 has an inner face 21 a which radially bulges as compared with the inner face 23a of the straight barrel part 23. The upper end portion of the gas induction part 21 is narrower than the lower end portion and constitutes an opening part 2a of the waste melting furnace 2.

[0030] An inner cylinder 25 is inserted into the opening part 2a. The inner cylinder 25 has a cylindrical form centered at the axis CL1 and introduces the waste and a carbon-based combustible material into the waste melting furnace 2. The lower end portion of the inner cylinder 25 is located higher than that of the gas induction part 21. The upper portion of the gas induction part 21 is provided with an exhaust port 26. The exhaust port 26 discharges gases generated from the waste within the main part 20. The exhaust port 26 is connected to the combustion chamber 6 through the exhaust duct.

[0031] The melt reservoir part 22 is provided with lower tuyeres 40 for feeding air enriched with oxygen (hereinafter referred to as "oxygen-enriched gas") into the furnace. The oxygen enrichment is meant to enhance the oxygen concentration. The lower tuyeres 40 are arranged at a plurality of locations aligning circumferentially of the side wall part 22a. In a preferred example of their arrangement, the lower tuyeres 40 are arranged at eight locations circumferentially aligning at intervals of 45°. The leading end portion of each lower tuyere 40 may or may not project into the melt reservoir part 22.

[0032] The taper part 24 is provided with upper tuyeres 30, 31, 32, 33 for feeding air into the furnace. The upper tuyeres 30, 31, 32, 33 align from the upside to downside. The number of stages of the vertically aligning upper tuyeres is not limited to 4 but may be less or more than 4. The respective sets of upper tuyeres 30, 31, 32, 33 are each arranged at a plurality of locations aligning circumferentially of the taper part 24. In a preferred example of their arrangement, each set of the upper tuyeres 30, 31, 32, 33 are arranged at four locations circumferentially aligning at intervals of 90°. The leading end portion of each of the upper tuyeres 30, 31, 32, 33 may or may not project into the taper part 24.

[0033] A blower 42 is connected to the upper tuyeres 30, 31, 32, 33 and lower tuyeres 40. Flow paths from the blower 42 to the sets of upper tuyeres 30, 31, 32, 33 and lower tuyere 40 are provided with flow regulating valves 30a, 31a, 32a, 33a, 40a, respectively. An oxygen generator 41 for enriching air with oxygen is also connected to the flow path from the flow regulating valve 40a to the lower tuyeres 40.

[0034] As illustrated in Fig. 2, the waste melting furnace 2 is arranged with thermometers T1 to T5 for measuring in-furnace temperatures. The thermometer T1 is arranged in the upper portion of the gas introduction part 21. The thermometer T5 is embedded in the refractory material constituting the bottom part 22b of the melt reservoir part 22. The thermometers T2, T3, T4 align from the upside to downside between the thermometers T1, T5. The waste melting furnace 2 is also arranged with a plurality of pressure gauges for measuring in-furnace pressures. The pressure gauge P1 is arranged in the upper portion of the gas induction part 21. The pressure gauges P2, P3, P4 are arranged in the upper, middle, and lower portions of the taper part 24, respectively.

[0035] Operations of the waste melting furnace 2 will now be explained in detail. First, before putting the waste in, a carbon-based combustible material is introduced into the furnace 2 through the inner cylinder 25. An example of the carbon-based combustible material is coke. Coke may wholly or partly be replaced by carbides of biomass such as wood. The coke accumulated on the bottom part 22b in the waste melting furnace 2 is ignited by a burner (not depicted) or the like. This forms a so-called coke bed 81 on the bottom part in the furnace.

[0036] Next, a mixture of coke and waste is introduced into the waste melting furnace 2 through the inner cylinder 25 and fills the main part 20. The kind of the waste is not limited in particular but may be any of general and industrial waste. This can process shredder dust (ASR), dug-up refuse, burned ash, and the like either singly or in mixtures with or without combustible refuse. Dry-distilled waste may also be put in. Limestone and the like as an alkalinity adjuster may be added to the waste in addition to coke.

[0037] In this state, the oxygen-enriched gas is fed into the furnace through the lower tuyeres 40. In a preferred example for setting the blast pressure of the oxygen-enriched gas, it is set within the range of 5 to 25 kPa. Fuel gases such as LNG may be mixed with the oxygen-enriched gas fed into the furnace through the lower tuyeres 40. An air is fed into the furnace through the upper tuyeres 30, 31, 32, 33. In a preferred example for setting the blast pressure of the air, it is set within the range of 5 to 25 kPa.

[0038] On the bottom part 22b side of the waste melting furnace 2, the oxygen-enriched gas fed from the lower tuyeres 40 keeps coke burning, thereby producing a high-temperature in-furnace gas, which ascends. The air fed from the upper tuyeres 30, 31, 32, 33 partly burns the waste in the taper part 24, thereby producing a high-temperature in-furnace gas, which ascends. The waste is guided to the main part 20 and descends against upward flows of the in-furnace gases. In this process, heat exchange occurs between the waste and the in-furnace gases, thereby promoting the drying and thermal decomposition of the waste. Gases produced by the thermal decomposition of the waste concentrate in the gas induction part 21 and are guided to the upside, so as to be discharged through the exhaust port 26. The discharged gases are sent to the combustion chamber 6 through the exhaust duct.

[0039] Thermal decomposition residues (carbides), together with ashes and noncombustible matters, accumulate on the bottom part 22b side of the waste melting furnace 2 along the inner face 24a of the taper part 2, thereby forming a carbide particle layer (so-called char layer) 82 on the coke bed 81. The char layer 82 functions as a ventilation-resistance layer and adjusts flows of the oxygen-enriched gas fed from the lower tuyeres 40. This prevents local blowout of the oxygen-enriched air fed from the lower tuyeres 40.

[0040] The combustible dry-distilled product (fixed carbon) in the thermal decomposition residue is burned with coke. The combustion gas of coke and combustible dry-distilled product attains the highest temperature in a region near the upper end of the coke bed 81. The ashes and noncombustible matters melt in this region. The melt enters the melt reservoir part 22 through interstices of the coke bed, so as to be retained. Thus retained melt is intermittently taken out from the tap hole 27. The melt taken out from the tap hole 27 is granulated and cooled in the granulation pit 5, so as to be collected as slag and metals. Subsequently, the furnace is refilled with the mixture of coke and waste, and the waste melting processing is continued.

[0041] Here, while continuing the waste melting processing, the drying region 70 is formed in the upper portion within the waste melting furnace 2. The drying region 70 mainly performs the drying and preheating of the waste. The thermal decomposition region 71 is formed under the drying region 70. The thermal decomposition region 71 1. mainly performs the thermal decomposition and gasification of combustible components in the dried waste. A melting region 72 is formed under the thermal decomposition region 71. The melting region 72 mainly performs the melting of ashes and noncombustible matters (see Fig. 3). As mentioned above, the upper end portion of the taper part 24 is higher than in the case where the straight barrel part 23 occupies the largest height, thus reaching the drying region 70, whereby the boundary between the drying region 70 and thermal decomposition region 71 is located in the taper part 24.

[0042] Among the upper tuyeres 30, 31, 32, 33, the upper tuyeres 30 arranged at the uppermost stage are located in the drying region 70. The upper tuyeres 30 are located closer to the lower end portion of the drying region 70 between the lower end portion of the drying region 70 and the upper end portion of the taper part 24.

[0043] A greater gap is formed between waste pieces in the drying region 70 than in the thermal decomposition region 71, whereby the waste in the drying region 70 is easier to move than that in the thermal decomposition region 71. Therefore, if the upper tuyeres 30 of the drying region 70 yield a too much amount of blast, it may foster the formation of blowout paths for the in-furnace gases. It is therefore preferable for the amount of blast from the upper tuyeres 30 to be 50 Nm^3/h or less per location. It is not always necessary for the drying region 70 to be provided with the upper tuyeres 30. Two or more stages of the four-stage upper tuyeres 30, 31, 32, 33 may be arranged within the drying region 70.

[0044] Which parts in the furnace are the drying region 70, thermal decomposition region 71, and melting region 72 can be grasped according to in-furnace temperatures, for instance. For example, a part exhibiting an in-furnace temperature of 350 to 600°C is the drying region, a part exhibiting an in-furnace temperature of 600 to 1200°C is the thermal decomposition region, and a part exhibiting an in-furnace temperature of 1200 to 1800°C is the melting region. In this embodiment, the thermometers T1 to T5 are arranged within the waste melting furnace 2 from its upper portion to lower portion. The extent of the drying region 70, thermal decomposition region 71, and melting region 72 can roughly be grasped according to the respective temperatures measured by the thermometers.

