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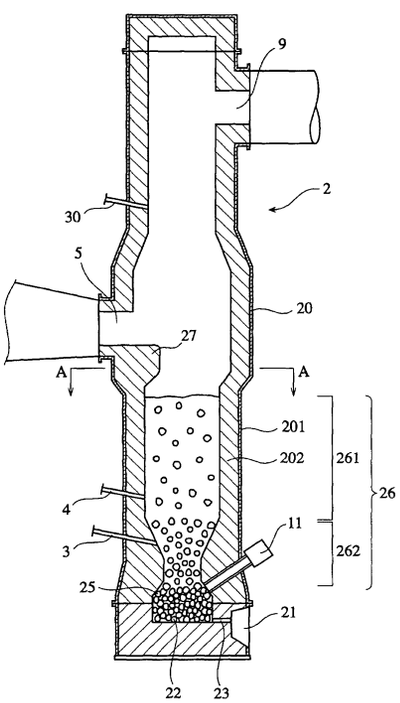
(54) GASIFICATION MELTING FURNACE AND GASIFICATION MELTING METHOD FOR COMBUSTIBLE REFUSE AND/OR BURNED ASH

(57) A gasification melting furnace (2), comprising a plasma torch (11) for blowing hot air into an auxiliary fuel layer formed at a furnace bottom part (22) under a positive pressure of 5 kPa or below on average, wherein combustible refuse and/or burned ash and auxiliary fuel are fed into the gasification melting furnace (shaft furnace) (2), and residue produced by the thermal decomposition of the combustible refuse and/or burned ash in an atmosphere containing air of an amount equal to or less than the amount of stoichiometry for the combustible refuse and/or burned ash and auxiliary fuel is discharged as fused slag from a residue outlet (23).

Fig. 4



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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a gasification-melting furnace and a gasification-melting method for gasifying combustible wastes and/or ashes by combustion and discharging their residue as molten slag, a plasma torch used in the gasification-melting furnace, and an electrode holder for the plasma torch.

BACKGROUND OF THE INVENTION

[0002] In general, combustible wastes and/or ashes containing organic materials, such as wastes, garbage, sewage sludge, etc. have conventionally been incinerated by stoker furnaces and fluid bed furnaces, with their ashes buried in landfill. However, it is recently recommended to turn ashes to a molten slag for landfill, for the reasons that the volume of ashes is not sufficiently reduced for landfill, and that the ashes are scattered in burying in landfills to adversely affect the environment, etc.

[0003] Gasification-melting furnaces for drying, thermally decomposing, burning and melting combustible wastes and/or ashes are divided to kiln-type furnaces, fluid bed-type furnaces and shaft furnaces. The kiln-type furnaces and the fluid bed-type furnaces utilise the amount of heat of combustible wastes and/or ashes themselves without using an auxiliary fuel such as coke to melt the combustible wastes and/or the ashes, so that they need only small operation cost. However, they need the pretreatment of wastes, such as crushing, drying, etc., and also suffer from a complicated treatment flow. The complicated treatment flow disadvantageously requires a lot of operators skilled in operation and maintenance.

[0004] Though the shaft furnaces require an auxiliary fuel such as coke, they are advantageous in requiring no pretreatment such as crushing, drying, etc., and having a relatively simple treatment flow. Because the shaft furnaces have simple structures, their operation and maintenance are easy.

[0005] There are two types of shaft furnaces; a top charge-type shaft furnace of shaft furnace, in which combustible wastes and/or ashes and coke are supplied from a top of a furnace body 2 as shown in Fig. 1, and a side charge-type shaft furnace, in which combustible wastes and/or ashes and coke are supplied from a side of a furnace body 2 as shown in Fig. 2.

[0006] In the top charge-type shaft furnace as shown in Fig. 1, a supply port 5 mounted to the top of the furnace body 2 is connected to a pusher 6, to which a feeder 7 for combustible wastes and/or ashes and a coke feeder 8 are connected. The pusher 6, the feeder 7 for combustible wastes and/or ashes and the coke feeder 8 constitute a feeding mechanism 60. The furnace body 2 is provided, in a furnace bottom portion 22, with an molten slag outlet 23 communicating with the furnace body 2, and a slag trough 15 and a slag-cooling water tank 16 are connected to the molten slag outlet 23. An exhaust gas outlet 9 arranged in an upper portion of the furnace body 2 is connected to a secondary combustion furnace 10 via an exhaust gas-introducing pipe 28. Connected to the secondary combustion furnace 10 are a primary cooling tower 11, a heat exchanger 12, a secondary cooling tower 13 and a dust collector 14 in this order. An inducing draft fan 18 and an exhaust gas tower 19 are connected to the downstream side of the dust collector 14. Air from the fan 17 is heated in the heat exchanger 12 and sent to air supply means 3, 4.

[0007] Because the top charge-type shaft furnace comprises the feeding mechanism 60 at a high position, a building for containing the furnace should have a high roof Also, because combustible wastes and/or ashes and coke are stored at low positions, usually on a floor or in an underground pit, large transporting facilities such as conveyers, cranes, etc. are needed to convey them to the feeding mechanism 60. To limit the height of the shaft furnace, the secondary combustion furnace 10 is built at a position adjacent to the furnace body 2, and the top of the furnace body 2 is connected to the secondary combustion furnace 10 via the horizontal exhaust gas-introducing pipe 28. However, because the supply port 5 for combustible wastes and/or ashes and coke is disposed at a position at which a combustion gas flow is horizontal, dust contained in combustible wastes and/or ashes flows into the secondary combustion furnace 10 together with the combustion gas. Part of the dust is melted to form clinker in the secondary combustion furnace 10, and adheres to the wall of the secondary combustion furnace 10. Further, some of the dust flows into the primary cooling tower 11, thereby adversely affecting treatment in the primary cooling tower 11 and subsequent towers.

[0008] On the other hand, because the side charge-type shaft furnace is provided with a feeding mechanism 60 at a relatively low position, a building for containing the shaft furnace need not have a high roof, and large transporting facilities such as conveyers, cranes, etc. are not required. In addition, because a supply port 5 is disposed at such a position that a combustion gas flow becomes upward, there is extremely less likelihood that small pieces having small specific gravities such as dust, etc. in the combustible wastes and/or the ashes supplied flow into the secondary combustion furnace 10 together with the combustion gas. The side charge-type shaft furnace is more preferable from the above-mentioned aspects.

[0009] However, because the supply port 5 opens on a wall surface of the furnace body 2 having a circular cross

section in the case of the side charge-type shaft furnace, the combustible wastes and/or the ashes and the coke are accumulated higher as closer to the supply port 5, and the accumulation tends to decrease by the angle of repose as separating from the supply port 5. When the combustible wastes and/or the ashes and the coke are non-uniformly accumulated in the furnace body 2, a high-temperature gas flowing upward from a heat source is subjected to non-uniform resistance while passing through a layer of the combustible wastes and/or the ashes and the coke. As a result, the high-temperature gas is subjected to a biased flow that a larger amount of the high-temperature gas passes through a low-resistance zone in the layer of the combustible wastes and/or the ashes and the coke, while a smaller amount of the high-temperature gas passes through a high-resistance zone therein.

[0010] If there were a biased flow in the layer of the combustible wastes and/or the ashes and the coke, there would be insufficient drying, thermal decomposition and melting of the residue in the combustible wastes and/or the ashes, which are less contacted with the high-temperature gas. If sufficient drying, thermal decomposition and melting of the residue were sought in the combustible wastes and/or the ashes, which are less contacted with the high-temperature gas, much energy would be needed, resulting in increase in the operation cost.

[0011] It is recently recommended to turn ashes to a molten slag for landfill, for the reasons that when the wastes are buried as ashes in landfill, the volume of ashes is not sufficiently reduced, and that when the ashes are buried in landfill, they are likely to be scattered, adversely affecting the ambient environment, etc. Systems for turning combustible wastes and/or ashes to molten slag in one furnace are described in JP 56-2243 B, JP 60-11766 B, JP 2-298717 A and JP 4-124515 A.

[0012] The gasification-melting furnaces described in JP 56-2243 B and JP 60-11766 B burn coke and combustible wastes and/or ashes for a heat source, supply an oxygen-rich air to burn them, and intermittently discharge a molten slag. However, these gasification-melting furnaces need additional means for producing an oxygen-rich air, and the operation of opening and closing an exit to intermittently discharge a molten slag.

[0013] The gasification-melting furnaces described in JP 2-298717 A and JP 4-124515 A utilise the combustion of coke and a hot air from a plasma torch for a heat source. However, these gasification-melting furnaces do not have additional air supply means for blowing air into the furnaces to burn combustible wastes, etc., almost failing to utilise the heat of combustion of the combustible wastes. Therefore, they should disadvantageously have large additional heat sources such as coke, electric power to the plasma torch, etc.

[0014] Also, the lower calorific value of city wastes (calorific value in an undried state) has relatively large variations. The variations of the lower calorific value of city wastes include long-range variations due to such seasonal factors that for instance, the lower calorific value is low in the summer season by increase in wet refuse (garbage), while it is high in the winter season by increase in plastic wastes, and short-range variations (changing with time) that the lower calorific value is low in a certain time range because the combustible wastes are wet, while it is high in another time range because the combustible wastes are dry.

[0015] The gasification-melting methods of combustible wastes described in JP 56-2243 B and JP 60-11766 B use coke other than combustible wastes as a heat source, thereby making it possible to keep the overall calorific value constant by controlling the amount of coke supplied depending on the variations of the lower calorific value of combustible wastes. However, controlling with the amount of coke supplied is effective only for the long-range variations of the calorific value, because it is difficult to properly control the amount of coke intermittently supplied depending on the short-range variations of the lower calorific value of combustible wastes, and because there is a time lag from the start of burning coke to sufficient heat generation.

[0016] Ashes discharged from a stoker furnace burning combustible wastes are melted by another melting furnace, converted to a slag and buried. To expand the remaining capacity of landfill, it may be a good idea to dig up already buried ashes and wastes, melt them in a melting furnace to form a slag with a reduced volume, and then bury the slag.

[0017] For instance, JP 10-192815 A describes a method for extending the life of a landfill comprising digging up buried ashes, melting them in a melting furnace, and burying the resultant slag or utilising it as civil engineering materials and soil improvers. Though JP 10-192815 A suggests that a plasma-type melting furnace can be used as a furnace for melting ashes, however, it fails to teach its specifics at all. In addition, JP 10-192815 A describes the use of burner-type melting furnaces and plasma-type melting furnaces for melting ashes.

[0018] Japanese Patent 3,012,665 discloses that wastes dug out from wastes landfills are melted in a coke bed-type shaft furnace provided with a plasma torch, and continuously discharged as a glassy slag from the furnace. However, Japanese Patent 3,012,665 fails to teach the structure of the shaft furnace and its operation conditions suitable for continuously discharging the slag.

[0019] In the shaft furnace-type gasification-melting furnace, the temperature of a hot gas discharged from a furnace top is 200°C to 300°C. However, when the accumulation height H of combustible wastes and/or ashes is too larger than the inner diameter D of a furnace body, the temperature of an upper portion of accumulated combustible wastes and/or ashes is relatively low, so that so-called "bridging" easily occurs, in which resins, etc. contained in the accumulated layer become partly melted and fused to each other. The "bridging" is a phenomenon that combustible wastes and/or ashes form bridges in the furnace for some reasons, the bridges supporting combustible wastes and/or ashes

thereabove, thereby preventing the combustible wastes and/or the ashes from shifting toward a furnace bottom portion. When the bridges collapse, explosive combustion occurs in the furnace, thereby being likely to cause damage to the furnace body, etc. Further, because of the large accumulation height of the combustible wastes and/or the ashes, there is a large air flow resistance in the layer, and thus the internal pressure of a furnace bottom portion becomes a positive pressure as high as about 1,500 mmAq. Thus, a molten slag is vigorously ejected from a molten slag outlet, causing risk.

[0020] It has become paying attention to dioxin in exhaust gases and ashes discharged by the incineration treatment of combustible wastes. The concentration of dioxin generated by burning combustible wastes such as city wastes and industrial wastes, etc. has a strong correlation with the concentration of carbon monoxide in the exhaust gas; the higher the concentration of carbon monoxide in the exhaust gas, the higher the concentration of the resultant dioxin. Most of dioxin discharged from the gasification-melting furnace is adsorbed onto flying ashes contained in the exhaust gas.

[0021] Various methods for reducing dioxin were proposed. For instance, JP 10-8118 A, JP 10-196930 A and JP 11-76753 A disclose methods for treating an exhaust gas comprising subjecting a cooled exhaust gas to a dioxin-adsorbing treatment with activated carbon, and then neutralising an acidic gas. The dioxin-adsorbing treatment comprises blowing activated carbon into the cooled exhaust gas, and removing the activated carbon adsorbing dioxin and flying ashes by a dust collector, a bag filter or an activated carbon adsorption tower. The neutralisation treatment of an acidic gas comprises adding calcium hydroxide to an exhaust gas deprived of dioxin and flying ashes, causing the exhaust gas to pass through a dust collector or a bag filter to collect powder floating in the exhaust gas, and finally neutralising an acidic gas in the exhaust gas. In these exhaust gas treatment methods, however, dioxin and heavy metals contained in the used activated carbon and the flying ashes collected by a bag filter should be subjected to a treatment for making them harmless before burying in landfills.

[0022] In an exhaust gas treatment method described in JP 2001-41429 A, two bag filters are disposed in series; calcium hydroxide is introduced into an upstream bag filter to remove not only an acidic gas by neutralisation but also smoke dust, and activated carbon is introduced into a downstream bag filter to remove dioxin by adsorption. The smoke dust collected in the upstream stage and the used activated carbon collected in the downstream stage are returned to a gasification-melting furnace, in which the dioxin and the activated carbon are decomposed by incineration.

[0023] In the method for treating an exhaust gas described in JP 2001-41429 A, all of the smoke dust collected in an upstream stage and the used activated carbon collected in a downstream stage are returned to a gasification-melting furnace, in which dioxin and the activated carbon are decomposed by combustion, requiring no treatment for making harmless and no landfill. However, when calcium chloride (formed from calcium hydroxide) contained in the smoke dust collected by a bag filter is exposed to a high temperature, hydrogen chloride is generated. Also, when calcium chloride is mixed into a molten slag, the molten slag has so decreased quality that its reuse becomes difficult. JP 2001-41429 A also proposes a treatment method in which the smoke dust is not returned to the gasification-melting furnace. However, dioxin and heavy metals contained therein should be buried in landfills after made harmless.

[0024] Conventionally used as gasification-melting furnaces for combustible wastes such as city wastes, industrial wastes, etc. are vertical two-stage combustion furnaces. However, in the conventional vertical two-stage combustion furnaces, an exhaust gas is not completely burned in secondary combustion furnaces, so that part of the unburned gas containing dioxin, carbon monoxide, hydrocarbons, etc. is discharged.

[0025] As a two-stage combustion furnace for solving this problem, there is an incinerator proposed, for instance, by JP 7-229610 A. This incinerator comprises a primary combustion furnace, a substantially cylindrical secondary combustion furnace, and an exhaust gas-introducing pipe for sending the exhaust gas from the primary combustion furnace to the secondary combustion furnace, an opening of the exhaust gas-introducing pipe being biased from a centre line of the secondary combustion furnace, such that the exhaust gas is swirled in the secondary combustion furnace. Also, to efficiently mix the unburned gas with air to completely burn the unburned gas, a path for supplying the air to the secondary combustion furnace opens at a position biased from the centre line of the secondary combustion furnace.

[0026] However, the incinerator of JP 7-229610 A is disadvantageous in that the direction and speed of the exhaust gas charged into the secondary combustion furnace cannot properly be changed depending on the conditions of combustible wastes. Also, in the presently available secondary combustion furnace generating no swirling flow, the removal of dioxin is insufficient, and a huge cost would be incurred if the exhaust gas-introducing pipe were mounted to the secondary combustion furnace at such a position that the swirling flow of the exhaust gas is generated.

