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54 **Method for the disposal of solid municipal waste by gasification and slagging and an apparatus for performing this method**

⑤7) A method for the disposal of solid municipal waste comprises a gasification and slagging phase, a combustion phase for the combustible gases produced, with hot burnt gases being obtained, and a heating phase, using, as heating fluid for the burnt gases, air to be used in the above phases in the required amounts and at the required temperature.

Furthermore, an apparatus (1) for performing the above method comprises a gasification and slagging reactor (2) in which the gasification and slagging phase occurs, a burner (18) for producing the hot burnt gases, and an exchanger (23), supplied with air by a suitable compressor (25), for heating the air to be used in the gasification and slagging and combustion phases.

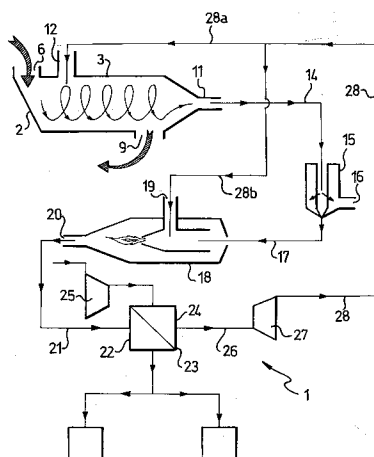


FIG. 3

The present invention relates in general to a method for the disposal of solid municipal waste by gasification and slagging.

It further relates to an apparatus for the disposal of solid municipal waste which performs the above method and can thereby extract energy in the form of heat or electricity, producing a harmless vitrified dross as slag.

What is meant by solid municipal waste is all the waste produced overall at a domestic level by average urban consumption and which comprises, for example, food scraps, cardboard or plastic boxes, rubber, fabric, glass, metal, etc..

At present, three methods are used for waste disposal, the most elementary being dumping which has enormous and obvious problems of an environmental nature with a loss of a possible source of energy.

A further method is represented by fermentative processes which are, however, harmful and difficult to control.

The third method concerns thermal processes which comprise two different procedures, combustion and gasification.

Combustion consists simply in burning the solid municipal waste to generate heat which can be used for various purposes. In addition, slag and ash are also produced which, if produced at low temperatures, are volatile since they are not incorporated in vitrified capsules which only form at high temperatures. It is thus necessary to operate at high temperatures in order to reduce the impact on the environment.

A further disadvantage of combustion is that it is necessary to operate with a considerable excess of air which involves the production of a large amount of fumes which are cooled to prevent their leading to the formation of toxic compounds.

With respect to the methods mentioned above, gasification has certain undisputed advantages. In fact, it is not necessary to operate with an excess of air, furthermore, the elimination of NO_x-type compounds is facilitated by suitable burners and, finally, the formation of other toxic compounds is greatly reduced.

At present, three methods are used for the gasification of solid municipal waste:

- gasification in a fixed bed which is only suitable for biomasses, requires extensive pretreatment of the latter, and cannot be used for large-scale installations;
- gasification with a circulating bed which requires preselection of the solid municipal waste and which allows a lean fuel to be obtained;
- gasification in a molten bath which has lower thermal efficiency than that of incineration.

Thus, in general, in order to increase the diffusion of apparatus which utilize gasification for disposing of solid municipal waste, thus responding to a global requirement of an environmental and energy nature, it is necessary to increase the flexibility of the installation and running of these apparatus, whilst simultaneously increasing their output of energy.

The technical problem on which the present invention is based is that of providing a method for the disposal of solid municipal waste which enables the above requirement to be satisfied whilst overcoming the disadvantages cited with reference to the prior art.

This object is achieved by a method of the specified type, characterized in that it comprises the following successive phases:

- gasification and slagging of solid municipal waste in a closed environment, with the injection of hot air, and obtaining combustible gas;
- combustion of at least part of the combustible gas using hot air as comburent, and obtaining burnt gases; and
- heating, by means of indirect heat exchange which uses at least some of the burnt gases as heating fluid, air at ambient temperature, at least in an amount sufficient to be used for the injection of hot air in the above gasification and slagging phase and as comburent in the combustion phase.