[0045] The position of the boundary between the drying region 70 and thermal decomposition region 71 can also be grasped according to in-furnace differential pressures. In the drying region 70, the waste reduces its volume by losing the moisture upon drying. In the thermal decomposition region, the waste forms carbide particles by being thermally decomposed, so as to further reduce its volume, thereby thickening. Therefore, a difference of about 0.5 kPa/m, for example, exists between the differential pressure in the drying region and that in the thermal decomposition region. Here, the differential pressure is the amount of rise in pressure caused by a descent of 1 m. Hence, grasping a part where the differential pressure rises by about 0.5 kPa/m as compared with that in the upper region can roughly figure out the boundary between the drying region 70 and the thermal decomposition region 71. The respective differential pressures in the individual parts within the furnace can roughly be grasped by the pressure gauges P1 to P4 arranged within the furnace. For example, when the differential pressure near the middle pressure gauge P3 is higher than that in the upper region by about 0.5 kPa/m, the vicinity of the middle pressure gauge P3 is grasped as the boundary between the drying region 70 and the thermal decomposition region 71.

[0046] That is, the thermal decomposition region 71 of the waste is a region located lower than the part where the differential pressure has completely risen to 0.5 kPa/m or more within the drying region 70. Here, the differential pressure means the differential pressure at the time when the operation of the furnace is relatively stable, while excluding the differential pressure at the time when the gas blowout and the like occur.

[0047] In the waste melting furnace 2 explained in the foregoing, the taper part 24 occupies the largest height in all of the parts constituting the main part 20. Therefore, the inner face 24a of the taper part 24 forms a greater angle of inclination with the horizontal plane than in the case where the non-tapered straight barrel part 23 occupies the largest height. As a consequence, the waste in the vicinity of the inner face 24a of the taper part 24 is guided smoothly to the downside. Further, the inner face 24a of the taper part 24 tilts moderately with respect to the inner face 23a of the straight barrel part 23, thereby making it hard for the waste to stop at the upper end portion of the taper part 24. When the taper part 24 occupies the largest height, the upper end portion of the taper part 24 is located on the upper side of the main part 20. The waste reduces its volume by being dried and thermally decomposed as it descends through the main part 20. The volume reduction also proceeds on the upper side of the main part 20. When the upper end portion of the taper part 24 is located on the upper side of the main part 20, the cross-sectional area of the main part 20 becomes smaller from the upper side to downside in conformity to the volume reduction also proceeding on the upper side of the main part 20. This inhibits spaces from being formed and prevents the gas blowout from occurring. These allow the efficiency in heat exchange between the waste and the in-furnace gases to improve over that in the case where the straight barrel part 23 occupies the largest height. Hence, the consumption of coke can be reduced.

[0048] Here, the fact that the inner volume of the main part 20 is smaller than that in the case where the straight barrel part 23 occupies the largest height does not adversely affect the efficiency in processing the waste. This is because the efficiency in heat exchange between the waste and the in-furnace gases improves as mentioned above, so that the waste reduces its volume efficiently.

[0049] The inner face 24a of the taper part 24 forms an angle of inclination greater than 75° but less than 90° with the horizontal plane. This more securely prevents the waste from stagnating. Hence, the efficiency in heat exchange between the waste and the in-furnace gas can further be improved.

[0050] The boundary between the drying region 70 and the thermal decomposition region 71 is located in the taper part 24. As a consequence, the upper end portion of the taper part 24 is located in the drying region 70. The above-mentioned volume reduction of the waste also proceeds within the drying region 70. When the upper end portion of the taper part 24 is located in the drying region 70, the cross-sectional area of the main part 20 becomes smaller from within the drying region 70 to the downside in conformity to the volume reduction also proceeding within the drying region 70. This can more securely inhibit spaces from occurring.

[0051] The upper tuyeres 30 are located in the drying region 70. This further promotes the drying of the waste in the drying region 70. Since the upper end portion of the taper part 24 is located in the drying region 70 as mentioned above, the waste in the drying region 70 descends along the taper part 24. The waste further reduces its volume as the drying thereof is promoted, whereby the burden descent along the taper part 24 is more smoothened. The waste having reduced its volume by promoting the drying thereof is accumulated at the center by the taper part 24, whereby spaces are inhibited from being formed. Thus, the fact that the upper end portion of the taper part 24 is located in the drying region 70 cooperates with the fact that the drying region 70 is provided with the upper tuyeres 30, thereby making it possible to promote the drying of the waste while inhibiting spaces from being formed.

[0052] The upper tuyeres 30 are located closer to the lower end portion of the drying region 70 between the lower end portion of the drying region 70 and the upper end portion of the taper part 24. This can separate the upper tuyeres 30 located in the drying region 70 from the boundary between the straight barrel part 23 and the taper part 24 and more securely inhibit spaces from occurring.

[0053] Further, the waste melting furnace 2 inhibits thermal decomposition residues from adhering and thus can dramatically reduce the workload at the time of maintenance of the waste melting furnace 2. Since spaces are restrained from occurring, the waste melting furnace 2 can be operated stably. If a space occurs and then grows, the in-furnace differential pressure will decrease. When the growing space is filled by a load shift, the in-furnace differential pressure rises drastically. Restraining spaces from occurring suppresses such fluctuations in the in-furnace differential pressure, thereby enabling the waste melting furnace to operate stably.

[0054] In the waste melting furnace 2, the inner diameter of the thermal decomposition region 71 is smaller than that in the conventional furnace as compared with the case where the straight barrel part 23 occupies the largest height. The char layer can accordingly increase its thickness, thereby securing a sufficient in-furnace differential pressure. This also contributes to stabilizing the operation of the waste melting furnace 2.

[0055] Though a preferred embodiment of the present invention is explained in the foregoing, the present invention is not necessarily limited to the above-mentioned embodiment but may be modified in various ways within the scope not deviating from the gist thereof. For example, the main part 20 may be constituted by the taper part 24 alone without the straight barrel part 23. That is, the taper part 24 may occupy the total height H1 of the main part 20.

[0056] In the following, examples of the present invention, which do not restrict the present invention, and a comparative example will be illustrated.

(1) Example 1

[0057] As Example 1, a waste melting furnace 2A schematically illustrated in Fig. 4(a) was prepared. The waste melting furnace 2A corresponds to the waste melting furnace 2 of the above-mentioned embodiment. The ratio of the height H2 of the taper part 24 with respect to the total height H1 of the main part 20 is 95%. The inner face 24a of the taper part 24 forms an angle of inclination θ of 80° with the horizontal plane. In the waste melting furnace 2A, the above-mentioned thermometers T2 are disposed at four locations which align circumferentially at intervals of 90°.

(2) Example 2

[0058] As Example 2, a waste melting furnace 2B schematically illustrated in Fig. 4(b) was prepared. The waste melting furnace 2B corresponds to the waste melting furnace 2 of the above-mentioned embodiment. The ratio of the height H2 of the taper part 24 with respect to the total height H1 of the main part 20 is 50%. The inner face 24a of the taper part 24 forms an angle of inclination θ of 75° with the horizontal plane. The inner diameter of the straight barrel part 23, the inner diameter of the lower end portion of the taper part 24, and the total height H1 of the main part 20 in the waste melting furnace 2B are equal to those in the waste melting furnace 2A.

(3) Comparative Example 1

[0059] As Comparative Example 1, a waste melting furnace 2C schematically illustrated in Fig. 4(c) was prepared. The waste melting furnace 2C differs from the above-mentioned waste melting furnace 2 in the following points. The straight barrel part 23 occupies the largest height in all of the parts constituting the main part 20. The ratio of the height H2 of the taper part 24 with respect to the total height H1 of the main part 20 is 35%. Among the upper tuyeres 30, 31, 32, 33, the uppermost ones 30 are omitted. All of the upper tuyeres 31, 32, 33 are located in the thermal decomposition region 71. The inner face 24a of the taper part 24 forms an angle of inclination 0 of 70° with the horizontal plane.

[0060] The inner diameter of the straight barrel part 23, the inner diameter of the lower end portion of the taper part 24, and the total height H1 of the main part 20 in the waste melting furnace 2C are equal to those in the waste melting furnace 2A. The above-mentioned thermometers T2 are disposed at four locations which align circumferentially at intervals of 90° also in the waste melting furnace 2C.

(4) Comparative Evaluation of In-Furnace Differential Pressure, Furnace-Top Gas Temperature, and Middle-Furnace Gas Temperature

[0061] The waste melting furnaces 2A, 2B, 2C of Examples 1 and 2 and Comparative Example 1 were operated at the same period of time, and their in-furnace differential pressures were measured. As for the furnaces 2A, 2C of Example 1 and Comparative Example 1, their furnace-top gas temperature and middle-furnace gas temperature were measured. For evaluating only the effects of forms of the main part 20 while using Comparative Example 1 having no upper tuyeres 30 as a subject for comparison, no air was fed from the upper tuyeres 30 in Examples 1 and 2.

[0062] The in-furnace differential pressure in this test example is the difference between the value detected by the pressure gauge P4 disposed in the lower portion of the taper part 24 and the value detected by the pressure gauge P1 disposed in the upper portion of the gas induction part 21. The furnace-top gas temperature is the value detected by the thermometer T1 disposed in the upper portion of the gas induction part 21. The middle-furnace gas temperature is the value measured by the thermometer T2.

[0063] Fig. 5 is a graph illustrating daily shifts in the in-furnace differential pressure. In Comparative Example 1, as a polygonal line L1 in Fig. 5 indicates, the in-furnace differential pressure was low during the period from the first day to the third day, thereby falling below the lower limit LL of a range suitable for operating the furnace. It is speculated from these results that the gas blowout occurred during the period from the first day to the third day in the waste melting furnace 2C, thereby lowering the in-furnace differential pressure.