OBJECT OF THE INVENTION

[0027] Accordingly, an object of the present invention is to provide a furnace and a method for the gasification-melting of combustible wastes and/or ashes, which can efficiently subject combustible wastes and/or ashes to an incineration treatment or a melting treatment, and continuously discharge the resultant molten slag.

[0028] Another object of the present invention is to provide a low-cost, shaft furnace-type gasification-melting furnace substantially free from damage to a secondary combustion furnace wall and adverse influence on treatments down-

stream of a primary cooling tower.

[0029] A further object of the present invention is to provide a shaft furnace-type gasification-melting furnace with a reduced operation cost by decrease in a biased flow of a high-temperature gas in a layer of combustible wastes and/or ashes.

[0030] A still further object of the present invention is to provide a gasification-melting furnace of combustible wastes and/or ashes with suppressed generation of bridging and decreased internal pressure of a furnace bottom portion for preventing the spewing of a molten slag.

[0031] A still further object of the present invention is to provide a gasification-melting method of combustible wastes free from discharging of smoke dust containing dioxin and heavy metals and the accumulation of the reaction products of calcium hydroxide in the system.

[0032] A still further object of the present invention is to provide an incinerator with the suppressed generation of carbon monoxide, dioxin, etc.

[0033] A still further object of the present invention is to provide a long-life electrode holder and a plasma torch comprising it.

DISCLOSURE OF THE INVENTION

[0034] As a result of intense research in view of the above objects, the inventors have found:

(a) Because the lower calorific value of city wastes is usually 3,000 to 12,000 kJ/kg, the amount of coke supplied may be as small as 30 kg/hr to stably carry out a gasification-melting treatment of 1,000 kg/hr of combustible wastes while continuously discharging a molten slag, in a shaft furnace using coke and a plasma torch as a heat source.

(b) When the lower calorific value is as high as 9,800 to 12,000 kJ/kg, the amount of coke supplied may be as small as 20 kg/hr to carry out a gasification-melting treatment of 1,000 kg/hr of combustible wastes.

(c) Because an internal pressure of a furnace bottom portion affects the stability of discharging of a molten slag, it is necessary to control the internal pressure of a furnace bottom portion at a predetermined positive pressure to continuously and stably discharging the molten slag.

(d) By returning dioxin-adsorbed activated carbon to a high temperature gasification-melting furnace, the dioxin is decomposed, so that the amount of dioxin discharged outside the furnace can be reduced.

(e) An electrode holder for a plasma torch made of an insulating ceramic having an excellent thermal shock resistance is resistant to breakage even by thermal stress, resulting in an extremely long life in the resultant plasma torch.

[0035] The present invention has been completed based on the above findings.

[0036] The gasification-melting furnace according to one embodiment of the present invention supplies combustible wastes and/or ashes and an auxiliary fuel into a shaft furnace, in an atmosphere containing air in a stoichiometric amount or less relative to them, and thermally decomposes the combustible wastes and/or ashes to discharge the resultant residue as a molten slag from a slag exit, the gasification-melting furnace comprising a plasma torch for blowing a hot air into an auxiliary fuel layer in a furnace bottom portion, which is at a positive pressure of 5 kPa or less on average.

[0037] In a preferred embodiment of the present invention, H/D is 2 or less, wherein H is a height from a furnace bottom to a top surface of a layer of accumulated combustible wastes and/or ashes, and D is an inner diameter of a furnace body in a zone in which there is a top surface of a layer of the combustible wastes and/or ashes.

[0038] The shaft furnace-type gasification-melting furnace according to another embodiment of the present invention supplies combustible wastes and/or ashes and an auxiliary fuel into a furnace, burns the combustible wastes and/or the ashes for gasification by a heat source disposed in a furnace bottom portion, and discharges molten residue from a residue-discharging outlet, supply ports for the combustible wastes and/or the ashes and the auxiliary fuel being mounted to a side surface of the shaft furnace with the lower portions of the supply ports projecting into the furnace. The heat source may be a plasma torch and a coke layer.

[0039] The gasification-melting method of combustible wastes according to a further embodiment of the present invention comprises using a shaft furnace-type gasification-melting furnace provided with a plasma torch, supplying the combustible wastes and the auxiliary fuel into the shaft furnace, blowing a hot air into an auxiliary fuel layer in a furnace bottom portion by the plasma torch, burning the combustible wastes for gasification in an atmosphere containing a stoichiometric amount or less of air relative to the combustible wastes and the auxiliary fuel, and discharging residue as a molten slag outside the furnace, the amount of electric power supplied to the plasma torch being controlled depending on the variations of a lower calorific value of the combustible wastes.

[0040] The gasification-melting method of combustible wastes according to a still further embodiment of the present

invention comprises using a shaft furnace-type gasification-melting furnace provided with a plasma torch, supplying the combustible wastes and the auxiliary fuel into the shaft furnace, blowing a hot air into an auxiliary fuel layer in a furnace bottom portion by the plasma torch, burning the combustible wastes for gasification in an atmosphere containing a stoichiometric amount or less of air relative to the combustible wastes and the auxiliary fuel, and discharging residue as a molten slag outside the furnace, the amount of electric power supplied to the plasma torch being increased in the short-range decrease of the lower calorific value of the combustible wastes, and decreased in the short-range increase of the lower calorific value of the combustible wastes.

[0041] The gasification-melting method of combustible wastes according to a still further embodiment of the present invention comprises using a shaft furnace-type gasification-melting furnace provided with a plasma torch, supplying the combustible wastes and the auxiliary fuel into the shaft furnace, blowing a hot air into an auxiliary fuel layer in a furnace bottom portion by the plasma torch, burning the combustible wastes for gasification in an atmosphere containing a stoichiometric amount or less of air relative to the combustible wastes and the auxiliary fuel, and discharging residue as a molten slag outside the furnace, the amount of the auxiliary fuel supplied to the shaft furnace being increased in the long-range decrease of the lower calorific value of the combustible wastes, and decreased in the long-range increase of the lower calorific value of the combustible wastes.

[0042] The gasification-melting method of combustible wastes according to a still further embodiment of the present invention comprises using a shaft furnace-type gasification-melting furnace provided with a plasma torch, supplying the combustible wastes and the auxiliary fuel into the shaft furnace, blowing a hot air into an auxiliary fuel layer in a furnace bottom portion by the plasma torch, burning the combustible wastes for gasification in an atmosphere containing a stoichiometric amount or less of air relative to the combustible wastes and the auxiliary fuel, and discharging residue as a molten slag outside the furnace, the amount of electric power supplied to the plasma torch being increased in the short-range decrease of the lower calorific value of the combustible wastes, and decreased in the short-range increase of the lower calorific value of the combustible wastes, and the amount of the auxiliary fuel supplied to the shaft furnace being increased in the long-range decrease of the lower calorific value of the combustible wastes, and decreased in the long-range increase of the lower calorific value of the combustible wastes.

[0043] The gasification-melting method of combustible wastes and/or ashes according to a still further embodiment of the present invention comprises burning a gas generated by thermally decomposing the combustible wastes and/or ashes in a gasification-melting furnace, bringing the resultant exhaust gas into contact with activated carbon, smoke dust containing the activated carbon and flying ashes being removed from the exhaust gas; and returning the smoke dust to the gasification-melting furnace.

[0044] In a preferred embodiment, the gasification-melting method of the above combustible wastes and/or ashes comprises using a shaft furnace-type gasification-melting furnace provided with a plasma torch, supplying combustible wastes and/or ashes and an auxiliary fuel into the shaft furnace, blowing a hot air into an auxiliary fuel layer in a furnace bottom portion by the plasma torch, burning the combustible wastes and/or ashes for gasification in an atmosphere containing a stoichiometric amount or less of air relative to the combustible wastes and/or ashes and the auxiliary fuel, discharging the residue outside the furnace as a molten slag, burning a gas generated by thermally decomposing the combustible wastes and/or ashes in the gasification-melting furnace, bringing the resultant exhaust gas into contact with activated carbon, wherein smoke dust containing the activated carbon and flying ashes is removed from the exhaust gas; and returning the smoke dust to the gasification-melting furnace.

[0045] The gasification-melting method of combustible wastes and/or ashes according to a still further embodiment of the present invention comprises burning a gas generated by thermally decomposing the combustible wastes and/or ashes in the gasification-melting furnace, wherein the resultant primary exhaust gas is brought into contact with activated carbon; wherein smoke dust containing the activated carbon and flying ashes is removed from the exhaust gas; wherein the smoke dust is returned to the gasification-melting furnace; wherein a secondary exhaust gas obtained by removing the smoke dust is brought into contact with a salt-removing agent; and removing the resultant salts from the secondary exhaust gas.

[0046] In a preferred embodiment, the gasification-melting method of the above combustible wastes and/or ashes comprises using a shaft furnace-type gasification-melting furnace provided with a plasma torch, supplying combustible wastes and/or ashes and an auxiliary fuel into the shaft furnace, blowing a hot air into an auxiliary fuel layer in a furnace bottom portion by the plasma torch, burning the combustible wastes and/or ashes for gasification in an atmosphere containing a stoichiometric amount or less of air relative to the combustible wastes and/or ashes and the auxiliary fuel, discharging the residue outside the furnace as a molten slag, burning a gas generated by thermally decomposing the combustible wastes and/or ashes in the gasification-melting furnace, wherein the resultant primary exhaust gas is brought into contact with activated carbon; wherein smoke dust containing the activated carbon and flying ashes is removed from the exhaust gas; wherein the smoke dust is returned to the gasification-melting furnace; wherein a secondary exhaust gas obtained by removing the smoke dust is brought into contact with a salt-removing agent; and removing the resultant salts from the secondary exhaust gas.

[0047] The incinerator of combustible wastes and/or ashes according to a still further embodiment of the present

invention comprises a primary combustion furnace for burning combustible wastes and/or ashes, a substantially cylindrical, secondary combustion furnace, and an exhaust gas-introducing pipe connecting the primary combustion furnace and the secondary combustion furnace for introducing an exhaust gas from the primary combustion furnace to the secondary combustion furnace, and a baffle plate mounted to the exhaust gas-introducing pipe for controlling the flow rate and direction of the exhaust gas flowing into the secondary combustion furnace.

[0048] The electrode holder according to a still further embodiment of the present invention is disposed in a plasma torch for fixing at least one of a pair of electrodes to keep a constant distance between both electrodes while keeping electric insulation therebetween, the electrode holder being made of an insulating ceramic having a thermal shock resistance ΔT of 400°C or more.

[0049] The plasma torch according to a still further embodiment of the present invention comprises a pair of electrodes, and an electrode holder for fixing at least one of the electrodes, the electrode holder being made of an insulating ceramic having a thermal shock resistance ΔT of 400°C or more, whereby both electrodes are kept at a constant distance with electric insulation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0050]

Fig. 1 is a schematic view showing one example of gasification-melting furnace systems, to which the gasification-melting method of the present invention is applicable;

Fig. 2 is a schematic view showing another example of gasification-melting furnace systems, to which the gasification-melting method of the present invention is applicable;

Fig. 3 is a vertical cross-sectional view showing one example of the gasification-melting furnaces of the present invention;

Fig. 4 is a vertical cross-sectional view showing another example of the gasification-melting furnaces of the present invention;

Fig. 5 is a cross-sectional view taken along the line A-A in Fig. 4;

Fig. 6 is a vertical cross-sectional view showing a combination of a gasification-melting furnace and a secondary combustion furnace;

Fig. 7 is a schematic, lateral, cross-sectional view showing a combination of a gasification-melting furnace and a secondary combustion furnace, which corresponds to a cross-sectional view taken along the line C-C in Fig. 8;

Fig. 8 is a schematic, vertical, cross-sectional view showing a combination of a gasification-melting furnace and a secondary combustion furnace

Fig. 9 is a cross-sectional view taken along the line B-B in Fig. 7;

Fig. 10 is a schematic, vertical, cross-sectional view showing a measuring point of turbulence energy in a secondary combustion furnace;

Fig. 11 is a schematic view showing a further example of gasification-melting furnace systems of the present invention;

Fig. 12 is a partial cross-sectional view showing one example of a plasma torch having the electrode holder of the present invention; and

Fig. 13 is a partial cross-sectional view showing another example of a plasma torch comprising the electrode holder of the present invention.

THE BEST MODE FOR CARRYING OUT THE INVENTION

[0051] The gasification-melting furnace of the present invention for combustible wastes (including landfill wastes, etc.) and/or ashes burns a coke layer formed on a bottom of a shaft furnace by a hot air blown from a plasma torch, heating combustible wastes and/or ashes accumulated on the coke layer by this heat and the hot air from the plasma torch to a molten slag, and discharging the molten slag outside the furnace. The molten slag is glassy, and its volume is about 1/5 of that of the wastes, with heavy metals, etc. sealed therein so that they do not eluate.

[0052] The hot air injecting from the plasma torch is as hot as 1,800°C to 2,500°C, to heat the coke layer and burn part of the coke layer with oxygen in the hot air and air blown from the air supply means, so that the temperature of the coke layer is stably kept at about 1,500°C. Though an oxygen-rich air is needed to keep the temperature of the coke layer at 1,500°C only with the heat of combustion of coke, air blown from the air supply means need not be an oxygen-rich air, because both the coke layer and the plasma torch are used in the gasification-melting furnace of the present invention.

[0053] To burn the coke only with a plasma air from the plasma torch and a shroud air (cooling air), there should be a lot of the shroud air. This would lead to decrease in the temperature of the hot air from the plasma torch, failing to

keep the temperature of the coke layer at about 1,500°C. However, because the gasification-melting furnace of the present invention comprises, in addition to the plasma torch, an air supply means for blowing a combustion air into the furnace at a position above the plasma torch, at which it faces the coke layer, the temperature of the coke layer can be kept at 1,500°C or higher without lowering the temperature of the hot air from the plasma torch.

[0054] By the injecting pressure (positive pressure of 15 kPa) of the plasma air from the plasma torch and the shroud air, the internal pressure of a furnace bottom portion in which there is the coke layer is kept at a positive pressure of 0.3 to 5 kPa on average. When the internal pressure is more than 5 kPa, the molten slag and the hot air at about 1,500°C are strongly injected from a molten slag outlet, resulting in risky operation around the furnace, and thus the disadvantage that a large amount of heat is discharged from the furnace to the outside. On the other hand, to carry out stable discharging of the molten slag, the internal pressure of the furnace bottom portion is preferably at least about 0.3 kPa. The internal pressure of the furnace bottom portion is more preferably a positive pressure of 0.3 to 2 kPa.

[0055] Here, "positive pressure" is determined relative to the atmospheric pressure outside the furnace. The pressure of the furnace bottom portion always varies depending on the total height and void ratio (air flow resistance) of the layer 26 of combustible wastes and/or ashes and the coke layer 25 in the shaft furnace 2, the amount of air supplied from the plasma torch 11, the amount of air induced by an inducing fan, etc. Accordingly, the pressure of the furnace bottom portion is expressed by an average value with time.

[0056] To maintain the stability of the entire system, it is desirable to control the pressure of the furnace bottom portion by adjusting the height of the combustible waste layer 26. The increase in the amount of electric power supplied to the plasma torch 11 or the amount of coke charged leads to increase in the melting speed of the combustible wastes, resulting in a lower height of the combustible waste layer 26 and thus a lower pressure of the furnace bottom portion. On the other hand, the decrease in the amount of electric power supplied to the plasma torch 11 or the amount of coke charged leads to decrease in the melting speed of the combustible wastes, resulting in a higher height of the combustible waste layer 26 and thus a higher pressure of the furnace bottom portion.

[0057] Referring to Figs. 1 and 2, mounted to the shaft furnace 2 are a plasma torch 11 near the bottom and a first air supply means 3 and a second air supply means 4 above the plasma torch 11. In this embodiment, two plasma torches 11 are mounted to the furnace body on a periphery of the same height, with the direction of a hot air blown from the plasma torches 11 aligned with the diameter direction of the furnace body and toward the edge of the furnace bottom portion. Both of the first air supply means 3 and the second air supply means 4 are similarly provided at six points on the periphery. Air blown from the first air supply means 3 and the second air supply means 4 is at a high temperature by heat exchanging with a high-temperature gas of a secondary combustion furnace in a heat exchanger.