The present invention also relates to an apparatus for performing the above method, characterized in that it comprises:

- a gasification and slagging reactor, defined by an elongate container, comprising a charging portion for the solid municipal waste, a discharge portion for the slag, a manifold for the expulsion of the combustible gas and at least one principal injector for the tangential injection of air;
- a combustible gas burner having an inlet portion for the comburent air and an outlet portion for the burnt gases; and
- an indirect heat exchanger having a hot path, supplied with burnt gases by the burner, and a cold path, supplied with air from at least one compressor and connected, at the outlet, to the injector, for the tangential injection of air into the gasification and slagging reactor, and to the inlet portion for the comburent air from the burner, by means of a plurality of pipes.

The principal advantage of the method of disposing of solid municipal waste according to the invention and of the apparatus for performing this method consists in that the recovery of some of the heat produced during the combustion process increases the efficiency of the gasification process which can dispose of a wide range of waste, thus increasing operating efficiency.

Further characteristics and advantages of the method according to the invention and of the apparatus for performing it will become clearer from the detailed description of a preferred embodiment, given below by way of non-limiting example and with reference to the following figures, in which:

- Figure 1 shows a diagram for the performance of the method for the disposal of solid municipal waste according to the invention;
- Figure 2 shows a diagram for the performance of the method of Figure 1 with a variant;
- Figure 3 shows schematically an apparatus for performing the method of Figure 1; and
- Figure 4 shows a perspective view partially in section of the gasification and slagging reactor of Figure 3.

On average, solid municipal waste contains, as weight percentages:

. water	25%
. incombustible components	25%
. organic components	50%.

In order to perform the method according to the invention, it is suitable to reduce the weight percentage of the incombustible components to at least 15% and preferably to approximately 10%.

This can be achieved by pretreatment and also by selected collection of the solid municipal waste. The latter practice is, above all, already very widespread in more industrialized countries where the problem of waste disposal is more apparent.

At this point, the range of solid municipal waste is subjected to the gasification and slagging phase which occurs in a closed atmosphere into which the waste is introduced by a non-return mechanism.

Inside this closed atmosphere, where there is a high temperature, the waste is made to move in a turbulent rotating motion by means of the injection of hot air tangential to the incoming flow of waste, at a temperature of at least 350 °C. In order to ensure that the necessary chemical reactions occur in optimum manner, this temperature is advantageously between 500 °C and 650 °C.

The injection of air provides the necessary oxygen for the chemical processes of gasification and combustion of the solid municipal waste, which are triggered by the high temperature.

In order to render these processes more efficient, it is advantageously possible to inject steam into the closed atmosphere.

By virtue of these processes, the carbon present in the solid municipal waste is subjected to a chemical reaction at the end of which the following components are obtained, by way of indication:

. CO	55.4%
. CO ₂	36.0%
. CH ₄	8.3%
. other	0.3%

in gas form whilst approximately 25% of the total carbon is lost in the ashes.

The conditions of turbulent motion are ideal for facilitating the transmission of heat and transferring mass in the flow of waste in the process of transformation whilst the rotation of this flow favours the deposition of the ashes and of all the unburnt components by virtue of the centrifugal force acting on the heavier particles.

By virtue of the high temperature, the ashes and the unburnt components are mainly in the molten state which favours the expulsion of the slag, composed in this way, from the closed atmosphere. Furthermore, as it cools, the expelled slag is vitrified and transformed into dross which is inactive from the biological point of view having a low environmental impact such that it can advantageously be used as filler material in construction.

The combustible gas obtained in the gasification phase is at a temperature of at least 600 °C. Advantageously, in order to ensure the elimination of the most dangerous harmful incombustible agents, this temperature is in the range of between 900 °C and 1100 °C.

In the gasification and slagging phase, it is possible to obtain a content of solid particles of less than 3000 mg/Nm³, in which Nm³ means a cubic metre of normalized gas, or brought to reference conditions which are ambient temperature (20 °C) and atmospheric pressure.

The solid particles further have an average diameter of less than 40 µm.

5 According to a preferred variant of the method according to the invention, the combustible gas is subjected to a purification phase in order to reduce the content of solid particles to below 400 mg/Nm³, with an average diameter of less than 7 µm.

Following the purification phase, the method comprises a phase for the combustion of at least some of the combustible gas using a flow of hot air, at a temperature of at least 350 °C, as comburent.
10 Advantageously, in order to optimize the efficiency of the combustion process, this temperature is in the range of between 500 °C and 650 °C.

Preferably, the ratio of excess air with which the combustion process is performed is less than 1.25 so as to keep the formation of NO_x under strict control.

The flame temperature at which combustion occurs is more than approximately 1400 °C, which value
15 guarantees the evaporation of the remaining solid particles.