[0064] The gas blowout seems to be caused by the waste stagnating in the vicinity of the inner face 24a of the taper part 24 in the waste melting furnace 2C (see hatched parts in Fig. 4(c)). The stagnating waste, if any, may locally be thermally decomposed by the air from the upper tuyeres 31, 32, 33, for example, so as to generate spaces, which may grow, thereby forming flow paths for the in-furnace gases (this phenomenon is likely to occur in particular in the vicinity of the boundary between the inner face 23a of the straight barrel part 23 and the inner face 24a of the taper part 24).

[0065] By contrast, as a polygonal line L2 in Fig. 5 indicates, the in-furnace differential pressure in Example 1 exceeded the lower limit LL of the range desirable for operating the furnace, while its width of daily shift was small. As a polygonal line L3 in Fig. 5 indicates, the in-furnace differential pressure in Example 2 was lower than that in Example 1 but exceeded the lower limit LL, while its width of daily shift was small. It is speculated from these results that the gas blowout is suppressed in Examples 1 and 2.

[0066] Fig. 6 is a graph illustrating daily shifts in the furnace-top gas temperature. As a polygonal line L4 in Fig. 6 indicates, the furnace-top gas temperature in Comparative Example 1 is high during the period from the first day to the third day and differs much from that on the fourth day and thereafter. The temperature during the period from the first day to the third day exceeds the upper limit ML of a range desirable for operating the furnace. It is seen from these results that the gas blowout occurred during the period from the first day to the third day in Comparative Example 1, thereby raising the furnace-top gas temperature.

[0067] By contrast, as a polygonal line L5 in Fig. 6 indicates, the furnace-top gas temperature in Example 1 was lower than the upper limit ML of the range desirable for operating the furnace, while its width of daily shift was small. It is speculated from these results that the gas blowout is restrained from occurring in Example 1.

[0068] Fig. 7 illustrates results of measurement of the middle-furnace gas temperature. Fig. 7 is a set of graphs illustrating shifts in the middle-furnace gas temperature with time. As Fig. 7(a) indicates, a large temperature fluctuation with time was seen in each of the four thermometers T2 in Comparative Example 1. Time slots when the temperature fluctuated vary among the thermometers. It is speculated from these results that the gas blowouts occurred one after another at different locations in different time slots within the furnace in Comparative Example 1.

[0069] By contrast, as Fig. 7(b) indicates, no large temperature fluctuation was seen in any of the four thermometers T2 in Example 1. It is speculated from these results that the gas blowout is much more restrained from occurring than in the waste melting furnace 2C of Comparative Example 1.

[0070] It is seen from the foregoing results that the present invention can restrain the gas blowout from occurring. In particular, from the fact that the ratio of the height H2 of the taper part 24 with respect to the total height H1 of the main part 20 is 50% or more in Example 2, it is substantially seen that the gas blowout can be restrained from occurring if the condition that the taper part occupies the largest height in all of the parts constituting the main part 20 is satisfied.

[0071] The operation was stopped after the lapse of one month, and the inside of each furnace was inspected. The results showed that adhering substances made of melted thermal decomposition residues were formed on the inner face of the waste melting furnace 2C of Comparative Example 1. By contrast, no adhering substances made of melted thermal decomposition residues were seen on the inner face of the waste melting furnace 2A of Example 1.

(5) Comparative Evaluation of Coke Ratio

[0072] The waste melting furnaces 2A, 2C of Example 1 and Comparative Example 1 were operated for about one week at the same period of time, and their coke ratios were compared with each other. For evaluating only the effects of forms of the main part 20 while using Comparative Example 1 having no upper tuyeres 30 as a subject for comparison, no air was fed from the upper tuyeres 30 in Examples 1 and 2.

[0073] Fig. 8 is a chart illustrating results of measurement of the amount of waste processed, coke ratio, in-furnace differential pressure, and furnace-top gas temperature. The coke ratio, in-furnace differential pressure, and furnace-top gas temperature are indicated by differences from the results of measurement of Comparative Example 1 serving as a reference. The coke ratio (kg/TR) is a value obtained by dividing the amount (kg) of coke put into the melting furnace by the total amount (t) of the waste processed in the melting furnace. As Fig. 8 illustrates, the coke ratio was lower in Example 1 by about 12.7 kg/TR than in Comparative Example 1 in a short-term test of about one week. It is seen from these results that the present invention can reduce the consumption of carbon-based combustible materials.

[0074] According to the results of Fig. 8, the furnace-top gas temperature in Example 1 is lower by about 100°C than that in Comparative Example 1. The in-furnace differential pressure in Example 1 is higher by about 1.5 kPa than that in Comparative Example 1. It is speculated from these results that the stagnation of waste and the occurrence of gas blowout are suppressed in the waste melting furnace 2A. This seems to contribute greatly to cutting down the consumption of carbon-based combustible materials.

(6) Comparative Evaluation of Drying Capacity

[0075] The waste melting furnaces 2A, 2C of Example 1 and Comparative Example 1 were operated at the same period of time, and their drying capacities were compared with each other. As parameters related to the drying capacities, their in-furnace gas flow rates (superficial velocities), in-furnace differential pressures, coke ratios, in-furnace heat exchange temperatures, moisture drying capacities per volume, and heat transfer efficiencies were measured during the operation and compared. This evaluation is aimed at verifying effects obtained when the lower end portion of the drying region 70 is located in the taper part 24 while the drying region 70 is provided with the upper tuyeres 30. Therefore, the air was fed from the upper tuyeres 30 in Example 1.

[0076] Fig. 9(a) is a graph illustrating in-furnace gas flow rate (superficial velocity) distributions in the furnace height direction. Curves L6, L7 illustrate in-furnace gas flow rates in Example 1 and Comparative Example 1, respectively. Reference lines b1, b2, b3, b4 indicate where the upper tuyeres 30, 31, 32, 33 are placed, respectively. Fig. 9(b) is a chart plotting an in-furnace differential pressure distribution in the furnace height direction. Reference lines a1, a2, a3, a4, a5 indicate where pressure gauges used for measuring the in-furnace differential pressures are placed. The pressure gauges used here differ from the above-mentioned pressure gauges P1, P2, P3, P4. Dots F1, F2, F3, F4 indicate the differential pressure between the reference lines a2, a1, the differential pressure between the reference lines a3, a2, the differential pressure between the reference lines a4, a3, and the differential pressure between the reference lines a5, a4, respectively. Figs. 9(a) and 9(b) are represented with their ordinates indicating the furnace height, while the scale of each ordinate is in conformity to the height in the sectional view of the furnace illustrated in Fig. 9(c).

[0077] As the curves L6, L7 in Fig. 9(a) illustrate, the in-furnace gas flow rate is higher in Example 1 than in Comparative Example 1. From this, it is speculated that Example 1 improves the efficiency in heat exchange between the in-furnace gas and the waste and enhances the drying capacity. Also, as mentioned above, Example 1 inhibits the gas blowout from occurring and stabilizes the in-furnace gas flow. Therefore, the fact that the in-furnace gas flow rate becomes higher and the fact that the in-furnace gas flow is stabilized are assumed to cooperate with each other, so as to further improve the efficiency in heat exchange between the in-furnace gas and the waste.

[0078] In Comparative Example 1, the gas blowout often occurred during the operation, thereby raising the furnace-top gas temperature, thus forcing to stop blasting from the upper tuyeres 31. The result also appears in the flow rate data in Fig. 9. By contrast, Example 1 restrained the gas blowout from occurring, thus enabling stable and steady blasting from the upper tuyeres 31.

[0079] Fig. 10 is a chart plotting results of measurement of in-furnace heat exchange temperature (°C) and coke ratio (kg/TR). In the charts, black circles indicate the results of measurement of Example 1, while white triangles indicate the results of measurement of Comparative Example 1. The in-furnace heat exchange temperature is calculated by the following expression:

In-furnace heat exchange temperature = in-furnace combustion temperature in the thermal decomposition region 1000°C (assumed) – furnace-top temperature (actual value).

As Fig. 10 indicates, Example 1 exhibited higher heat exchange temperature and lower coke ratio than Comparative Example 1. That is, Example 1 is seen to promote the drying of the waste as compared with Comparative Example 1.

[0080] Fig. 11 is a chart plotting results of measurement of moisture drying capacity per volume (Mcal/(m^3·h)) and coke ratio (kg/TR). In the charts, black circles indicate the results of measurement of Example 1, while white triangles indicate the results of measurement of Comparative Example 1. The moisture drying capacity per volume is calculated by the following expression:

$$\text{Moisture drying capacity per volume} = [\text{input waste amount (t/h)} \times \text{moisture in waste (\%)} \times \text{moisture evaporation latent heat (Mcal/t)}]/\text{drying region volume } (m^3).$$

[0081] Fig. 12 is a chart plotting results of measurement of heat transfer efficiency (Mcal/(m3·h·°C)) and in-furnace gas flow rate (superficial velocity) (Bm/s). In the charts, black circles indicate the results of measurement of Example 1, while white triangles indicate the results of measurement of Comparative Example 1. The heat transfer efficiency is calculated by the following expression:

$$\text{Heat transfer efficiency} = \text{heat transfer area} \times \text{heat transfer coefficient.}$$

The in-furnace gas flow rate indicates the flow rate at the height of the upper tuyeres 30. As Figs. 11 and 12 illustrate, Example 1 is seen to have a drying capacity which is about 2.5 times that of Comparative Example 1. According to the heat transfer area and heat transfer coefficient, the 2.5-fold improvement in drying capacity is caused by about a 1.7-fold improvement due to the stabilization of the in-furnace gas flow and about a 1.5-fold improvement due to the increased in-furnace gas flow rate.