[0058] As shown in Fig. 3, the furnace body 2 is constituted by an outer shell 201 and a refractory liner layer 202. The furnace body 2 has a structure constituted by a combination of a furnace body part 20 and a furnace bottom part 21, the furnace bottom part 21 being suspended from the furnace body part 20. If necessary, the furnace bottom part 21 may be detached onto a carriage (not shown) to move to a predetermined place. Because of this structure, checking and repair are easy in the furnace bottom part 21 and the plasma torch 11 as well as the inside of the furnace body part 20.

[0059] In the side-charge-type shaft furnace shown in Fig. 2, a supply port 5 is mounted to the furnace body 2 in a substantially middle portion in a vertical direction, and a pusher 6 is connected to the supply port 5. A combustible waste feeder 7 and a coke feeder 8 are connected to the pusher 6. The combustible waste feeder 7 and the coke feeder 8 are provided with double-butterfly valves (not shown), to prevent the outside air from entering. Mounted above the supply port 5 is an air supply means 30.

[0060] As shown in Figs. 1 and 2, the furnace body 2 is provided with an exhaust gas exit 9 in an upper portion thereof, and the exhaust gas exit 9 is successively connected to a secondary combustion furnace 10, a primary cooling tower 11, a heat exchanger 12, a secondary cooling tower 13 and a dust collector 14. Connected downstream of the dust collector 14 are an inducing fan 18 and an exhaust gas tower 19. A furnace bottom portion 22 of the furnace body 2 is provided with a molten slag outlet 23 communicating with the furnace body 2, and the molten slag outlet 23 is connected to a slag trough 15 and a slag-cooling water bath 16.

[0061] Referring to Fig. 1, the combustible wastes are charged into the shaft furnace 2 together with coke and limestone, and the resultant gas is discharged to the secondary combustion chamber 10 via the upper portion of the furnace. In secondary combustion chamber 10, combustible components contained in this gas are burned in a reducing atmosphere, so that nitrogen compounds are decomposed to N2. To prevent the generation of dioxin, secondary combustion is carried out such that the combustion temperature is in a range of 1,000°C to 1,200°C, and that the residence time of the resultant gas is 2 seconds or more. This combustion gas is cooled to 500°C to 700°C by the primary cooling chamber 11, heat-exchanged by the heat exchanger (air-preheating chamber)12, and then rapidly cooled to 150°C to 200°C by the secondary cooling chamber 13 so that it quickly passes through a dioxin resynthesis temperature range. To neutralise toxic gases (chlorine gas, etc.), it passes through the dust collector 14 containing a mixture of activated carbon and calcium hydroxide to make the exhaust gas innocuous, and then discharged to the air. Incidentally, dust generated in the secondary combustion chamber 10, the primary cooling chamber 11, the secondary cooling

chamber 13 and the heat exchanger 12 are collected and solidified to become reusable.

[0062] When the temperature elevation of the shaft furnace body 2 is started, the furnace bottom portion 22 is filled with coke to form a coke layer 25, and the plasma torch 11 is then ignited to blow a hot air at 1,000°C to 2,500°C (for instance, about 1,800°C) into the coke layer 25. The temperature of the furnace bottom portion 22 and the coke layer 25 is elevated to, for instance, about 1,500°C after about 3 hours by the heat of combustion of the coke with the hot air supplied from the plasma torch 11. Supplied into the furnace body 2 in this state are combustible wastes from the combustible waste feeder 7 by the pusher 6 and a mixture of coke and limestone from the coke feeder 8 by the pusher 6. A weight ratio of the coke to the combustible wastes is preferably, for instance, 2% by weight.

[0063] When the combustible wastes (in some cases, ashes and/or landfill wastes) and the coke are supplied, a combustible waste layer 26 is formed on the coke layer 25 in substantially alternate layers of the combustible wastes and the coke.

[0064] The air is supplied from the plasma torch 11 and, if necessary, the air supply means 3 into the furnace body 2. The total amount of the air is a stoichiometric amount or less to the coke in the furnace body 2; specifically, a ratio of the stoichiometric amount of air to the total amount of air is preferably 1/0.2 to 1/0.9.

[0065] The ashes and the landfill wastes contain more inorganic components and less combustible components as compared with general combustible wastes. Accordingly, the amount of heat for melting them is supplied from the coke or the plasma torch 11. To reduce a running cost, the combustion of the coke should be suppressed as much as possible. However, when the ashes and the landfill wastes, etc. have too small calorific values, the coke should also be a heat source. In this case, air in an amount about 0.2 to 0.9 times the stoichiometric amount of air to the coke is preferably supplied into the furnace body 2. The amount of heat necessary for melting the ashes and the landfill wastes can be supplied from the hot air injected from the plasma torch 11.

[0066] The layer 26 of combustible wastes and/or ashes (referred to simply as "combustible waste layer" hereinafter) accumulated on the heated coke layer 25 is dried. Part of the combustible waste layer 26 is burned with the above combustion air, while the other part of the combustible waste layer 26 is gasified because the combustion air is consumed by the above combustion. Ashes generated by the combustion of the combustible wastes and char generated by gasification are melted by the hot air from the coke layer 25 heated at about 1,500°C to form a molten slag, which flows down in the coke layer 25 and stored in the furnace bottom portion 22. The molten slag residing in the furnace bottom portion 22 is discharged from the molten slag outlet 23 mounted to the furnace bottom to the outside of the furnace.

[0067] When the supply of the combustible wastes and the coke is carried out, for instance, at a ratio of 3:1 by the number of supply operations, the combustible wastes and the coke are accumulated in substantially alternate layers. Though a ratio of the coke to the combustible wastes is about 2% by weight, the combustion of the combustible wastes consumes most of the above combustion air, because the combustion of the combustible wastes is much faster than that of the coke. As a result, it is difficult to burn the coke, resulting in a small amount of the coke consumed. Thus, an upper portion of the combustible waste layer 26 becomes a wastes-rich layer 261, and an intermediate portion of the combustible waste layer 26 in which the combustion and gasification of the combustible wastes proceed becomes a combustible wastes-coke mixture layer 262. As a result, the coke layer 25 is continuously formed to a predetermined height in the furnace bottom portion 22, and the coke layer 25 is kept at a height at which the amount of coke consumed and the amount of coke supplied are balanced.

[0068] The molten slag outlet 23 preferably has a structure as short and linear as possible to prevent the molten slag from being solidified and thus clogging it. To prevent the solidification of the molten slag, it is also effective to heat the molten slag outlet 23 by a burner, etc. from outside the furnace body 2.

[0069] As shown in Fig. 3, a ratio (H/D) of the accumulation height H of the combustible wastes and/or the ashes to the inner diameter D of the shaft furnace 2 at a position of a top surface of the combustible waste layer 26 is preferably 2 or less. By setting the accumulation height H of the combustible wastes and/or the ashes relatively low, the distance from the coke layer 25 to the top surface of the combustible waste layer 26 can be made small, such that the temperature of a gas passing through the combustible waste layer 26 is 500°C to 1,000°C. Accordingly, it is unlikely that resins in the wastes are melted to form bridges. Even when the resins form large fused bulks, bridges are less likely formed with a large inner diameter D of the furnace body. Accordingly, in the shaft furnace 2 of the present invention, the bridging of the combustible wastes and/or the ashes less likely occurs, and further the flow resistance of air is small, resulting in a small internal pressure in the furnace bottom portion. Namely, even if the injecting pressure of a plasma air and a shroud air from the plasma torch is a positive pressure of 14.7 kPa, the furnace bottom portion having the coke layer is at a positive pressure not exceeding 5 kPa.

[0070] However, when H/D is too small, namely, when the accumulation height H of the combustible wastes and/or the ashes is too small, the temperature of a gas passing through the combustible waste layer 26 becomes too high, resulting in such problems as an unstable gasification reaction of the combustible wastes and/or the ashes, and large variations in the accumulation height H of the combustible wastes and/or the ashes. On the other hand, when the furnace body has too large an inner diameter D, variations easily occur in a radial direction in the types of wastes and

in the accumulation height of the combustible wastes and/or the ashes due to the angle of repose of the combustible wastes and/or the ashes, resulting in difficulty in keeping the gasification-melting reaction uniform in a radial direction. H/D is preferably 0.8 or more, more preferably 1.0 or more.

[0071] As shown in Fig. 4, a lower portion of the supply port 5 is provided with a ledge 27, which projects inside the furnace from the refractory member 202. The extent of projection of the ledge 27 inside the furnace is preferably 20 to 70%, particularly about 1/2, of a radius of the wastes-rich layer 261 in the shaft furnace.

[0072] In the shaft furnace without the ledge 27, the combustible wastes and/or the ashes and the coke are accumulated higher at positions closer to the supply port 5, and the amount of their accumulation decreases as separating from the supply port 5 because of the angle of repose. As a result, there is larger likelihood that the accumulation of the combustible wastes and/or the ashes and the coke in the furnace body 2 becomes non-uniform. In the shaft furnace provided with the ledge 27, on the other hand, the combustible wastes and/or the ashes and the coke fall down in the furnace body 2 at a position deviated from the supply port 5 by substantially the same distance as the length of the ledge 27 projecting inside the furnace. Accordingly, the accumulation distribution of the combustible wastes and/or the ashes and the coke becomes uniform in the furnace body 2 of a circular cross section.

[0073] As shown in Fig. 5, when the length X of the ledge 27 projecting inside the furnace is 1/2 of the radius D/2 of the wastes-rich layer 261 in the shaft furnace, falls are divided substantially equally on both sides of a centre O by the angle of repose, resulting in less nonuniformity in the accumulation of the combustible wastes and/or the ashes and the coke in the furnace body 2.

[0074] Fig. 6 shows a combustion furnace system comprising a primary combustion furnace 2 and a secondary combustion furnace 10. The primary combustion furnace 2 per se may be the same as the shaft furnace shown in Fig. 3. A combustible gas burned in the shaft furnace 2 is further burned in the secondary combustion furnace 10. Air is preferably supplied from a second additional air supply means 36 disposed near a gas inlet of the secondary combustion furnace 10 or near a gas outlet of the shaft furnace 2, to keep the secondary combustion furnace filled with a stoichiometric amount or more of air. This keeps an oxidative atmosphere in the secondary combustion furnace 10, so that the remaining combustible components in the combustible gas are completely burned.

[0075] To maintain an oxidative atmosphere and a particular combustion temperature, the amount and temperature of air supplied from the second additional air supply means 36, the percentage of oxygen contained therein, the outlet temperature of the shaft furnace, etc. need only be properly set.

[0076] Figs. 7 and 8 are schematic, lateral, cross-sectional views showing the incinerator of Fig. 6. This incinerator comprises the primary combustion furnace 2, the secondary combustion furnace 10 having substantially cylindrical shape with a centre line extending along the vertical direction, and an exhaust gas-introducing pipe 28 connecting the secondary combustion furnace 10 to the primary combustion furnace 2. The primary combustion furnace 2 and the secondary combustion furnace 10 may be the same as shown in Fig. 6. An exhaust gas generated by the combustion of the combustible wastes is charged into the secondary combustion furnace 10 via the exhaust gas-introducing pipe 28. The secondary combustion furnace 10 is provided with a gas-discharging path 10a in its lower portion. The substantially cylindrical exhaust gas-introducing pipe 28 is connected to an upper side surface of the secondary combustion furnace 10 in a horizontal diameter direction.

[0077] The exhaust gas-introducing pipe 28 has a baffle plate 38. The baffle plate 38 is, as shown in Figs. 7 and 9, mounted near a junction with the secondary combustion furnace 10, such that part of the flow path of the exhaust gas-introducing pipe 28 is shut in a direction substantially along a centreline V of the secondary combustion furnace 10. The distance of the baffle plate 38 from a junction of the exhaust gas-introducing pipe 28 and the secondary combustion furnace 10 is preferably smaller than the inner diameter of the exhaust gas-introducing pipe 28. The baffle plate 38 is desirably movable such that an area of shutting the flow path of the exhaust gas-introducing pipe 28 can be controlled.

[0078] A zone of the flow path of the exhaust gas-introducing pipe 28 shut by the baffle plate 38 extends substantially in parallel with the centre line V of the secondary combustion furnace 10. Therefore, the baffle plate 38 can bias the direction of an exhaust gas flowing into the secondary combustion furnace 10 from the centre line V of the secondary combustion furnace 10 and change the flow rate of the exhaust gas, thereby generating a swirling flow SF of predetermined strength along a wall surface of the secondary combustion furnace 10. In addition, by making the baffle plate 38 movable in a radial direction of the exhaust gas-introducing pipe 28, the throttle area S of the exhaust gas-introducing pipe 28 can be controlled, thereby properly controlling the flow rate and direction of the exhaust gas.

[0079] The distance HB between the baffle plate 38 and an opening of the secondary combustion furnace 10 is smaller than the inner diameter DP of the exhaust gas-introducing pipe 28. If the baffle plate 38 were separated from the opening by this length or more, the exhaust gas throttled by the baffle plate 38 is expanded, failing to generate a sufficient swirling flow SF in the secondary combustion furnace 10 To completely burn the exhaust gas in the secondary combustion furnace 10, a secondary combustion air is supplied. Accordingly, it is preferable that a secondary combustion air supply path 36 is mounted such that its opening is positioned at least at a junction of the exhaust gas-introducing pipe 28 and the secondary combustion furnace 10, and that air is supplied from the secondary combustion air supply path 36 in the same direction as the swirling direction of the exhaust gas in the secondary combustion furnace 10. This

can strengthen an exhaust gas flow generated by the baffle plate 38 and sufficiently mix the exhaust gas with a combustion air. Though there may be one secondary combustion air supply path 36, it is desirably mounted at plural positions. The secondary combustion air supply path 36 may not be mounted to the side wall of the secondary combustion furnace 10, but may be mounted to the exhaust gas-introducing pipe 28 depending on a mounting position of the baffle plate 38.

[0080] The flow rate and direction of the exhaust gas passing through the exhaust gas-introducing pipe 28 are changed by the baffle plate 38, such that the exhaust gas flows into the secondary combustion furnace 10 along its side wall, resulting in swirling as shown in Fig. 8. Further, the exhaust gas is mixed with a secondary air supplied from the secondary air-supplying path 36, resulting in strong swirling. As a result, the exhaust gas flowing into the secondary combustion furnace 10 becomes a strong swirling flow SF involving the secondary air, resulting in substantially complete combustion and thus leading to drastic decrease in carbon monoxide, hydrocarbons, etc., and substantial decomposition of dioxin. The exhaust gas completely burned in the secondary combustion furnace 10 is discharged from an exit 10a.

[0081] To completely burn the exhaust gas, it is important to uniformly mix the exhaust gas with the secondary air. Accordingly, a strong swirling flow SF is generated. The strength of the swirling flow SF correlates to the flow rate of the secondary air and the speed of the exhaust gas charged into the secondary combustion furnace 10, and the speed of the exhaust gas charged into the secondary combustion furnace 10 is inversely proportional to the throttle area S of the baffle plate 38 in the exhaust gas-introducing pipe 28. Accordingly, to generate a strong swirling flow SF, the baffle plate 38 preferably has a larger shutting area. However, too large a shutting area of the baffle plate 38 leads to too high the speed of the exhaust gas, resulting in excess wearing in the wall of the secondary combustion furnace 10. Thus, the shutting area of the baffle plate 38 is preferably about half of the cross section area of the exhaust gas-introducing pipe 28.