The temperature of the burnt gases obtained during the combustion phase is at least 900 °C, preferably in the range of between 1500 °C and 1800 °, in order to be used in a subsequent heating phase.

This consists in heating, by means of an indirect heat-exchanger using at least some of the burnt gases as heating fluid, air, taken at ambient temperature from the atmosphere, in an amount sufficient to be used
20 for the tangential injection of hot air in the above-mentioned gasification and slagging phase, and as comburent in the combustion phase.

The air heated in this way is then injected during the gasification and slagging phase in order to supply oxygen to the solid municipal waste in the process of transformation, and is further used in the combustion phase as comburent for the combustible gas.

25 Between the heating phase and the phase in which it is used, this air is not subjected to any further processes for increasing its temperature, this increase being imparted to the air entirely during the heating phase.

In order to be subjected to the heating phase, the air must be compressed to high pressure values which increases the amount of energy in this air, which is further increased during the heating phase.

30 Some of this energy content can advantageously be recovered by means, for example, of a turbine to which the air can be conveyed before being used in the above phases.

Downstream of the heating phase, the burnt gases used as heating fluid still have a considerable enthalpic content which can advantageously be used.

Depending on the need and on the amount of these burnt gases used in the heating phase, they can be
35 used to produce hot water intended for public or industrial use (Figure 1) or they can be used as thermal carrier fluid for producing a steam cycle for the production of electrical or mechanical energy (Figure 2).

It is possible for the amount of burnt gases produced during the combustion phase to be greater than required in the following phase, and some of the burnt gases can thus be used for the above-mentioned purposes immediately downstream of the combustion phase.

40 A further variant consists in producing energy, for example, as a result of the burnt gases obtained during the combustion phase passing through a gas turbine before the heating phase, nevertheless, such that the energy content of the gases is sufficient to heat the air, during the heating phase, to the necessary extent and in the necessary amount for the above phases.

In addition to the above-mentioned advantage, the method described above permits gasification to be
45 performed at a high temperature, the formation of toxic carbides and tars being avoided.

In particular, the thermochemical conditions imposed prevent the formation of dioxin.

Furthermore, the vitrification of the slag produced prevents the dispersion of poisonous heavy metals, which remain incorporated in the dross, and permits a reduction in the residual volumes which can then be stocked without particular precautions.

50 Finally, with the above method, it is easy to control NO_x and SO₂.

With reference to Figures 3 and 4, a preferred embodiment of an apparatus for the disposal of solid municipal waste according to the invention and performing the above method will now be described.

In the drawings, an apparatus of the type specified is designated 1 and comprises a gasification and slagging reactor 2, defined by an elongate container 3, which is substantially symmetrical relative to an axis
55 A and is disposed horizontally, and which has inner walls 4 advantageously covered with heat-proof materials.

At one end 5, the reactor 2 comprises a charging portion 6 for the solid municipal waste which has a screw feeder 7 constituting a non-return mechanism and, at the other end 8, a discharge portion 9 for the

slag which also has a screw extractor 10.

The reactor 2 further comprises a manifold 11 for expelling the combustible gas in correspondence with the end 8, at least one principal injector 12, for the tangential injection of air inside the container 3, and at least one secondary injector 13 for injecting steam.

5 The manifold 11 of the reactor 2 is hydraulically connected, by means of a first pipe 14, to a filtering structure 15, for example of the type with an axial vortex device, the function of which is to reduce the content of solid particles of the combustible gas without introducing great charging losses and without decreasing their temperature substantially.

10 This filtering structure 15 has an expulsion portion 16 for the combustible gas which is rich in solid particles and can thus advantageously be re-introduced during the gasification process.

The filtering structure 15 is connected, by a second pipe 17, to a burner 18 which has an inlet portion 19 for the comburent air and an outlet portion 20 for the burnt gases.

15 The burner 18 is of the type comprising heat-proof materials such as, for example, silicon carbide ceramics, and its interior does not have elbowed angles or passages with too small a diameter so as to prevent the condensation of solid particles resulting in clogging of the passages.

The latter is further covered externally with insulating material in order to restrict its surface temperature to less than 80 °C, for safety reasons.

The outlet portion 20 of the burner 18 is hydraulically connected, by means of a third pipe 21, to a hot path 22 of an indirect heat exchanger 23.