(7) Comparative Evaluation of Whether Upper Tuyeres 30 Exist or Not

[0082] While operating the waste melting furnace 2A of Example 1, times when the gas blowout occurred were compared between respective cases where the air was fed from the upper tuyeres 30 and not. Fig. 13 is a chart plotting results of measurement of gas blowout occurrence time and coke ratio. In the chart, black circles indicate the results of measurement in the case where the air was fed from the upper tuyeres 30, while white triangles indicate the results of measurement in the case where no air was fed from the upper tuyeres 30.

[0083] As Fig. 13 illustrates, when no air was blown in from the upper tuyeres 30, the gas blowout time fluctuated a lot, and there were instances where the blowout occurred for a long period of time. The white triangles also indicate a tendency of the coke ratio to increase under the influence of the long-term blowout when the latter occurs.

[0084] By contrast, when the air is blown from the upper tuyeres 30, the gas blowout time fluctuated less and was shorter in total. It is seen from these results that blowing the air from the upper tuyeres 30 further restrains the gas blowout from occurring and reduces the consumption of carbon-based combustible materials.

Industrial Applicability

[0085] The present invention can be utilized for processing general and industrial waste.

Reference Signs List

[0086] 2...waste melting furnace; 20...main part; 21...gas induction part; 22...melt reservoir part; 24...taper part; 24a...inner face; 26...exhaust port; 30, 31, 32, 33...upper tuyere; 40...lower tuyere; 70...drying region; 71...thermal decomposition region; 72...melting region; CL1... axis

Claims

1. A waste melting furnace for drying, thermally decomposing, and melting waste, the furnace comprising:

a cylindrical main part extending vertically so as to form a space for containing the waste and guide the waste from upside to downside;
a melt reservoir part, joined to a lower side of the main part along a center axis of the main part, for retaining melt generated from the waste; and
a gas induction part, joined to an upper side of the main part along the center axis of the main part, for collecting a gas generated from the waste and guiding the collected gas to an exhaust port;
wherein the main part has a taper part having an inner cross-sectional area gradually decreasing to the downside;

wherein the taper part vertically occupies the whole height of the main part or the largest height in all of parts constituting the main part; and
wherein an inner face of the taper part forms an angle of inclination exceeding 75° but less than 90° with a horizontal plane.

2. A waste melting furnace according to claim 1, wherein the main part has a drying region for drying the waste and a thermal decomposition region, placed under the drying region, for thermally decomposing the waste; and wherein a boundary between the drying and thermal decomposition regions is located in the taper part.

3. A waste melting furnace according to claim 2, wherein the melt reservoir part is provided with a lower tuyere for feeding an oxygen-enriched gas into the furnace; wherein the taper part is provided with an upper tuyere for feeding air into the furnace; and wherein at least one upper tuyere is located in the drying region.

4. A waste melting furnace according to claim 3, wherein the upper tuyere in the drying region is located closer to a lower end portion of the drying region between the lower end portion of the drying region and the upper end portion of the taper part.

Fig.1

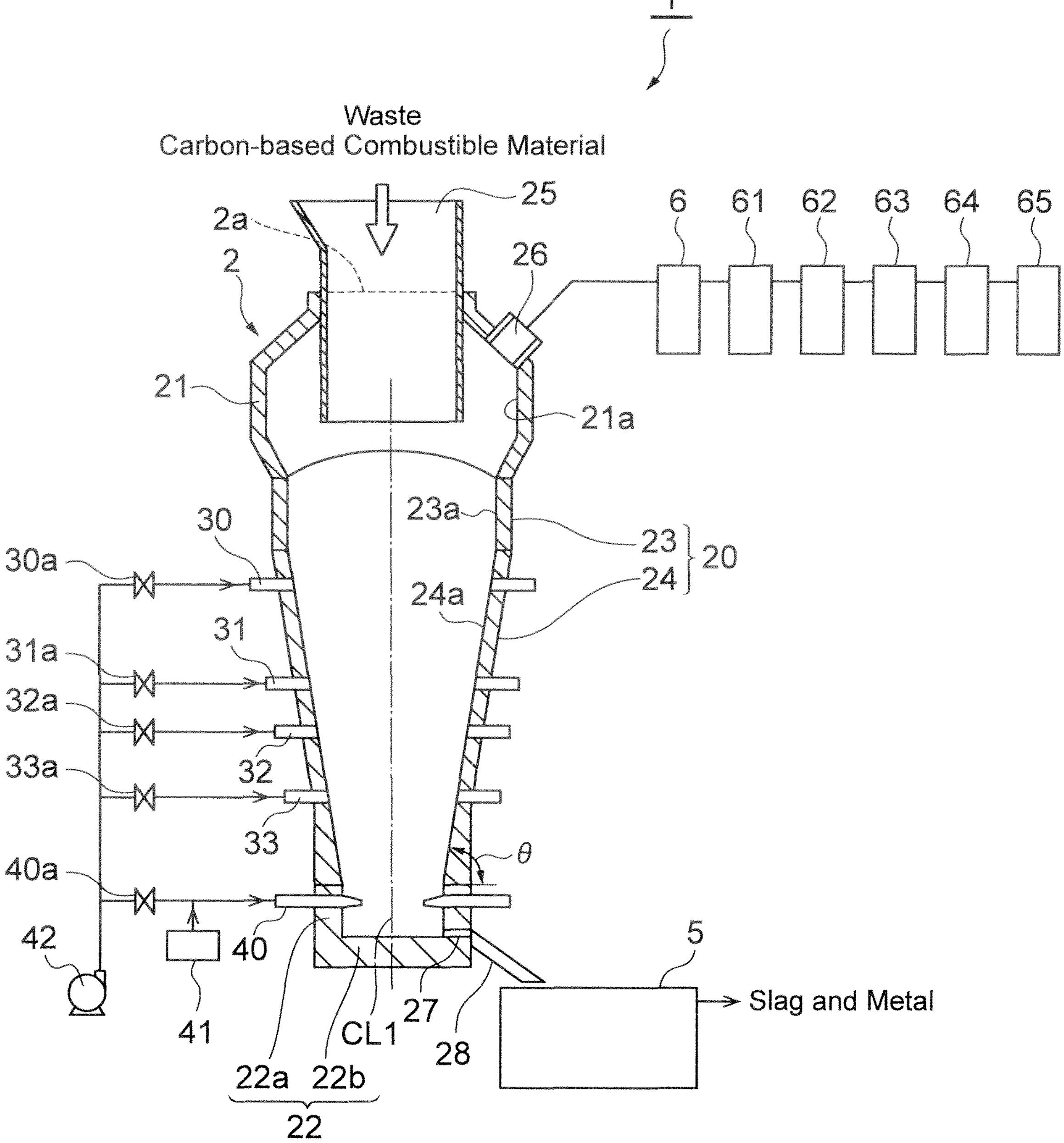

1
Waste
Carbon-based Combustible Material
25
2a
2
26
6
61
62
63
64
65
21
21a
23a
30
23
20
24
30a
24a
31
31a
32a
32
33a
33
θ
40a
42
40
41
5
Slag and Metal
27
CL1
28
22a
22b
22

Fig.2

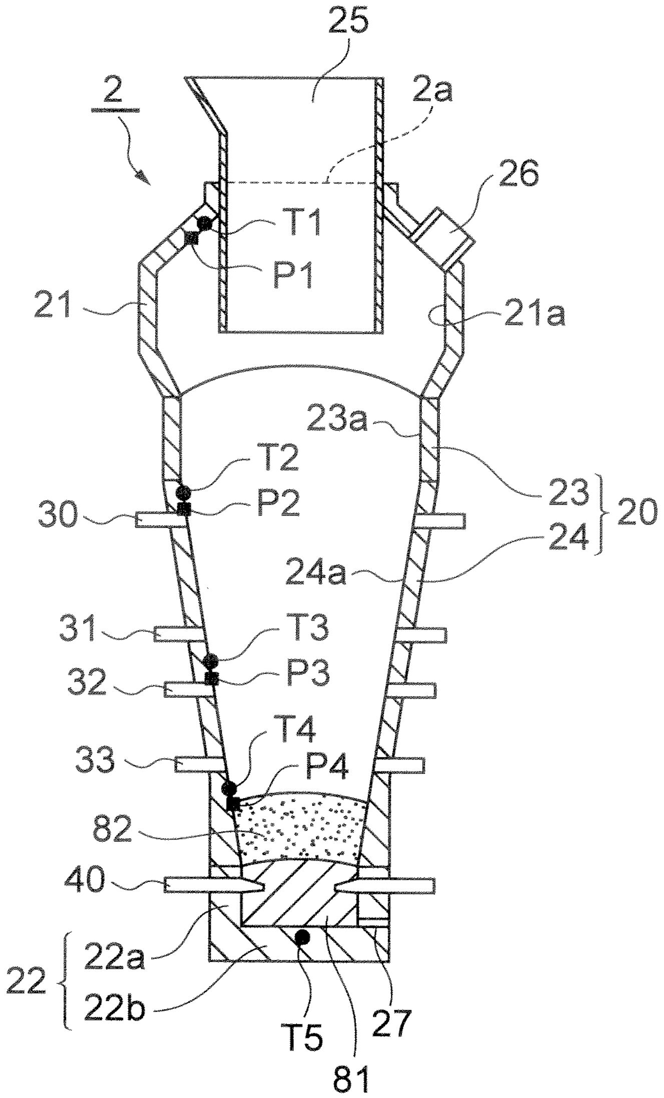

25
2
2a
26
T1
P1
21
21a
23a
T2
23
20
30
P2
24
24a
31
T3
32
P3
33
T4
P4
82
40
22a
22
22b
T5
27
81