[0082] The relation between the shutting area of the baffle plate 38 and the degree of mixing of the exhaust gas and the secondary air was determined by simulation at a position in the secondary combustion furnace 10 shown in Fig. 10. The results are shown in Table 1. The degree of mixing was determined by calculating turbulence energy by using heat fluid calculation. The turbulence energy is correlated with the change of a flow rate; the larger the turbulence energy (m^2/sec^2), the larger the variations of the flow rate, resulting in higher mixing. In the simulation, the inner diameter of the secondary combustion furnace 10 was 1.1 m, and the inner diameter of the exhaust gas-introducing pipe 28 was 0.6 m. As shown in Fig. 10, measurement was carried out at five points A to E in total on the centre line V of the secondary combustion furnace 10. The point A is an intersection of the centre line L of the exhaust gas-introducing pipe 28 and the centre line V of the secondary combustion furnace 10, and the points B to E are at positions downward from the point A in this order at a one-meter interval. There were four area ratios shutting the exhaust gas-introducing pipe 28 by the baffle plate 38. In a case 1 there is no baffle plate 38 (shutting area ratio of 0%), and in cases 2, 3 and 4 the shutting area ratios are 25%, 33% and 50%, respectively. Table 1 shows the relation between the shutting area ratio of the baffle plate 38 and turbulence energy.

Table 1

Case No.	Shutting Area Ratio of Baffle Plate	Turbulence Energy					
		A	B	C	D	E	Average
1	No Baffle Plate	9.0	11.9	19.5	16.4	12.5	13.9
2	25%	15.8	17.9	9.7	6.2	4.4	10.8
3	33%	24.1	22.4	11.8	8.7	6.2	14.6
4	50%	26.7	27.7	15.0	10.3	6.9	17.3

[0083] Whether or not the exhaust gas is completely burned in the secondary combustion furnace 10 is found by observing whether or not the exhaust gas charged from the exhaust gas-introducing pipe 28 is immediately mixed with the secondary air. Namely, it can be determined by observing whether or not there is large turbulence energy at the points A and B. More effectiveness is obtained by the baffle plate 38 having a larger shutting area ratio at this point. On the other hand, the average value of the points A to E indicates that the turbulence energy is lower in the case 2 than in the case of no baffle plate 38. It is thus clear that to achieve a sufficient mixing effect by the baffle plate 38, the cross section area of the baffle plate 38 is preferably 30% or more of the cross section area of the exhaust gas-introducing pipe 28.

[0084] Explanation has been made above on a case where the exhaust gas-introducing pipe 28 is mounted toward the centre line of the secondary combustion furnace 10, the exhaust gas-introducing pipe 28 may be biased from the centre line V of the secondary combustion furnace 10.

[0085] Fig. 11 shows a further example of the gasification-melting furnace system of the present invention. This system is to remove dioxin from the exhaust gas by causing activated carbon to adsorb dioxin in the exhaust gas. To remove smoke dust containing activated carbon and flying ashes from the exhaust gas, it is possible to use a dust collector, a bag filter or an activated carbon adsorption tower, etc. The bag filter is particularly suitable because of excellent contact with the exhaust gas and the activated carbon and the accuracy of removing flying ashes.

[0086] To remove salts, which are generated from calcium hydroxide added to remove acidic components from the exhaust gas, from the exhaust gas, a dust collector, a bag filter, etc. may be used. The bag filter is particularly suitable because of excellent accuracy of removing the salts.

[0087] Flying ashes contained in the smoke dust are easily scattered. If flying ashes returned to the gasification-melting furnace were scattered and entered into the exhaust gas again, there would be a large load in the step of removing the smoke dust from the exhaust gas, and there would be conditions easily generating dioxin. Accordingly in the present invention, the smoke dust collected in the exhaust gas treatment step is returned into the combustible waste layer in the gasification-melting furnace, to melt the smoke dust containing flying ashes and activated carbon while avoiding scattering, and further to expose dioxin in the smoke dust to a high temperature in the gasification-melting furnace for efficient thermal decomposition.

[0088] Dioxin not thermally decomposed in the gasification-melting furnace can be thermally decomposed in the gas combustion furnace. The exhaust gas generated by the thermal decomposition of the combustible wastes in the gasification-melting furnace is burned at a dioxin-decomposing temperature in the gas combustion furnace, and then cooled at a speed preventing the resynthesis of dioxin to reduce the concentration of dioxin in the exhaust gas.

[0089] In the gasification-melting furnace system shown in Fig. 11, the gas combustion furnace 102 connected to the gasification-melting furnace 2 (fan 142 is also connected) burns a combustible gas containing hydrocarbons, hydrogen, etc. generated by the thermal decomposition of combustible wastes in the gasification-melting furnace 2 at as high a temperature as 1,000°C to 1,200°C for at least about 2 to 3 seconds, to decompose dioxin. The gas cooling tower 103 cools a high-temperature exhaust gas discharged from the gas combustion furnace 2 to such a temperature (for instance, 500°C) that a heat exchanger, etc. disposed downstream are not damaged.

[0090] The first heat exchanger 104 performs heat exchange between the exhaust gas at about 500°C discharged from the gas cooling tower 103 and the air supplied from the fan 141, to heat the air. The hot air is sent to the gasification-melting furnace 2.

[0091] The second heat exchanger 105 performs heat exchange between the exhaust gas discharged from the first heat exchanger 104 and the air supplied from the fan 151, to heat the air. The hot air is sent to the exhaust gas tower 110, to elevate the temperature of the exhaust gas discharged from the exhaust gas tower 110, thereby preventing white fume.

[0092] The salt-removing tower 106 further lowers the temperature of the exhaust gas whose temperature is lowered by heat exchange with the air, thereby rapidly cooling the exhaust gas in a temperature range of 400°C to 200°C, in which the resynthesis of dioxin is likely to occur, to suppress the resynthesis of dioxin. It also functions to prevent heat damage on the bag filter disposed downstream.

[0093] Connected to the downstream of the salt-removing tower 106 are a first bag filter 107 and a second bag filter 108 in this order. An inlet of the first bag filter 107 is connected to an air-blowing pipe 172 of an activated carbon reservoir 171, through which activated carbon is introduced. As a result, the exhaust gas and the activated carbon flow into the first bag filter 107, and the activated carbon dispersed in the exhaust gas adsorbs dioxin. The dioxin-adsorbing activated carbon and the dioxin-containing flying ashes are collected by the first bag filter 107.

[0094] Connected to an inlet of the second bag filter 108 is an air-blowing pipe 182 connected to the calcium hydroxide reservoir 181 for introducing calcium hydroxide, a salt-removing agent, into the second bag filter 108. As a result, the exhaust gas and calcium hydroxide flow into the second bag filter 108, and calcium hydroxide neutralises the exhaust gas. Salts generated by a neutralisation reaction and unreacted calcium hydroxide are collected by the second bag filter 108. Connected to the downstream of the second bag filter 108 are an inducing fan 109 and an exhaust gas tower 110 in this order. The exhaust gas cleaned by the second bag filter 108 is sent to the exhaust gas tower 110 by the inducing fan 109, and discharged from the exhaust gas tower 110 to the air.

[0095] The bottom portions of the gas combustion furnace 2, the gas cooling tower 103, the salt-removing tower 106 and the first bag filter 107 are air-tightly connected to the dust-collecting conveyer 111, and the dust-collecting conveyer 111 is provided with a flying ash reservoir 112 at its front end. The flying ashes and the used activated carbon collected in each apparatus are collected in the flying ash reservoir 112 by the dust-collecting conveyer 111. The flying ash reservoir 112 is connected to the gasification-melting furnace 2 via the air-blowing pipe 121, the flying ashes and the used activated carbon stored in the flying ash reservoir 112 are returned to the gasification-melting furnace 2.

[0096] The collected flying ashes contain low-boiling point heavy metals. When returned to the gasification-melting furnace 2, the heavy metals are vaporised again and stored in the exhaust gas-treating system. Accordingly, when the concentrations of the heavy metals in the flying ashes reach predetermined levels, it is necessary to discharge the flying ashes from the system.

[0097] The bottom portion of the second bag filter 108 is air-tightly connected to the dust-collecting conveyer 113, and a dust-collecting conveyer 113 is provided with a reservoir 114 at its front end. The reaction products (salts) of calcium hydroxide and unreacted calcium hydroxide collected by the second bag filter 108 are sent to reservoir 114 via the dust-collecting conveyer 113, and stored there. They are further sent from the reservoir 114 to a kneading-type moulding machine 115 properly for solidification, and conveyed out from the melting treatment system.

[0098] The activated carbon charged into the inlet of the first bag filter 107 adsorbs dioxin in the exhaust gas, and the activated carbon adsorbing dioxin is collected in the bag filter 107. Flying ashes not collected in the gas combustion furnace 2, the gas cooling tower 103 and the salt-removing tower 106 are also collected in the first bag filter 107, and sent to the flying ash reservoir 112 by the dust-collecting conveyer 111. Further, flying ashes collected in the gas combustion furnace 2, the gas cooling tower 103 and the salt-removing tower 106 upstream of the first bag filter 107 are also sent to the flying ash reservoir 112 by the dust-collecting conveyer 111.

[0099] Because dioxin is adsorbed to the flying ashes on the same level as the activated carbon, the flying ashes are not conveyed out from the system but returned to the high-temperature gasification-melting furnace 2 together with the used activated carbon. In the gasification-melting furnace 2, dioxin is decomposed, the activated carbon is melted by incineration, and the flying ashes are melted. As a result, it is possible to prevent dioxin from being discharged outside the system.

[0100] Calcium hydroxide charged into the inlet of the second bag filter 108 absorbs HCl and SOx in the exhaust gas, thereby forming calcium chloride and calcium sulphate, which are collected in the second bag filter 108. Calcium chloride and calcium sulphate collected in the second bag filter 108 are conveyed to the reservoir 114 by the dust-collecting conveyer 113. They are properly mixed with cement, etc. and moulded to pellets by the kneading-type moulding machine 115, which are used for landfill, etc.

[0101] Because most of the flying ashes contained in the exhaust gas are collected by the first bag filter 107, and because most of dioxin in the exhaust gas is absorbed by the activated carbon, salt powder collected in the second bag filter 108 does not substantially contain dioxin and heavy metals. Accordingly, the mouldings of the salt powder would not cause any contamination problem in landfill, and are reusable as building materials, civil engineering materials, etc.

[0102] The plasma torch 11 used for the gasification-melting furnace of the present invention has a structure shown in Fig. 12. Disposed in an insert chip 203 is an electrode holder 202 made of an insulating refractory material, whose centre shaft has a hole, through which a tungsten bar electrode 204 penetrates. This electrode holder 202 positions the tungsten bar electrode 204 along the centre axis of the insert chip 203.

[0103] To ignite a pilot arc, a working gas such as Ar, etc. is first caused to flow between the tungsten bar electrode 204 and the insert chip 203. A high-frequency generator then applies a high-frequency voltage of 3,000 to 4,000 V at 1 to 2 MHz between the tungsten bar electrode 204 and the insert chip 203. Simultaneously with the application of the high-frequency voltage, a pilot arc power supply supplies a DC pilot current of 10 to 20 A between the tungsten bar electrode 204 and the insert chip 203. When electric discharge (insulation breakdown) occurs by high voltage with a high frequency from a tip end of the tungsten bar electrode 204, the working gas (Ar) is ionised, and a pilot arc is generated by the pilot current. As a result, by the momentum (kinetic energy) of the working gas, arc is discharged from a nozzle of the insert chip 203. With plasma arc current flowing between the tungsten bar electrode 204 and the electrode plate 205 by the plasma arc power, arc is generated between the tungsten bar electrode 204 and the electrode plate 205, so that plasma is discharged from the nozzle of the insert chip 203 onto the electrode plate 205.

[0104] Though an arc is generated in a space near a lower end surface of the electrode holder 202 inside the insert chip 203 by carrying out the above operation to ignite the pilot arc, an arc is not discharged from the nozzle of the insert chip 203 in some cases. If this mal-ignition continued, the insert chip 203, the electrode holder 202 and the tungsten bar electrode 204 would be overheated inside the torch, resulting in the erosion of the electrode holder 202, and in some cases the erosion of the insert chip 203. On the other hand, because the electrode holder 202 is in contact with the insert chip 203, it is indirectly cooled by cooling water in the insert chip 203. Thus, because the electrode holder 202 is simultaneously subjected to overheat and cooling, a large thermal gradient occurs in the member, resulting in breakage in some cases. Though not so remarkable as in the mal-ignition, the electrode holder 202 is likely to be influenced by overheat and cooling simultaneously even in a usual use in which a plasma is normally ejected from the nozzle of the insert chip 203, so that it is sometimes broken by use for a long period of time.

[0105] Accordingly, the plasma torch is provided with the electrode holder 202 for keeping the distance between the tungsten bar electrode 204 and the insert chip 203 constant while electrically insulating these electrodes. The electrode holder 202 is made of an insulating ceramic having a thermal shock resistance ΔT of 400°C or more.

[0106] Fig. 13 is a schematic, vertical, cross-sectional view showing another plasma torch 11. In Fig. 13, the same reference numerals as in Fig. 12 are assigned to portions corresponding to those of the plasma torch 11 shown in Fig. 12, with structures for flowing a shielding gas and a cooling water omitted. The plasma torch 11 comprises an electrode holder 202 for holding a tungsten bar electrode 204 and an insert chip 203 with a constant distance while electrically insulating these electrodes. The electrode holder 202 is made of an insulating ceramic having a thermal shock resist-

ance ΔT of 400°C or more.

[0107] Suitable as ceramics for such electrode holder 202 are silicon nitride ceramics and zirconia. Sialon may be used as silicon nitride ceramics, and Sialon HCN-10 available from Hitachi Metals, Ltd., for instance, is preferable. This Sialon has an electrical resistivity of 1011 Ω·cm or more and a thermal shock resistance ΔT of 710°C. A plasma ejection experiment using the plasma torch 11 shown in Fig. 12 comprising the electrode holder 202 made of Sialon HCN-10 revealed that the electrode holder 202 of the present invention was resistant to erosion and breakage. The same effects could be obtained even by an electrode holder 202 made of Zirconia HCZ-40 having an electrical resistivity of 1010 Ω·cm or more and a thermal shock resistance ΔT of 430°C (available from Hitachi Metals, Ltd.). On the other hand, in a plasma ejection experiment using a plasma torch 11 comprising an electrode holder made of alumina having a thermal shock resistance ΔT of 210°C, in place of Sialon HCN-10, the electrode holder was not resistant to erosion and breakage.

[0108] It has been confirmed from the above plasma ejection experiment that the electrode holder 202 of the present invention is subjected to little wearing. When the working gas passes through the hole of the electrode holder 202 at a high speed, the electrode holder 202 would be worn if a trace amount of dust were contained in the working gas. To prevent the mal-ignition of the pilot arc, the working gas is supplied between the tungsten bar electrode 204 and the insert chip 203 from the hole of the electrode holder 202 in a swirling flow. The electrode holder 202 is worn by dust in the working gas, thereby changing the shape of this hole, resulting in turbulence in the swirling flow. To prevent wearing, the electrode holder 202 is preferably made of ceramics having a wear resistance of 5 mm^3 or less by wear volume. This wear volume is defined as volume decrease (slurry wear), when a test piece of 15 mm x 15 mm x 5 mm ground by #400 diamond is rotated with its surface of 15 mm x 15 mm in a peripheral direction in Al_2O_3 powder (60 mesh) at a peripheral speed of 7 m/s for 1 hour. The wear volume of Sialon HCN-10 is 1.4 mm^3, and the wear volume of Zirconia HCZ-40 is 0.8 mm^3.

[0109] Because the electrode holder 202 of the present invention needs high dimensional accuracy in inner and outer surfaces, it is preferable that a green body obtained by the rubber-pressing of ceramic powder is first subjected to a predetermined working, and finish-worked again in necessary portions after sintering.

[0110] The present invention will be explained in more detail with reference to Examples below without intention of restricting the scope of the present invention.

Example 1

[0111] The properties of ashes used in this Example are as follows;

Type of ashes	ashes available from a stoker furnace,
Moisture content	20% by weight,
Content of combustibles	4% by weight, and
Ash content	76% by weight.