20 This heat exchanger 23, of the type resistant to chemical attack from hydrochloric acid in particular, also has a cold path 24 supplied in batches with a suitable amount of air to be heated by a compressor 25.

By means of a fourth pipe 26, this cold path 24 in turn supplies a turbine 27 in order to utilize the excess enthalpy of the amount of air for producing electrical energy.

25 A fifth pipe 28 emerges from the turbine 27 and is divided into two branches 28a and 28b which supply hot air respectively to the principal injector 12 of the reactor 2 and to the portion 19 for the intake of comburent air of the burner 18.

The operation of the apparatus 1 for the disposal of solid municipal waste provides for the introduction of the pretreated or selected waste into the reactor 2, through the screw-type feeder 7.

30 The gasification and slagging phase for the solid municipal waste occurs inside the reactor 2. By virtue of the high temperature of approximately 1100 °C, this waste is subjected to the chemical processes of gasification and combustion from which the combustible gas is obtained.

The tangential injection of air causes a turbulent rotary motion of the waste about the axis A whilst the molten ashes and the incombustible components are deposited on the inner walls 4 from which they percolate towards the slag discharge portion 9.

35 The injection of steam through the secondary injector 13 assists these chemical processes.

The combustible gases produced are collected by the expulsion manifold 11 and, through the first pipe 14, pass to the filtering structure 15 where the purification process for the combustible gases occurs, with the reduction of the content of solid particles to a value which is at least less than 300 mg/Nm³, with an average particle diameter of less than 7 µm.

40 Subsequently, the combustible gases are conveyed to the burner 18 where the combustion phase occurs and hot burnt gases are obtained.

In the exchanger 23 the burnt gases are used for heating air to be introduced into the reactor 2 and the burner 18.

45 The burnt gases discharged from the hot path 22 of the exchanger 23 can then be used, for example, for producing hot water intended for public and/or industrial use or as heat-carrying fluid for a steam cycle for the production of electrical or mechanical energy.

If the production of burnt gases in the burner 18 exceeds the requirement of the exchanger, it is nevertheless always possible to divert some of the burnt gases immediately downstream of the burner 18 and use them for one of the above-mentioned purposes.

50 A further, variant possibility consists in interposing, between the burner and the exchanger, a gas turbine for generating energy from the burnt gases at high temperature before they are introduced into the hot path 22 of the exchanger 23.

55 However, in this case, establishing a pressure difference between the gasification and slagging reactor 2 and the exchanger 23, which are also connected by the pipes 26, 28, 28a, it is necessary to provide for the pressurization of the reactor 2.

Likewise, in the burner 18, it is possible to use only some of the combustible gas obtained in the reactor 2 whilst the remainder can be used for different purposes.

The apparatus 1 according to the invention has the advantage of being able to use different compositions and quantities of solid municipal waste.

Furthermore, the dimensions of the various components can be selected opportunely as a function of the amount of waste to be disposed of.

5 Finally, the apparatus 1 can easily be modified and can then be connected to a vast range of subsequent uses.

In particular, the reactor 2 has the advantage that it can be triggered by carbon powder for the performance of the gasification and slagging phase.

10 The entire apparatus 1 is thus of simple design, does not occupy a large site, and can be rapidly and economically constructed.

In order to satisfy particular and contingent requirements, a person skilled in the art can apply numerous variants to the method for the disposal of solid municipal waste by gasification and slagging and to the apparatus for its implementation, all of which, moreover, are covered by the protective scope of the invention as defined in the following claims.