Fig.3

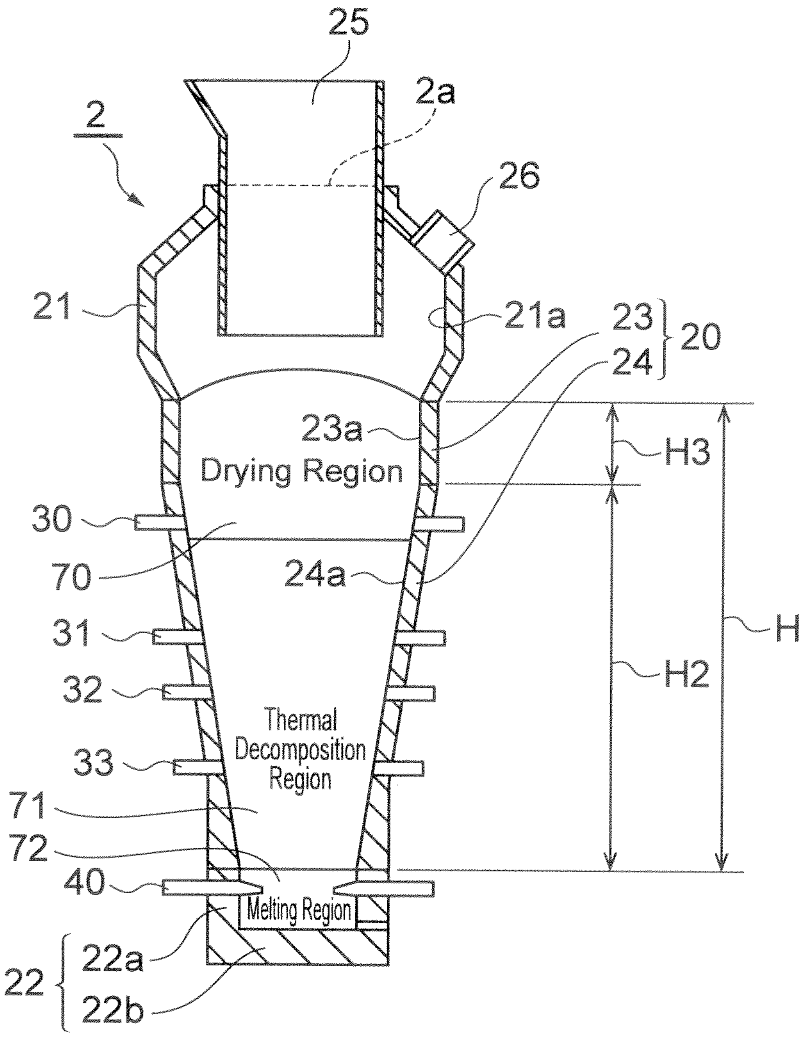

25
2a
2
26
21
21a
23
20
24
23a
Drying Region
H3
30
70
24a
H1
31
H2
32
Thermal Decomposition Region
33
71
72
40
Melting Region
22a
22
22b

Fig.4

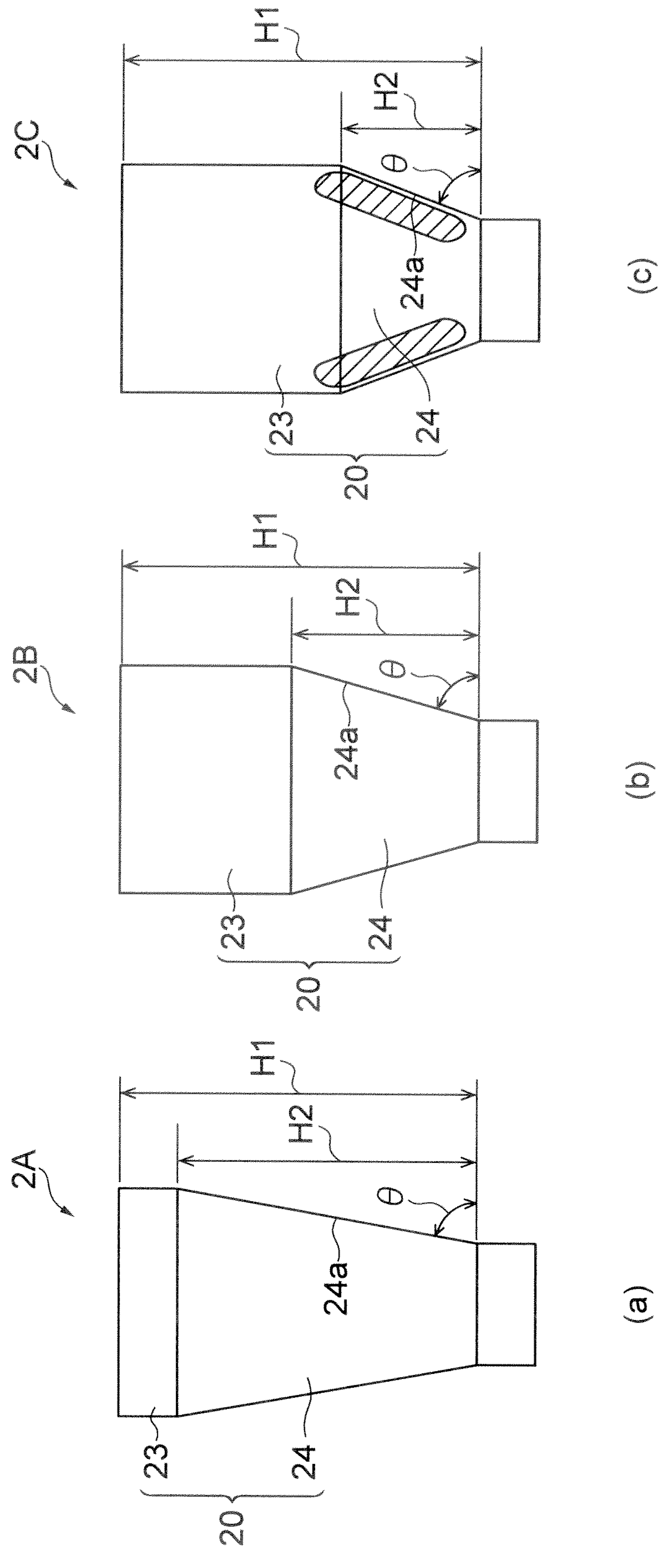

2A
H1
H2
θ
24a
23
24
20
(a)
2B
H1
H2
θ
24a
23
24
20
(b)
2C
H1
H2
θ
24a
23
24
20
(c)

Fig.5

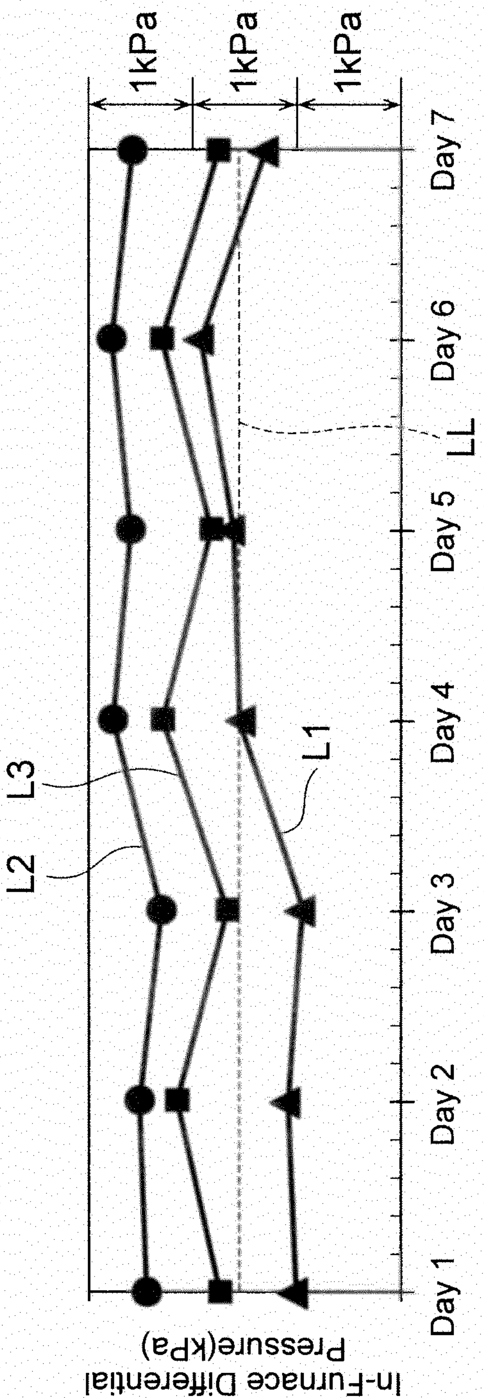

In-Furnace Differential Pressure(kPa)
1kPa
1kPa
1kPa
L1
L2
L3
LL
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7