[0112] The above ashes were gasification-melted under the following conditions;

Amount of ashes supplied	200 kg/hour,
Amount of coke supplied	35 kg/hour,
Amount of limestone supplied	6 kg/hour,
Total air volume	250 Nm^3/hour,
Air volume from plasma torch	250 Nm^3/hour,
Total air volume/stoichiometric air volume	0.82,
Temperature of hot air supplied from plasma torch	about 1,800°C,
Temperature of coke layer 25	1,500°C, and
Average internal pressure in furnace bottom portion 22	positive pressure of 1.0 kPa.

[0113] The temperature in the furnace body 2 was substantially as constant as about 1,500°C in the coke layer 25, and 500°C to 900°C in an upper space of the ash layer 26. This temperature variation occurs, because every time ashes are supplied at a pace of one batch per 1 minute, water in the ashes is evaporated to remove heat from the furnace. After about 10 minutes passed from starting the supply of ashes, a molten slag started to be discharged. The amount of a molten slag discharged was about 200 kg/hour on average.

Example 2

[0114] The properties of landfill wastes used in this Example are as follows;

Type of landfill wastes	dug landfill wastes,
Moisture content	33% by weight,
Content of combustibles	7% by weight, and
Ash content	60% by weight.

[0115] The above landfill wastes were gasification-melted under the following conditions;

Amount of wastes supplied	400 kg/hour,
Amount of coke supplied	40 kg/hour,
Amount of limestone supplied	10 kg/hour,
Total air volume	250 Nm^3/hour,
Air volume from plasma torch	250 Nm^3/hour,
Total air volume/stoichiometric air volume	0.57
Temperature of hot air supplied from plasma torch	about 1,800°C,
Temperature of coke layer 25	1,500°C, and
Average internal pressure in furnace bottom portion 22	positive pressure of 2 kPa.

[0116] It took about 10 minutes to start discharging a molten slag after supplying the wastes. The amount of the molten slag discharged was about 250 kg/hour on average.

[0117] In Examples 1 and 2, the hot air volume from the plasma torch was 250 Nm^3/hour. However, when the hot air volume was changed to 350 Nm^3/hour, the temperature in the furnace bottom portion 22 and in the coke layer 25 was lowered, failing to keep 1,500°C, so that the discharging of the molten slag slowed.

[0118] Because the coke layer 25 is a layer with extremely many voids, the molten slag easily flows down through the voids and is uniformly exposed to a hot air while residing on the furnace bottom, thus free from even partial solidification.

[0119] Because the coke layer 25 have many voids, it is possible to lower its resistance to air flow to keep the internal pressure in a furnace bottom portion at a proper level for continuously discharging the molten slag, even though it has a higher density than ashes or landfill wastes.

[0120] Because a hot air is blown from the plasma torch 11 into the lower layer of the coke layer 25, the entire coke layer 25 can be kept stably and uniformly at a high temperature of about 1,500°C, thereby keeping the molten slag stably in a melting state.

[0121] Though the pressure of a shroud air introduced through the plasma torch was set at 15 kPa in this Example, the pressure near the furnace bottom portion 22 was about I to 2 kPa because of the air flow resistance in the above coke layer 25 and the combustible waste layer 26. It was, however, sufficient to function as a pressure difference to push the molten slag out through furnace bottom portion 22. Even though the liquid surface of the molten slag is lowered to permit the hot air to eject from the furnace, the hot air' speed is low. Thus, by keeping the internal pressure of the furnace bottom portion 22 properly at a positive pressure, the stable, continuous discharging of the molten slag can be achieved.

Example 3

[0122] The properties of combustible wastes used in this Example are as follows;

Type of combustible wastes	general combustible wastes (mainly domestic garbage)
Moisture content	46.5% by weight,
Lower calorific value	8200 kJ/kg,
Ash content	7.9% by weight,

[0123] The above combustible wastes were gasification-melted under the following conditions;

Amount of electric power supplied to plasma torch	360 MJ/hr,

(continued)

Amount of coke supplied	30 kg/hr,
Amount of combustible wastes and/or ashes supplied	1,000 kg/hr,
Total air volume	700 Nm^3/hr,
Air volume from plasma torch	150 Nm^3/hr,
Temperature of hot air supplied from plasma torch	about 1,800°C,
Temperature of coke layer 25	1,500°C, and
Average internal pressure in furnace bottom portion 22	positive pressure of 1.5 kPa.

[0124] The temperature in the furnace body 2 was substantially constant at about 1,500°C in the coke layer 25, and 500°C to 900°C in an upper space of the combustible waste layer 26. Because a hot air is blown from the plasma torch into a lower layer of the coke layer 25, it is possible to keep the entire coke layer 25 uniformly and stably at a high temperature of about 1,500°C, thereby keeping the molten slag stably in a melting state.

[0125] Though the pressure of a shroud air introduced through the plasma torch was set at 14.7 kPa in this Example, the pressure near the furnace bottom portion 22 was about 1.5 kPa because of the air flow resistance in the coke layer 25 and the combustible waste layer 26. It was, however, sufficient to function as a pressure difference to push the molten slag out through the furnace bottom portion 22. Even though the liquid surface of the molten slag is lowered to permit a hot air to eject from the furnace, the hot air' speed is low. By lowering the internal pressure of the furnace bottom portion 22, the stable, continuous discharging of the molten slag can be achieved.

Example 4

[0126] In this Example, using combustible wastes with a lower calorific value lower than that of the combustible wastes of Example 3, the amount of electric power supplied to the plasma torch was increased. The following combustible wastes were gasification-melted under the same conditions as in Example 3 except for the following conditions. Like in Example 3, the molten slag could be kept stably in a melting state to continuously and stably discharge the molten slag.

Type of combustible wastes	general combustible wastes (mainly domestic garbage)
Moisture content	71.3% by weight,
Lower calorific value	3,400 kJ/kg,
Ash content	14.2% by weight, and
Amount of electric power supplied to plasma torch	790 MJ/hr.

Example 5

[0127] In this Example, using combustible wastes with a lower calorific value higher than that of the combustible wastes of Example 3, the amount of electric power supplied to the plasma torch was decreased to gasification-melt the combustible wastes. The gasification-melting of the combustible waste was conducted under the same conditions as in Example 3 except for the following conditions. In this Example, too, like in Example 3, the molten slag could be kept in a melting state stably, to carry out the continuous discharging of the molten slag stably.

Type of combustible wastes	general combustible wastes (mainly domestic garbage),
Moisture content	30.1 % by weight,
Lower calorific value	12,000 kJ/kg,
Ash content	3.5% by weight, and
Amount of electric power supplied to plasma torch	290 MJ/hr.

Example 6

[0128] In this Example, the amount of coke supplied to the following combustible wastes with a high lower calorific value was made smaller than those in Examples 3 to 5, to carry out gasification-melting. The gasification-melting conditions of the combustible wastes were the same as in Example 3 except for the following ones. In this Example, too, like in Example 3, the molten slag could be kept in a melting state stably, to carry out the continuous discharging of the molten slag stably.

Type of combustible wastes	general combustible wastes (mainly domestic garbage),
Moisture content	29.2% by weight,
Lower calorific value	9,800 kJ/kg,
Ash content	3.2% by weight,
Amount of electric power supplied to plasma torch	330 MJ/hr, and
Amount of coke supplied	20 kg/hr.

Example 7

[0129] In this Example, gasification melting was carried out, with the combustible wastes of Example 6 provided with an increased lower calorific value, and with the decreased amount of electric power supplied to the plasma torch. The gasification-melting conditions of the combustible wastes were the same as in Example 6 except for the following ones. In this Example, too, like in Example 3, the molten slag could be kept in a melting state stably, to carry out the continuous discharging of the molten slag stably.

Type of combustible wastes	general combustible wastes (mainly domestic garbage),
Moisture content	28.3% by weight,
Lower calorific value	11,000 kJ/kg,
Ash content	2.9% by weight, and
Amount of electric power supplied to plasma torch	300 MJ/hr

Example 8

[0130] In this Example, using combustible wastes with a lower calorific value higher than that of the combustible wastes of Example 7, gasification melting was carried out with the decreased amount of electric power supplied to the plasma torch. The gasification-melting conditions of the combustible wastes were the same as in Example 7 except for the following ones. In this Example, too, like in Example 3, the molten slag could be kept stably in a melting state, to carry out the continuous discharging of the molten slag stably.

Type of combustible wastes	general combustible wastes (mainly domestic garbage),
Moisture content	27.1% by weight,
Lower calorific value ;	12,000 kJ/kg,
Ash content	2.5% by weight, and
Amount of electric power supplied to plasma torch	260 MJ/hr.

Comparative Example 1

[0131] Combustible wastes were gasification-melted in the same manner as in Example 3 except for decreasing the amount of electric power supplied to the plasma torch to 290 MJ/hr. As a result, the temperature in the coke layer was 1,200°C to 1,280°C, which was lower than that in Example 3. Accordingly, because the molten slag was solidified at the molten slag outlet 23 and the slag trough 15, the molten slag was not discharged continuously.

Comparative Example 2

[0132] Combustible wastes were gasification-melted in the same manner as in Example 4 except for decreasing the amount of electric power supplied to the plasma torch to 600 MJ/hr. As a result, the temperature in the coke layer was 1230°C to 1330°C, which was lower than that in Example 4. Accordingly, because the molten slag was solidified at the molten slag outlet 23 and the slag trough 15, the molten slag was not discharged continuously.

Comparative Example 3

[0133] Combustible wastes were gasification-melted in the same manner as in Example 5 except for decreasing the amount of electric power supplied to the plasma torch to 210 MJ/hr. As a result, the temperature in the coke layer was 1,200°C to 1,280°C, which was lower than that in Example 5. Accordingly, because the molten slag was solidified at

the molten slag outlet 23 and the slag trough 15, the molten slag was not discharged continuously.

Comparative Example 4

[0134] Combustible wastes were gasification-melted in the same manner as in Example 6 except for decreasing the amount of electric power supplied to the plasma torch to 280 MJ/hr. As a result, the temperature in the coke layer was 1,220°C to 1,290°C, which was lower than that in Example 6. Accordingly, because the molten slag was solidified at the molten slag outlet 23 and the slag trough 15, the molten slag was not discharged continuously.

Comparative Example 5

[0135] Combustible wastes were gasification-melted in the same manner as in Example 7 except for decreasing the amount of electric power supplied to the plasma torch to 590 MJ/hr. As a result, the temperature in the coke layer was 1,200°C to 1,290°C, which was lower than that in Example 7. Accordingly, because the molten slag was solidified at the molten slag outlet 23 and the slag trough 15, the molten slag was not discharged continuously.

Comparative Example 6

[0136] Combustible wastes were gasification-melted in the same manner as in Example 8 except for decreasing the amount of electric power supplied to the plasma torch to 230 MJ/hr. As a result, the temperature in the coke layer was 1,250°C to 1,330°C, which was lower than that in Example 8. Accordingly, because the molten slag was solidified at the molten slag outlet 23 and the slag trough 15, the molten slag was not discharged continuously.

[0137] It is clear from Examples 3 to 5 and Comparative Examples 1 to 3 that the amount of coke necessary for continuously and stably gasification-melting 1,000 kg/hr of combustible wastes having a lower calorific value may usually be about 30 kg/hr, and that when the lower calorific value of the combustible wastes is reduced, the amount of electric power supplied to the plasma torch need only be increased. It is also clear from Examples 6 to 8 and Comparative Examples 4 to 6 that the amount of coke necessary for continuously and stably gasification-melting 1,000 kg/hr of combustible wastes, whose lower calorific value is high, may be 20 kg/hr, and that when the lower calorific value of the combustible wastes is reduced, the amount of electric power supplied to the plasma torch only be increased.

[0138] Examples 3 to 5 show cases where the short-range lower calorific value of the combustible wastes varies, while Examples 6 to 8 show cases where the long-range lower calorific value of the combustible wastes varies. It is clear that the increase of the long-range lower calorific value requires only the reduction of the amount of coke supplied. On the contrary, the reduction of the long-range lower calorific value requires only the increase of the amount of coke supplied.

[0139] In sum, what is needed to the short-range variations of the lower calorific value of the combustible wastes is to control the amount of electric power supplied to the plasma torch, with the amount of coke kept constant. On the other hand, the long-range variations of the lower calorific value of the combustible wastes can be managed by controlling the amount of coke supplied.

Example 9

[0140] The properties of combustible wastes used and the gasification-melting conditions are shown below. No bridging of the combustible wastes occurred in the gasification-melting furnace. The pressure in the furnace bottom portion 22 was a positive pressure of 5 kPa on average.

Type of combustible wastes	general combustible wastes (mainly domestic garbage),
Moisture content	55% by weight,
Resin content	12% by weight,
Lower calorific value	358 kJ/kg,
Amount of combustible wastes supplied	1,000 kg/hr,
Amount of coke supplied	20 kg/hr,
Total air volume	700 Nm^3/hr,
Air volume from plasma torch	150 Nm^3/hr,
Air pressure from plasma torch	14.7 MPa, and
H/D	2.0.

Example 10

[0141] Combustible wastes having the same properties as in Example 9 were subjected to a gasification-melting treatment under the following conditions. No bridging of combustible wastes occurred in the gasification-melting furnace. The pressure in the furnace bottom portion 22 was a positive pressure of 1.5 kPa on average.

Amount of combustible wastes and/or ashes supplied	1,000 kg/hr,
Amount of coke supplied	20 kg/hr,
Total air volume	700 Nm^3/hr,
Air volume from plasma torch	150 Nm^3/hr,
Air pressure from plasma torch	14.7 MPa, and
H/D	1.5.

[0142] In Examples 9 and 10, the temperature in the furnace body 2 was substantially constant at about 1,500°C in the coke layer 25, and 500°C to 900°C in an upper space of the combustible waste layer 26. After passing about 60 minutes from the start of supplying combustible wastes, a molten slag started to be discharged from the molten slag outlet 23. The amount of the molten slag discharged was about 80 kg per 1 hour on average.

[0143] In Example 10, though the pressure of a shroud air blown from the plasma torch 11 was set at 14.7 kPa, the pressure in the furnace bottom portion 22 was about 5 kPa to 1.5 kPa because of the air flow resistance in the coke layer 25 and the combustible waste layer 26. It was, however, sufficient as a pressure difference to push the molten slag out from the molten slag outlet 23. Even if the liquid surface of the molten slag was lowered to permit a hot air to eject from the furnace, its speed was so low that there was no vigorous ejection of the molten slag.

Comparative Example 7

[0144] Combustible wastes were subjected to a gasification-melting treatment under the same conditions as in Example 9 except for changing H/D to 2.5. The internal pressure of the furnace bottom portion 22 was a positive pressure of 8 kPa on average. No bridging occurred in the combustible waste layer 26 in the furnace. Because of the thick combustible waste layer 26, temperature decrease occurred in a high-temperature gas flowing upward from the furnace bottom portion 22 in the furnace, so that the temperature in an upper portion of the combustible waste layer 26 was about 200°C to 350°C. It is considered that bridging easily occurs at this temperature, because resins contained in combustible wastes were in a semi-melting state and thus fused to each other to form large bulks.

APPLICABILITY IN INDUSTRY

[0145] The gasification-melting furnace of the present invention can continuously gasification-melt combustible wastes and/or ashes and stably discharge the resultant molten slag.

[0146] When there are short-range variations in the lower calorific value of the combustible wastes, it is possible to carry out stable and continuous gasification-melting of combustible wastes only by controlling the amount of electric power supplied to the plasma torch without changing the amount of coke supplied. On the other hand, when there are long-range variations in the lower calorific value of the combustible wastes, the stable and continuous gasification-melting of combustible wastes can be conducted by controlling the amount of coke supplied.

[0147] By providing the supply port of the gasification-melting furnace with a ledge according to the present invention, it is possible to reduce a biased flow of a high-temperature gas in a layer of combustible wastes and/or ashes, thereby lowering the operation cost of the gasification-melting furnace.

[0148] By suppressing the bridging in the combustible waste layer in the gasification-melting furnace, and by maintaining the internal pressure of the furnace bottom portion low according to the present invention, the vigorous ejection of a hot air and a molten slag can be prevented.

[0149] According to the gasification-melting method of the present invention, combustible wastes and/or ashes can be subjected to a gasification-melting treatment, without discharging smoke dust containing dioxin and heavy metals, and without accumulating the reaction products of calcium hydroxide in the system.