Fig.6

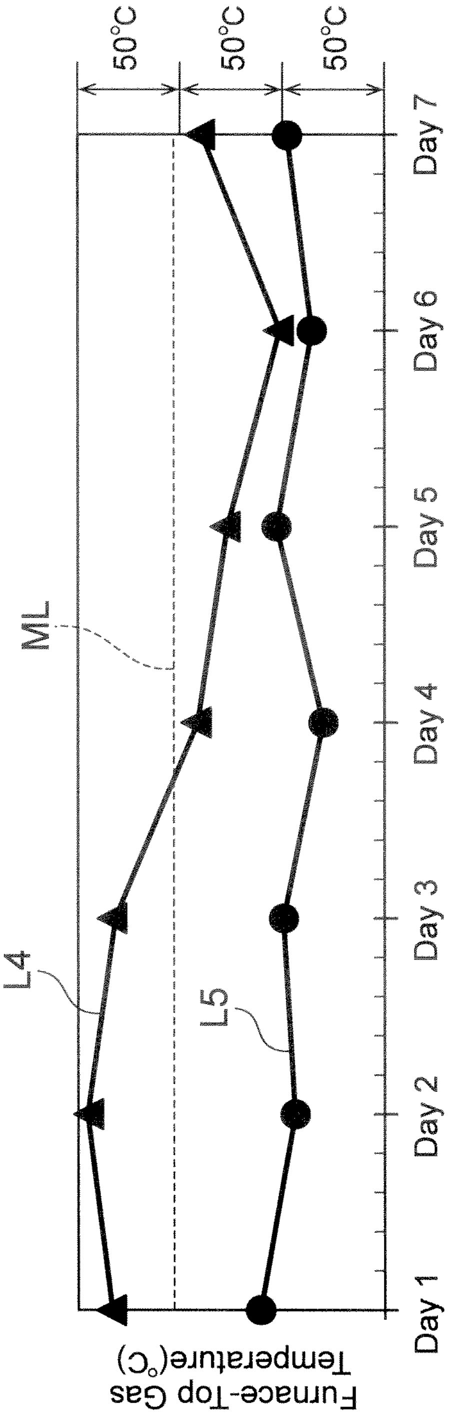

Furnace-Top Gas Temperature(°C)
50°C
50°C
50°C
ML
L4
L5
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7

Fig.7

(a)

(b)

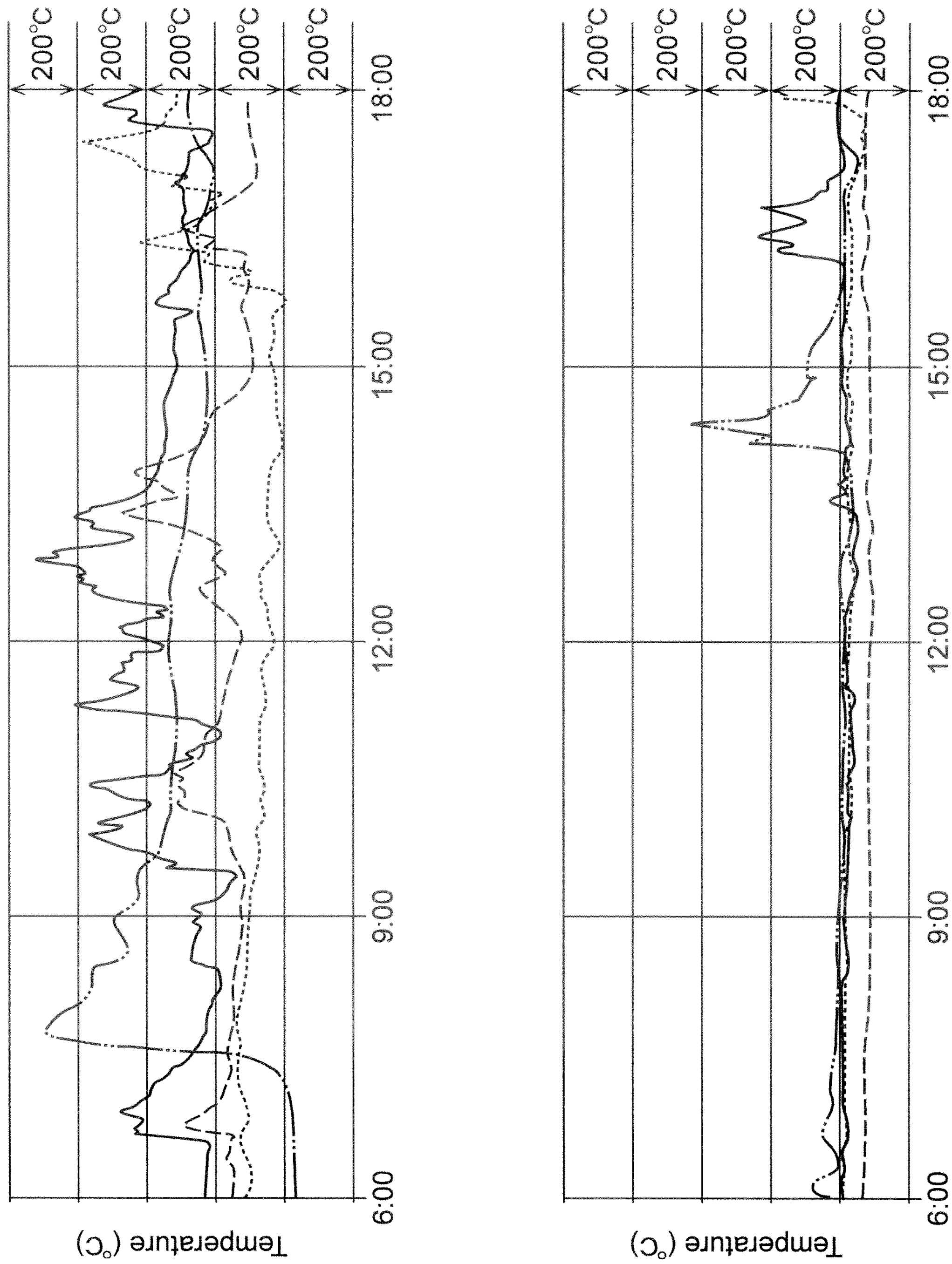

200°C
200°C
200°C
200°C
200°C
Temperature (°C)
6:00
9:00
12:00
15:00
18:00
200°C
200°C
200°C
200°C
200°C
Temperature (°C)
6:00
9:00
12:00
15:00
18:00

Fig.8

		Example 1	Comparative Example 1
Amount of waste processed	t/day	128.7	127.6
Coke ratio	kg/TR	-12.7	–
In-furnace differential pressure	kPa	+1.5	–
Furnace-top gas temperature	°C	-113	–