[0150] According to the present invention, the swirling flow of the exhaust gas can be controlled, thereby completely burning the exhaust gas, by disposing a baffle plate in an exhaust gas-introducing pipe connecting a primary incineration furnace and a secondary incineration furnace. Further, by supplying a secondary air in the same direction as the exhaust gas throttled by the baffle plate, the exhaust gas and the air are more strongly swirled in the secondary combustion furnace, so that the concentrations of carbon monoxide and hydrocarbons in the exhaust gas can effectively be reduced.

[0151] The electrode holder of the present invention and the plasma torch comprising it are resistant to erosion and

breakage at the time of mal-ignition or during ordinary use, thereby enjoying a long life.

Claims

1. A gasification-melting furnace for supplying combustible wastes and/or ashes and an auxiliary fuel into a shaft furnace and thermally decomposing said combustible wastes and/or ashes in an atmosphere containing air, in a stoichiometric amount or less relative to combustible wastes and/or ashes and an auxiliary fuel, to discharge the resultant residue as a molten slag from a slag exit, wherein said gasification-melting furnace comprises a plasma torch for blowing a hot air into an auxiliary fuel layer in a furnace bottom portion, which is at a positive pressure of 5 kPa or less on average.

2. The gasification-melting furnace for combustible wastes and/or ashes according to claim 1, wherein said molten slag is continuously discharged from a molten slag outlet disposed in said furnace bottom portion.

3. A gasification-melting furnace for combustible wastes and/or ashes, wherein H/D is 2 or less, wherein H is a height from a furnace bottom to a top surface of a layer of accumulated combustible wastes and/or ashes, and D is an inner diameter of a furnace body in a zone in which there is a top surface of a layer of said combustible wastes and/or ashes.

4. The gasification-melting furnace according to any one of claims 1-3, wherein the temperature of a gas passing through a layer of said combustible wastes and/or ashes is 500°C to 1,000°C.

5. A shaft furnace-type gasification-melting furnace for supplying combustible wastes and/or ashes and an auxiliary fuel into a furnace, burning said combustible wastes and/or said ashes for gasification by a heat source disposed in a furnace bottom portion, and discharging molten residue from a residue-discharging outlet, wherein supply ports for said combustible wastes and/or said ashes and said auxiliary fuel are mounted to a side surface of said shaft furnace with the lower portions of said supply ports projecting into said furnace.

6. The gasification-melting furnace according to claim 5, wherein the projecting distance of the projections of said supply ports into said furnace is 20 to 70% of the radius of a wastes-rich layer in said shaft furnace.

7. A gasification-melting method of combustible wastes comprising using a shaft furnace-type gasification-melting furnace provided with a plasma torch, supplying said combustible wastes and said auxiliary fuel into said shaft furnace, blowing a hot air into an auxiliary fuel layer in a furnace bottom portion by said plasma torch, burning said combustible wastes for gasification in an atmosphere containing a stoichiometric amount or less of air relative to said combustible wastes and said auxiliary fuel, and discharging residue as a molten slag outside said furnace, wherein the amount of electric power supplied to said plasma torch is controlled depending on the variations of a lower calorific value of said combustible wastes.

8. A gasification-melting method of combustible wastes comprising using a shaft furnace-type gasification-melting furnace provided with a plasma torch, supplying said combustible wastes and said auxiliary fuel into said shaft furnace, blowing a hot air into an auxiliary fuel layer in a furnace bottom portion by said plasma torch, burning said combustible wastes for gasification in an atmosphere containing a stoichiometric amount or less of air relative to said combustible wastes and said auxiliary fuel, and discharging residue as a molten slag outside said furnace, wherein the amount of electric power supplied to said plasma torch is increased in the short-range decrease of the lower calorific value of said combustible wastes, and decreased in the short-range increase of the lower calorific value of said combustible wastes.

9. A gasification-melting method of combustible wastes comprising using a shaft furnace-type gasification-melting furnace provided with a plasma torch, supplying said combustible wastes and said auxiliary fuel into said shaft furnace, blowing a hot air into an auxiliary fuel layer in a furnace bottom portion by said plasma torch, burning said combustible wastes for gasification in an atmosphere containing a stoichiometric amount or less of air relative to said combustible wastes and said auxiliary fuel, and discharging residue as a molten slag outside said furnace, wherein the amount of said auxiliary fuel supplied to said shaft furnace is increased in the long-range decrease of the lower calorific value of said combustible wastes, and decreased in the long-range increase of the lower calorific value of said combustible wastes.

10. A gasification-melting method of combustible wastes comprising using a shaft furnace-type gasification-melting furnace provided with a plasma torch, supplying said combustible wastes and said auxiliary fuel into said shaft furnace, blowing a hot air into an auxiliary fuel layer in a furnace bottom portion by said plasma torch, burning said combustible wastes for gasification in an atmosphere containing a stoichiometric amount or less of air relative to said combustible wastes and said auxiliary fuel, and discharging residue as a molten slag outside said furnace, wherein the amount of electric power supplied to said plasma torch is increased in the short-range decrease of the lower calorific value of said combustible wastes, and decreased in the short-range increase of the lower calorific value of said combustible wastes, and wherein the amount of said auxiliary fuel supplied to said shaft furnace is increased in the long-range decrease of the lower calorific value of said combustible wastes, and decreased in the long-range increase of the lower calorific value of said combustible wastes.

11. A gasification-melting method of combustible wastes and/or ashes comprising burning a gas generated by thermally decomposing said combustible wastes and/or ashes in a gasification-melting furnace, bringing the resultant exhaust gas into contact with activated carbon, wherein smoke dust containing said activated carbon and flying ashes is removed from said exhaust gas; and returning said smoke dust to said gasification-melting furnace.

12. A gasification-melting method of combustible wastes and/or ashes comprising using a shaft furnace-type gasification-melting furnace provided with a plasma torch, supplying combustible wastes and/or ashes and an auxiliary fuel into said shaft furnace, blowing a hot air into an auxiliary fuel layer in a furnace bottom portion by said plasma torch, burning said combustible wastes and/or ashes for gasification in an atmosphere containing a stoichiometric amount or less of air relative to said combustible wastes and/or ashes and said auxiliary fuel, discharging residue as a molten slag outside said furnace; wherein a gas generated by thermally decomposing said combustible wastes and/or ashes is burned in said gasification-melting furnace; wherein the resultant exhaust gas is brought into contact with activated carbon; wherein smoke dust containing said activated carbon and flying ashes is removed from said exhaust gas; and wherein said smoke dust is returned to said gasification-melting furnace.

13. The gasification-melting method of combustible wastes and/or ashes according to claim 11 or 12, wherein said exhaust gas is caused to pass through a bag filter to remove smoke dust containing activated carbon and flying ashes.

14. A gasification-melting method of combustible wastes and/or ashes comprising burning a gas generated by thermally decomposing said combustible wastes and/or ashes in a gasification-melting furnace, wherein the resultant primary exhaust gas is brought into contact with activated carbon; wherein smoke dust containing said activated carbon and flying ashes is removed from said exhaust gas; wherein said smoke dust is returned to said gasification-melting furnace; wherein a secondary exhaust gas obtained by removing said smoke dust is brought into contact with a salt-removing agent; and removing the resultant salts from said secondary exhaust gas.

15. A gasification-melting method of combustible wastes and/or ashes comprising using a shaft furnace-type gasification-melting furnace provided with a plasma torch, supplying combustible wastes and/or ashes and an auxiliary fuel into said shaft furnace, blowing a hot air into an auxiliary fuel layer in a furnace bottom portion by said plasma torch, burning said combustible wastes and/or ashes for gasification in an atmosphere containing a stoichiometric amount or less of air relative to said combustible wastes and/or ashes and said auxiliary fuel, and discharging residue as a molten slag outside said furnace, wherein a gas generated by thermally decomposing said combustible wastes and/or ashes is burned in said gasification-melting furnace; wherein the resultant primary exhaust gas is brought into contact with activated carbon; wherein smoke dust containing said activated carbon and flying ashes is removed from said exhaust gas; wherein said smoke dust is returned to said gasification-melting furnace; wherein a secondary exhaust gas obtained by removing said smoke dust is brought into contact with a salt-removing agent; and wherein the resultant salts is removed from said secondary exhaust gas.

16. The gasification-melting method of combustible wastes and/or ashes according to claim 14 or 15, wherein said primary exhaust gas is caused to pass through a bag filter to remove smoke dust containing activated carbon and flying ashes.

17. The gasification-melting method of combustible wastes and/or ashes according to any one of claims 14 to 16, wherein said secondary exhaust gas is caused to pass through a bag filter to remove salts.

18. The gasification-melting method of combustible wastes and/or ashes according to any one of claims 14 to 17, wherein said smoke dust is returned to said gasification-melting furnace.

19. The gasification-melting method of combustible wastes and/or ashes according to any one of claims 14 to 18, wherein a thermal decomposition gas of said combustible wastes and/or ashes is burned at a dioxin-decomposing temperature, and then cooled at a speed preventing the resynthesis of dioxin to form said exhaust gas.

20. An incinerator of combustible wastes and/or ashes comprising a primary combustion furnace for burning combustible wastes and/or ashes, a substantially cylindrical secondary combustion furnace, and an exhaust gas-introducing pipe connecting said primary combustion furnace and said secondary combustion furnace for introducing an exhaust gas from said primary combustion furnace to said secondary combustion furnace, wherein a baffle plate is mounted to said exhaust gas-introducing pipe to control the flow rate and direction of said exhaust gas flowing into said secondary combustion furnace.

21. The incinerator of combustible wastes and/or ashes according to claim 20, wherein said baffle plate is disposed in said exhaust gas-introducing pipe; wherein the distance between said baffle plate and a connection point of said exhaust gas-introducing pipe and said secondary combustion furnace is smaller than the inner diameter of said exhaust gas-introducing pipe; and wherein part of said exhaust gas-introducing pipe in which said baffle plate clogs its flow path extends substantially in parallel with a centre line of the secondary combustion furnace, whereby a swirling flow is generated in said secondary combustion furnace exhaust gas.

22. The incinerator of combustible wastes and/or ashes according to claim 20 or 21, wherein said baffle plate is movable so that an area in which said baffle plate shuts the flow path of said exhaust gas-introducing pipe can be controlled.

23. The incinerator of combustible wastes and/or ashes according to any one of claims 20 to 22, wherein a pipe for supplying said secondary air opens in said secondary combustion furnace in a direction strengthening the swirling flow of said exhaust gas at least at a junction of said exhaust gas-introducing pipe and said secondary combustion furnace.

24. An electrode holder disposed in a plasma torch for fixing at least one of a pair of electrodes to keep their gap constant while electrically insulating both electrodes, wherein said electrode holder is made of an insulating ceramic having a thermal shock resistance ΔT of 400°C or more.

25. The electrode holder according to claim 24, wherein said ceramic is silicon nitride.

26. A plasma torch comprising a pair of electrodes, and an electrode holder for fixing at least one of the electrodes, wherein said electrode holder is made of an insulating ceramic having a thermal shock resistance ΔT of 400°C or more, whereby the distance between both electrodes is kept constant with electric insulation.

27. The plasma torch according to claim 26, wherein said ceramic is silicon nitride.

Fig. 1

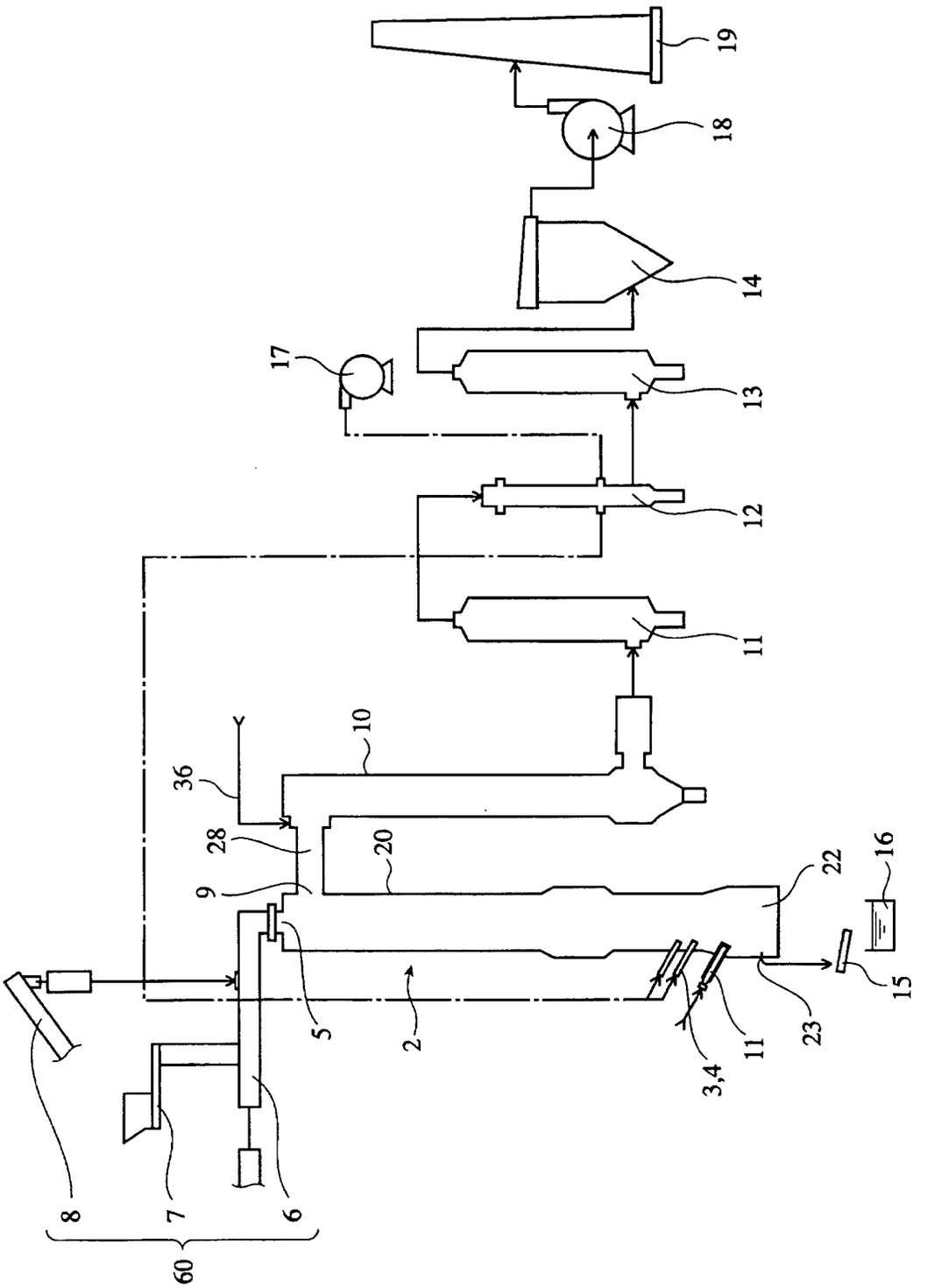

Fig. 2

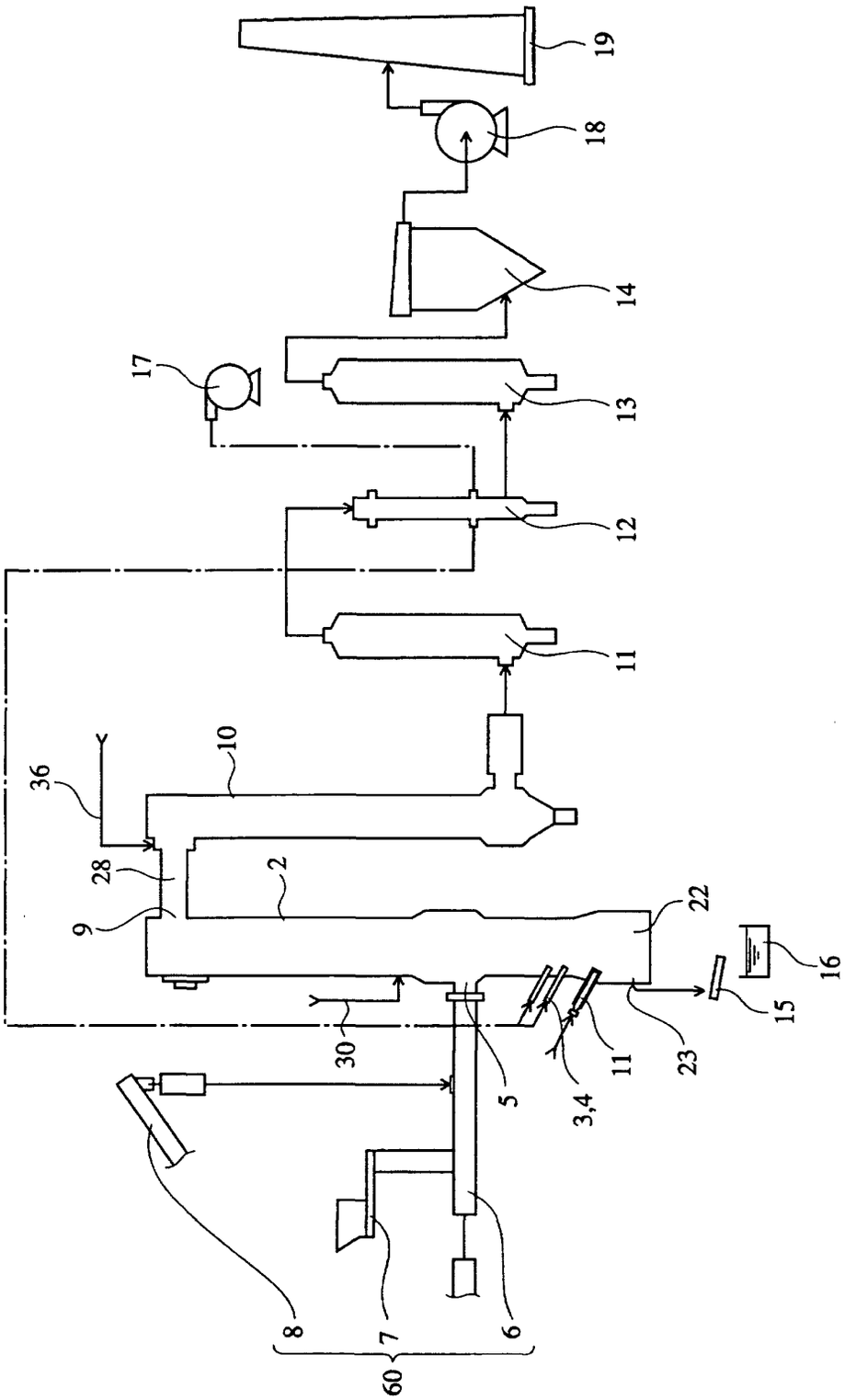

Fig. 3

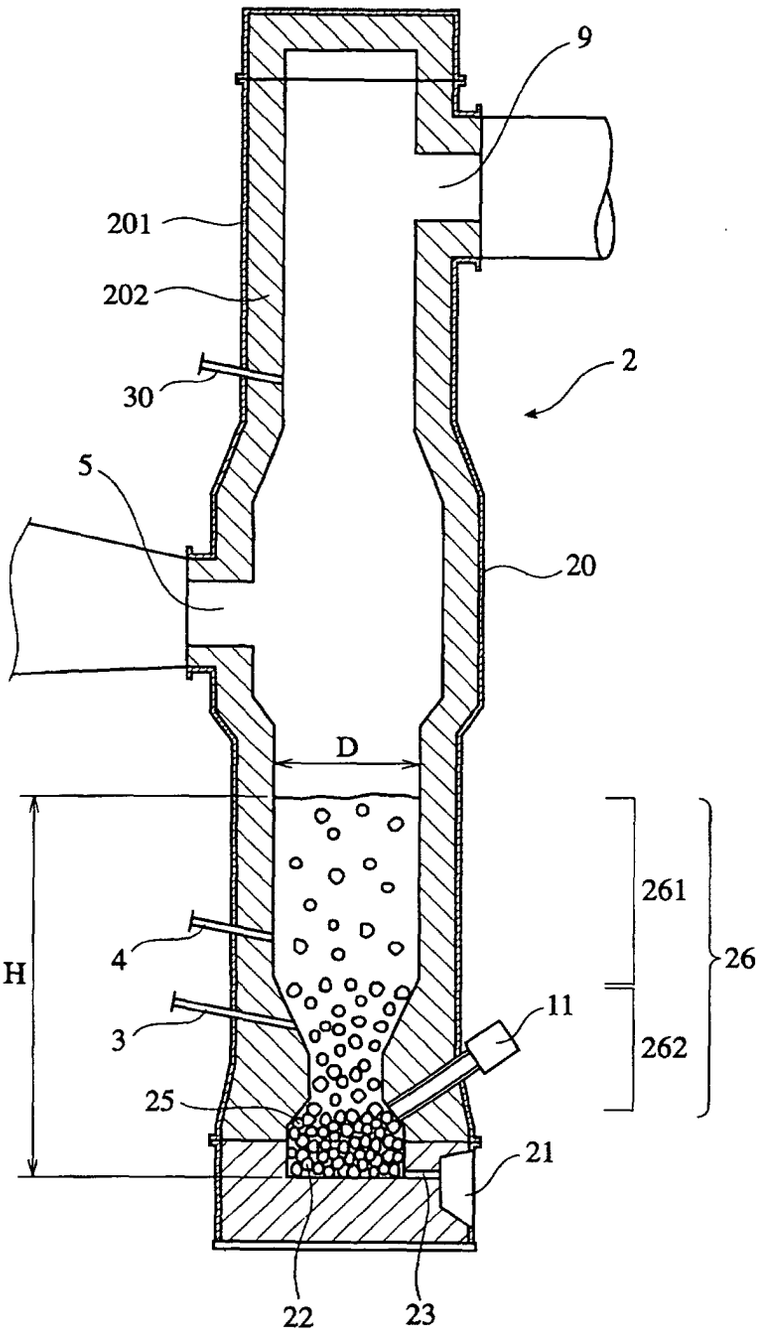

Fig. 4

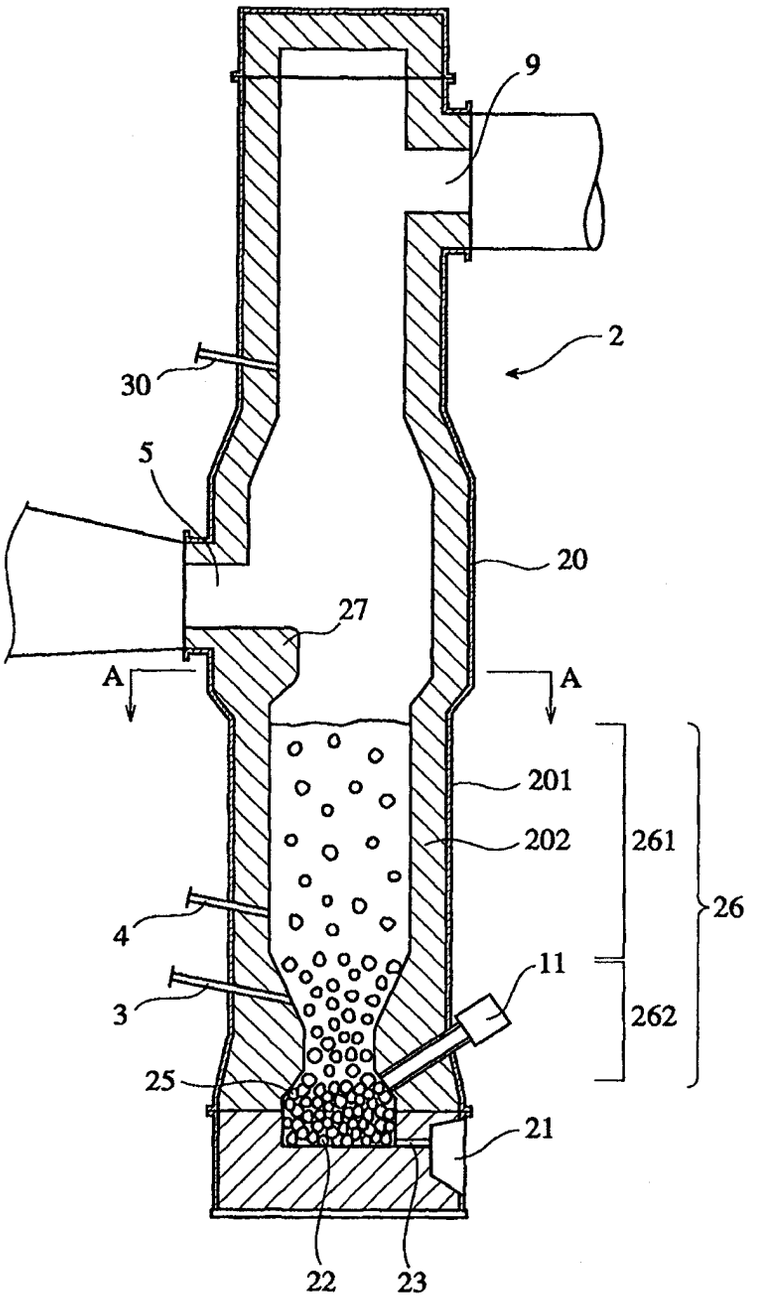

Fig. 5

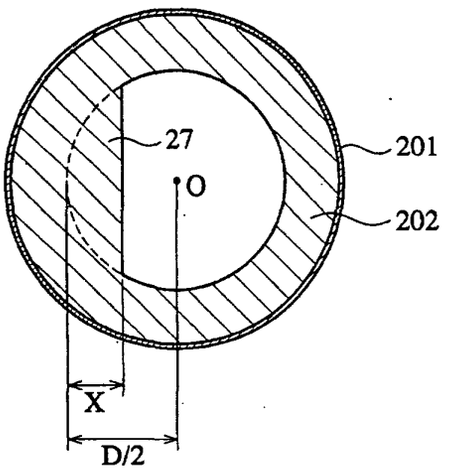
27
201
O
202
X
D/2

Fig. 13

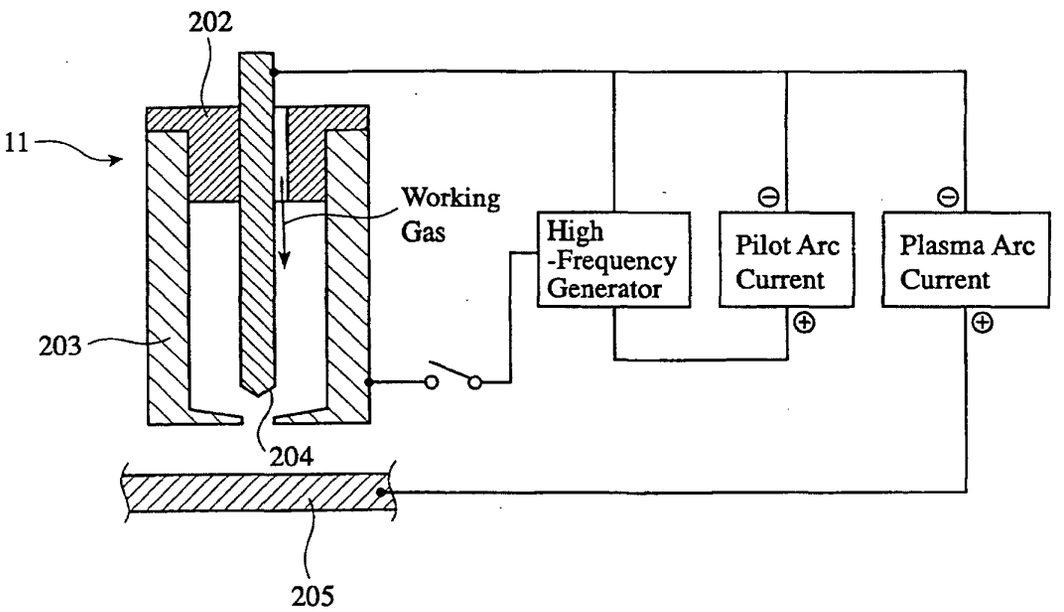
202
11
Working
Gas
High
-Frequency
Generator
Pilot Arc
Current
Plasma Arc
Current
203
204
205