Fig.9

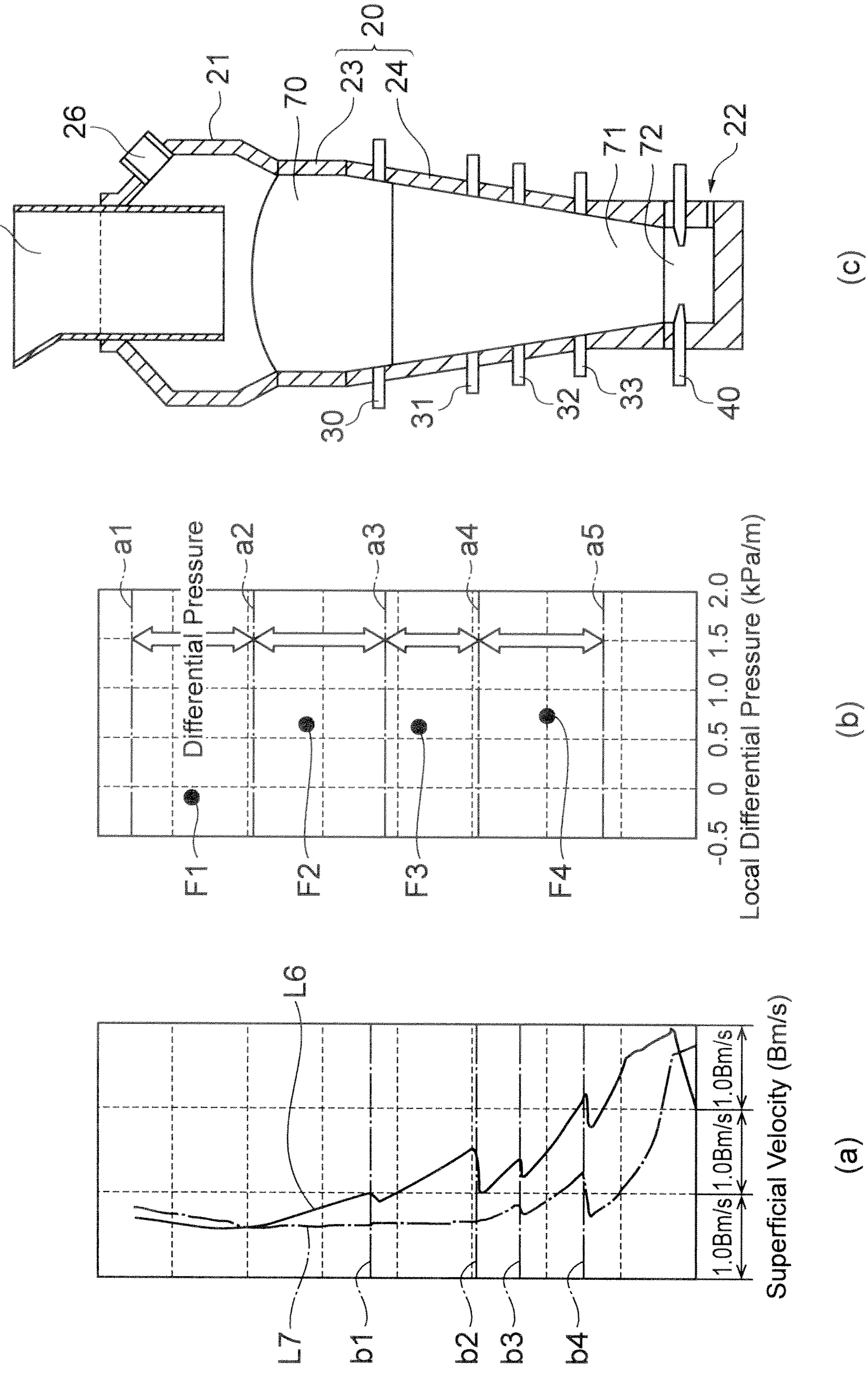

L6
L7
b1
b2
b3
b4
1.0Bm/s
1.0Bm/s
1.0Bm/s
Superficial Velocity (Bm/s)
(a)
a1
a2
a3
a4
a5
Differential Pressure
F1
F2
F3
F4
-0.5 0 0.5 1.0 1.5 2.0
Local Differential Pressure (kPa/m)
(b)
25
26
21
70
23
24
20
22
71
72
30
31
32
33
40
(c)

Fig.10

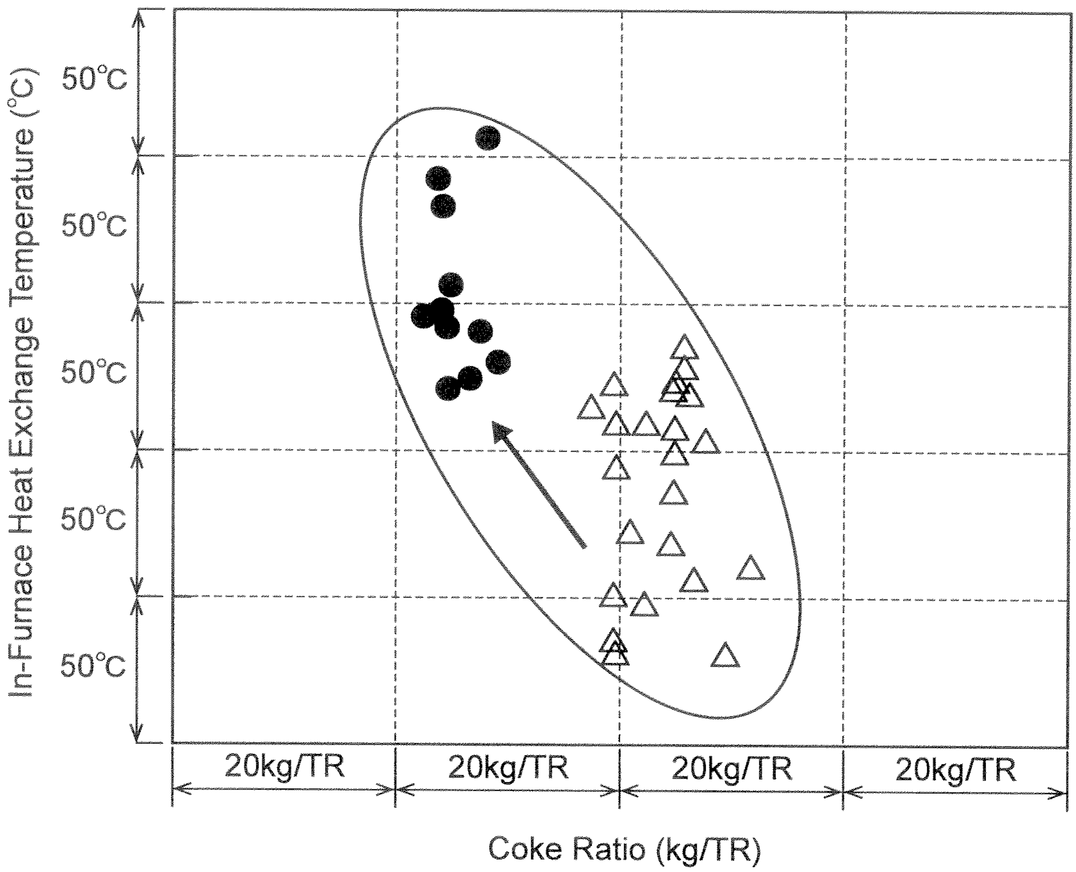
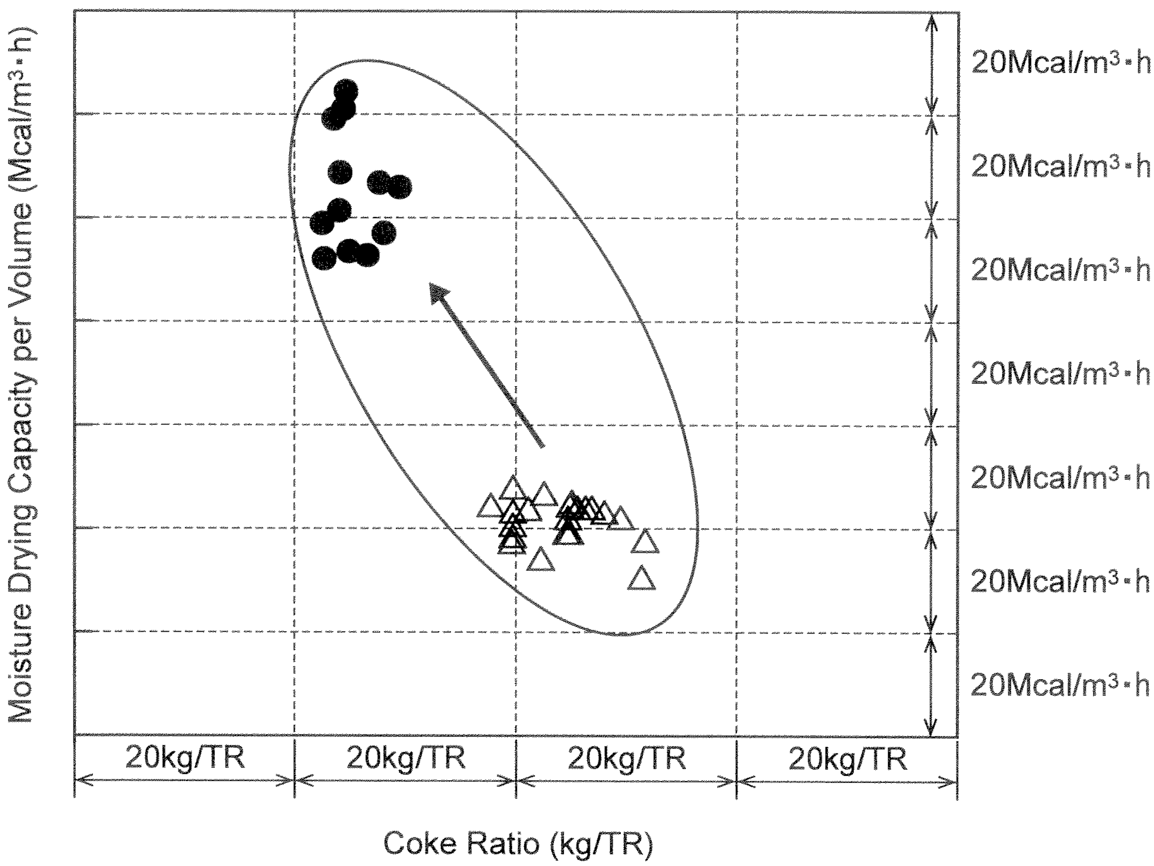
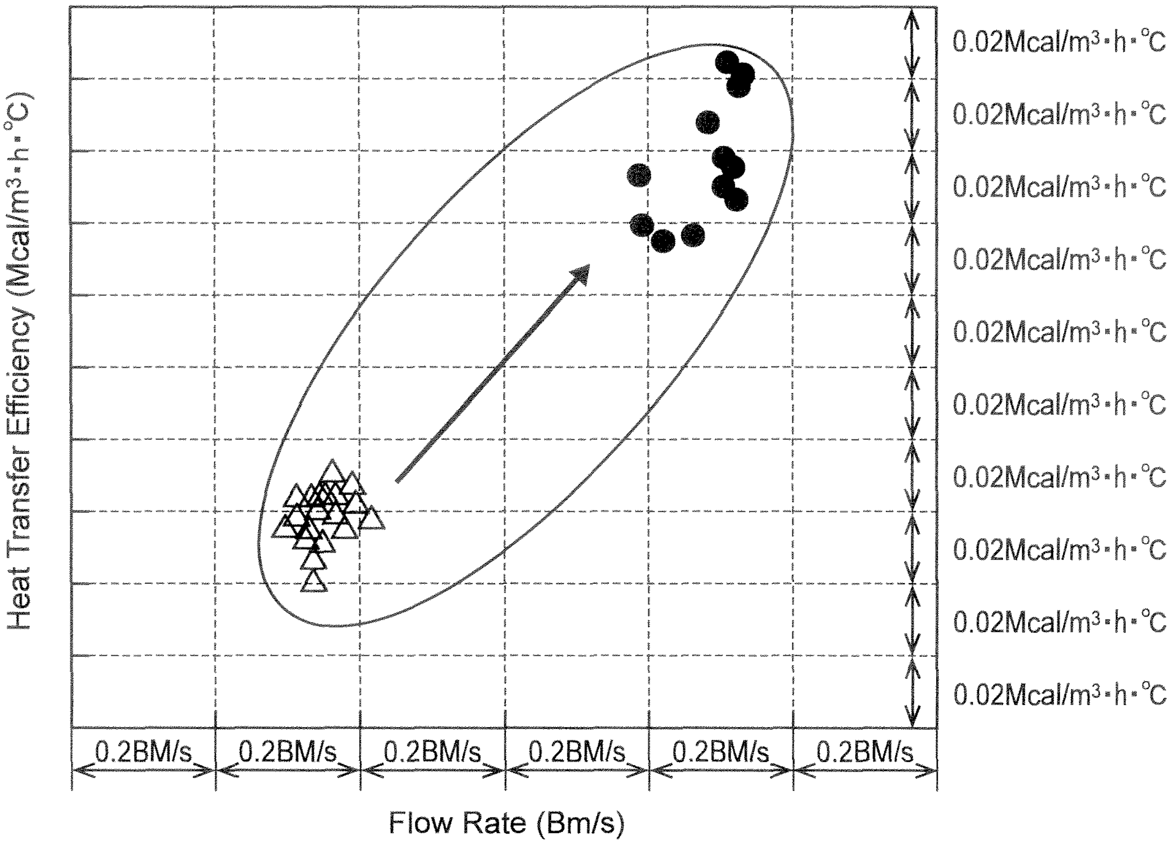

50°C
50°C
50°C
50°C
50°C
In-Furnace Heat Exchange Temperature (°C)
20kg/TR
20kg/TR
20kg/TR
20kg/TR
Coke Ratio (kg/TR)

Fig.11



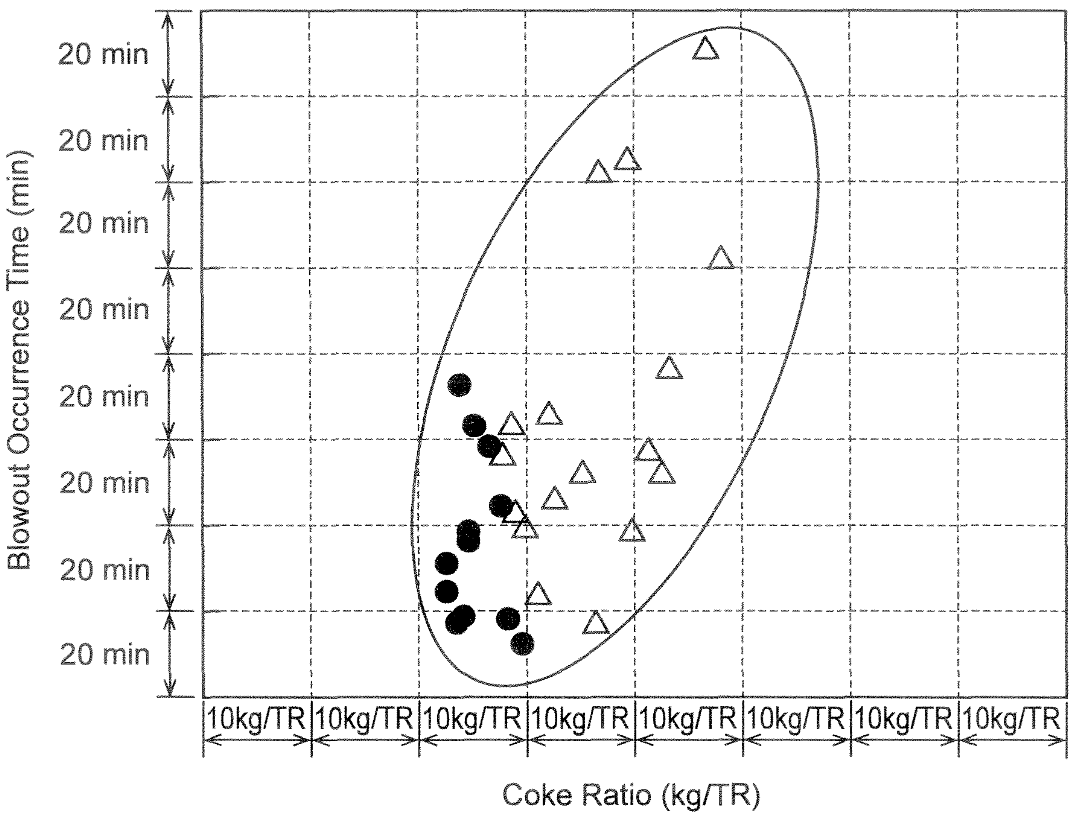
Moisture Drying Capacity per Volume (Mcal/m3・h)
20Mcal/m3・h
20Mcal/m3・h
20Mcal/m3・h
20Mcal/m3・h
20Mcal/m3・h
20Mcal/m3・h
20Mcal/m3・h
20kg/TR
20kg/TR
20kg/TR
20kg/TR
Coke Ratio (kg/TR)

Fig.12



Heat Transfer Efficiency (Mcal/m3·h·°C)
0.02Mcal/m3·h·°C
0.02Mcal/m3·h·°C
0.02Mcal/m3·h·°C
0.02Mcal/m3·h·°C
0.02Mcal/m3·h·°C
0.02Mcal/m3·h·°C
0.02Mcal/m3·h·°C
0.02Mcal/m3·h·°C
0.02Mcal/m3·h·°C
0.02Mcal/m3·h·°C
0.2BM/s
0.2BM/s
0.2BM/s
0.2BM/s
0.2BM/s
0.2BM/s
Flow Rate (Bm/s)

Fig.13


20 min
20 min
20 min
20 min
20 min
20 min
20 min
20 min
Blowout Occurrence Time (min)
10kg/TR
10kg/TR
10kg/TR
10kg/TR
10kg/TR
10kg/TR
10kg/TR
10kg/TR
Coke Ratio (kg/TR)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/070334

A. CLASSIFICATION OF SUBJECT MATTER
F23G5/24(2006.01)i, *F23G5/00*(2006.01)i, *F27B17/00*(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)
F23G5/24, F23G5/00, F27B17/00

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	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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.
A	JP 2011-12901 A (Nippon Steel Engineering Co., Ltd., Nittetsu Plant Designing Corp.), 20 January 2011 (20.01.2011), entire text; all drawings (Family: none)	1-4
A	JP 9-329313 A (Kubota Corp.), 22 December 1997 (22.12.1997), entire text; all drawings (Family: none)	1-4
A	JP 4-84012 A (Yoshimoto UKITA), 17 March 1992 (17.03.1992), entire text; all drawings (Family: none)	1-4

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 August, 2013 (06.08.13)	20 August, 2013 (20.08.13)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/070334

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 8-94036 A (Nippon Steel Corp.), 12 April 1996 (12.04.1996), entire text; all drawings (Family: none)	1-4
A	JP 2000-291919 A (Nippon Steel Corp.), 20 October 2000 (20.10.2000), entire text; all drawings (Family: none)	1-4
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A	JP 2001-304760 A (Kawasaki Giken Co., Ltd.), 31 October 2001 (31.10.2001), entire text; all drawings (Family: none)	1-4

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REFERENCES CITED IN THE DESCRIPTION

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- JP H0894036 B **[0006]**
- JP 2011089672 A **[0006]**
- JP 2002130632 A **[0006]**