Fig. 6

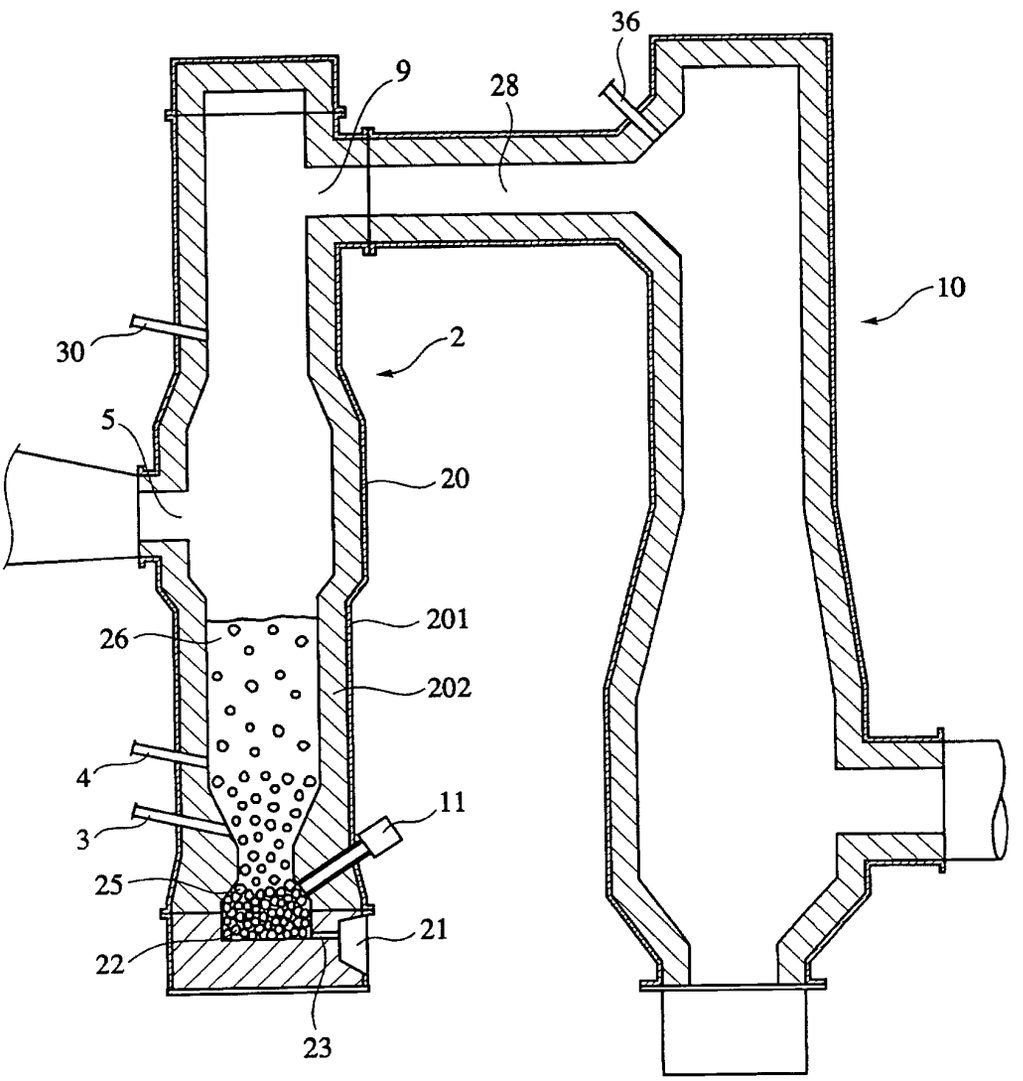

Fig. 7

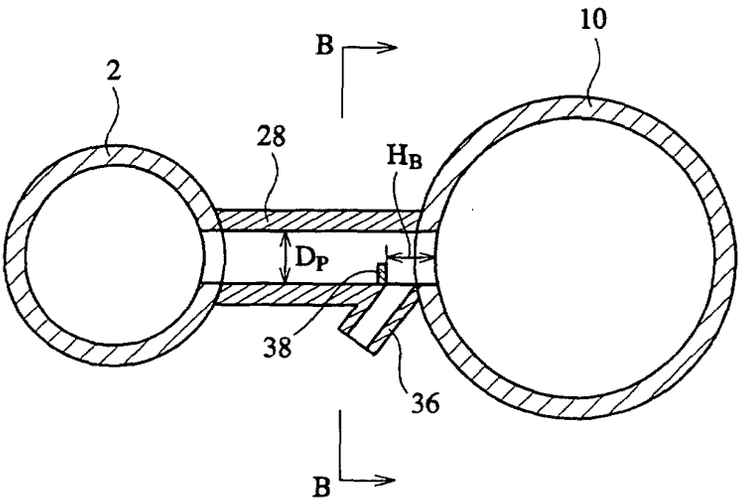

Fig. 8

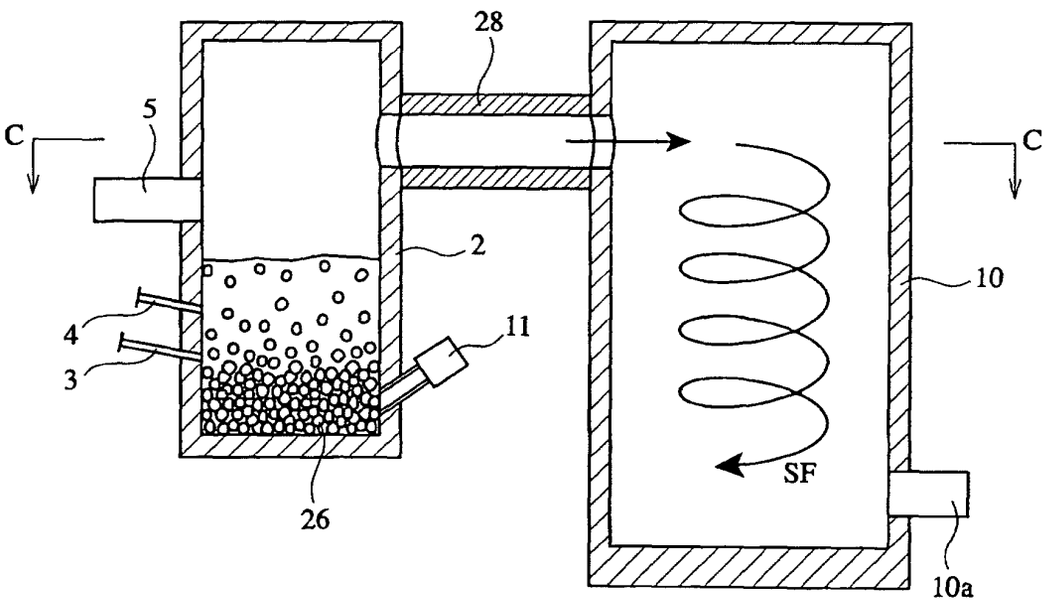

Fig. 9

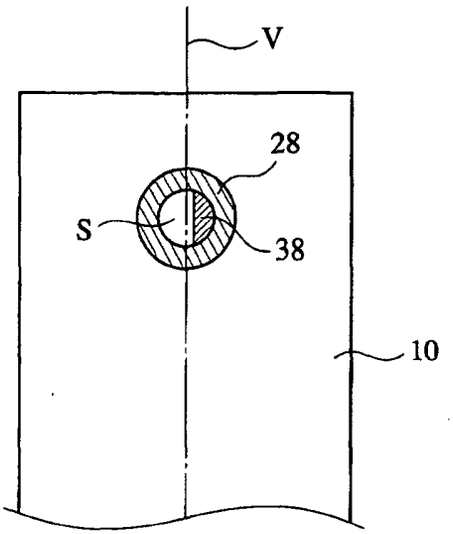

Fig. 10

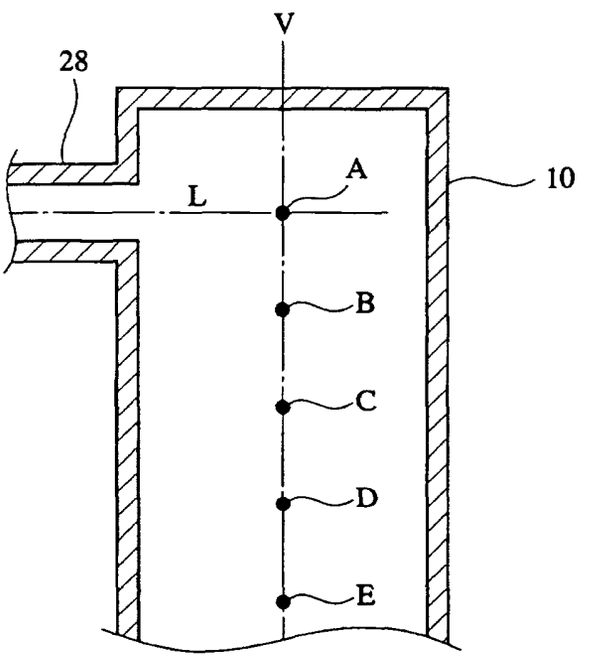

Fig. 11

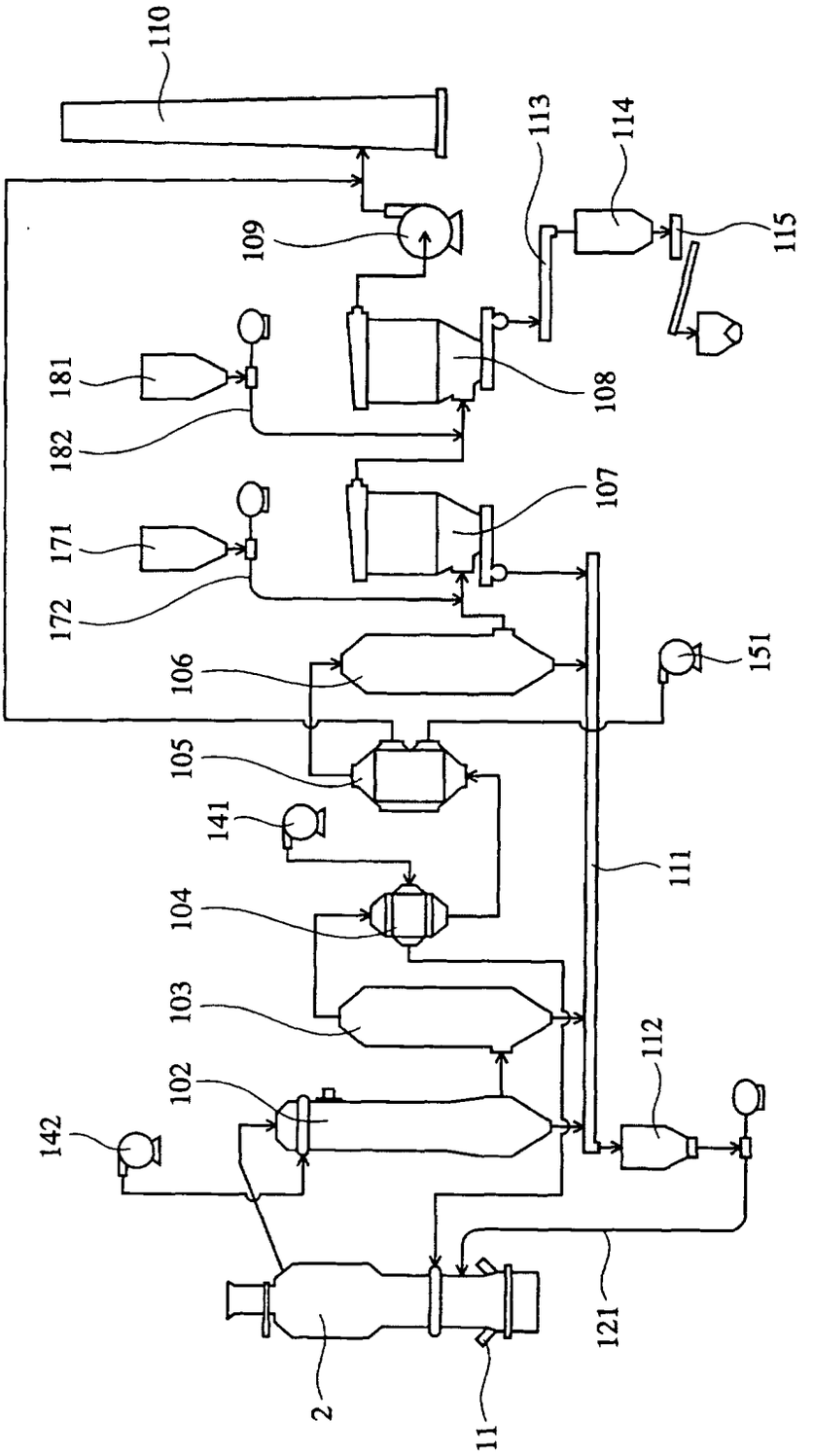
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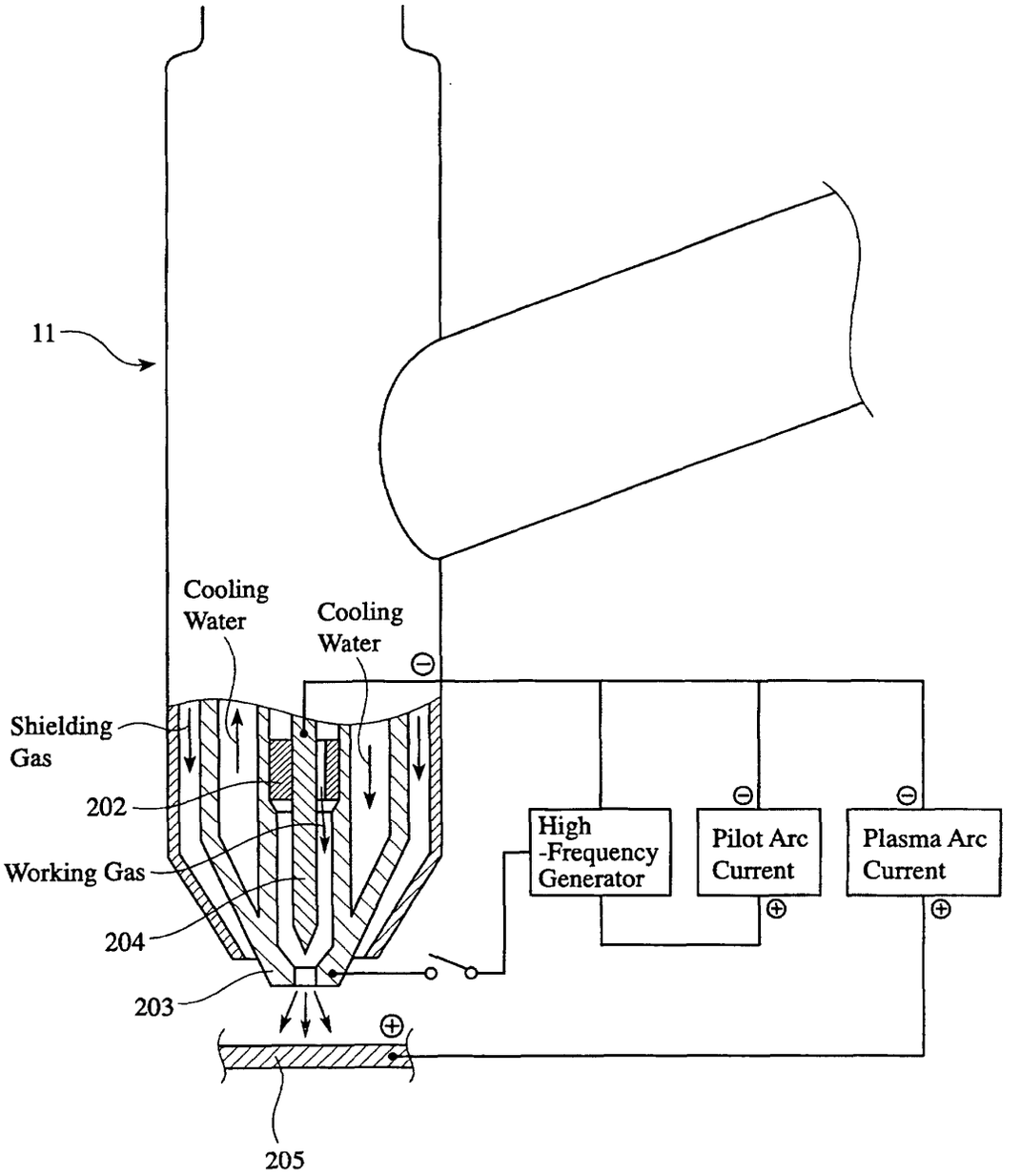
Fig. 12


11
Cooling Water
Cooling Water
Shielding Gas
202
Working Gas
204
203
205
High -Frequency Generator
Pilot Arc Current
Plasma Arc Current

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP02/00893

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] F23G5/24, F23G5/16

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)
Int.Cl[7] F23G5/24, F23G5/16, F23G5/50, F23G5/027

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

Jitsuyo Shinan Koho	1926-1996	Toroku Jitsuyo Shinan Koho	1994-2002
Kokai Jitsuyo Shinan Koho	1971-2002	Jitsuyo Shinan Toroku Koho	1996-2002

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 5-106826 A (Nippon Steel Corp.), 27 April, 1993 (27.04.93), Full text; Fig. 1 (Family: none)	1,2 3,4,7-19
Y	JP 5-346218 A (NKK Corp.), 27 December, 1993 (27.12.93), Full text; Figs. 1, 3, 4 (Family: none)	3,9,10
Y	JP 11-182826 A (Research Institute of Innovative Technology for the Earth), 06 July, 1999 (06.07.99), Par. Nos. [0002] to [0005]; Figs. 1 to 3 (Family: none)	3,4

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 April, 2002 (19.04.02)	14 May, 2002 (14.05.02)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP02/00893

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 11-201431 A (Chiyoda Corp.), 30 July, 1999 (30.07.99), Par. Nos. [0014], [0016]; Fig. 1 (Family: none)	5,6
X	JP 9-96406 A (NKK Corp.), 08 April, 1997 (08.04.97), Par. Nos. [0006], [0007]; Fig. 1 (Family: none)	5,6
Y	JP 54-41573 A (Mitsubishi Heavy Industries, Ltd.), 02 April, 1979 (02.04.79), Full text; drawings (Family: none)	7-10
Y	JP 58-125785 A (SKF Steel Engineering AB), 26 July, 1983 (26.07.83), Page 5, lower left column, line 5 to page 6, upper right column, line 9; drawings & SE 8200228 A	7-10
Y	JP 10-300043 A (Shin Maywa Industries, Ltd.), 13 November, 1998 (13.11.98), Full text; Fig. 2 (Family: none)	11-19
Y	JP 2000-111015 A (Nippon Steel Corp.), 18 April, 2000 (18.04.00), Par. No. [0027] (Family: none)	19
X Y	JP 3-274309 A (Kutsukuson·Puraiburiko Kabushiki Kaisha), 05 December, 1991 (05.12.91), Full text; Fig. 1 (Family: none)	20,21 22,23
Y	JP 48-36265 B1 (Shiro SADO), 02 November, 1973 (02.11.73), Page 1, column 2, lines 28 to 32 (Family: none)	22,23

Form PCT/ISA/210 (continuation of second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP02/00893

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Claims 1 to 10 relate to the in-furnace control of a gasification melting furnace.
Claims 11 to 19 relate to the flue gas treatment of the gasification melting furnace.
Claims 20 to 23 relate to the incineration equipment of a combustion furnace having primary and secondary combustion furnaces.
Claims 24 to 27 relate to an electrode holder.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: 1-23

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (1)) (July 1998)