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Claims

1. A method for the disposal of solid municipal waste by gasification and slagging, characterized in that it comprises the following successive phases:
 - 20 - gasification and slagging of the solid municipal waste in a closed environment, with the injection of hot air, and obtaining combustible gas;
 - combustion of at least part of the combustible gas using hot air as comburent, and obtaining burnt gases; and
 - 25 - heating, by means of indirect heat exchange which uses at least some of the burnt gases as heating fluid, air at ambient temperature, at least in an amount sufficient to be used for the injection of hot air in the above gasification and slagging phase, and as comburent in the combustion phase.
2. A method according to Claim 1, characterized in that the solid municipal waste is made to move with a turbulent rotary motion by the injection of hot air, tangential to the incoming flow of solid municipal waste.
3. A method according to Claim 1, characterized in that the hot air, used for injection during the gasification and slagging phase and as comburent in the combustion phase, is at a temperature of at least 350 °C.
- 35 4. A method according to Claim 3, characterized in that the temperature of the hot air is in the range of between 500 °C and 650 °C.
- 40 5. A method according to Claim 1, characterized in that the combustible gases obtained during the gasification and slagging phase are at a temperature of at least 600 °C.
6. A method according to Claim 5, characterized in that the temperature of the combustible gases is in the range of between 900 °C and 1100 °C.
- 45 7. A method according to Claim 1, characterized in that the ratio of excess air is less than 1.25 during the combustion phase.
8. A method according to Claim 1, characterized in that the combustible gas, obtained during the gasification and slagging phase, contains less than 3000 mg/Nm³ of solid particles.
- 50 9. A method according to Claim 1, characterized in that the solid particles, present in the combustible gas obtained during the gasification and slagging phase, have an average diameter of less than 40 μm.
- 55 10. A method according to Claim 1, characterized in that it comprises a phase of purification, following the gasification phase, with a combustible gas containing less than 400 mg/Nm³ of solid particles being obtained.

11. A method according to Claim 10, characterized in that the solid particles present in the combustible gas obtained during the purification phase have an average diameter of less than 7 μm .
- 5 12. A method according to Claim 1, characterized in that the burnt gases, obtained during the combustion phase, are at a temperature of at least 900 °C.
13. A method according to Claim 12, characterized in that the temperature of the burnt gases is in the range of between 1500 °C and 1800 °C.
- 10 14. A method according to Claim 1, characterized in that the burnt gases, downstream of the combustion and/or heating phase, are used for the production of hot water intended for public and/or industrial use.
- 15 15. A method according to Claim 1, characterized in that the burnt gases, downstream of the combustion and/or heating phase, are used as heat-carrying fluid in a steam cycle for the production of electrical or mechanical energy.
16. A method according to Claim 1, characterized in that the solid municipal waste to be disposed of has a content of incombustible components of less than 15% of the total weight.
- 20 17. A method according to Claim 1, characterized in that the air heated in the heating phase is conveyed to a turbine before being used in the above phases.
18. A method according to Claim 1, characterized in that slag consisting of molten ashes is produced during the gasification and slagging phase.
- 25 19. A method according to Claim 1, characterized in that the gasification and slagging phase comprises the injection of steam.
- 30 20. An apparatus (1) for the disposal of solid municipal waste by gasification and slagging for performing the method according to at least one of the preceding claims, characterized in that it comprises:
 - a gasification and slagging reactor (2), defined by an elongate container (3), comprising a charging portion (6) for the solid municipal waste, a discharge portion (9) for the slag, a manifold (1) for the expulsion of the combustible gas, and at least one principal injector (12) for the tangential injection of air;
 - 35 - a combustible gas burner (18) having an inlet portion (19) for the comburent air and an outlet portion (20) for the burnt gases; and
 - an indirect heat exchanger (23) having a hot path (22), supplied with burnt gases from the burner (18), and a cold path (24), supplied with air from at least one compressor (25) and connected, at the outlet, to the injector (12), for the tangential injection of air into the gasification and slagging reactor (2), and to the portion (19) for the intake of comburent air of the burner (18), by means of a plurality of pipes (26, 28, 28a, 28b).
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- 45 21. An apparatus (1) according to Claim 20, characterized in that it comprises a filtering structure (15) for the combustible gas between the expulsion manifold (11) of the gasification and slagging reactor (2) and the burner (18).
22. An apparatus (1) according to Claim 20, characterized in that it comprises a turbine (27) disposed along the plurality of pipes (26, 28, 28a, 28b).
- 50 23. An apparatus (1) according to Claim 20, characterized in that the burnt gases discharged from the outlet portion (20) of the burner (18) and/or from the hot path (22) of the exchanger (23) are used for producing hot water intended for public and/or industrial use.
- 55 24. An apparatus (1) according to Claim 20, characterized in that the burnt gases discharged from the outlet portion (20) of the burner (18) and/or from the hot path (22) of the exchanger (23) are used as heat-carrying fluid in a steam cycle for producing electrical or mechanical energy.

25. An apparatus (1) according to Claim 20, characterized in that the gasification and slagging reactor (2) comprises at least one secondary injector (13) for injecting steam.

5 26. A gasification and slagging reactor (2), characterized in that it is defined by an elongate container (3), substantially symmetrical relative to an axis (A) and disposed horizontally, the gasification and slagging reactor (2) comprising a charging portion (6) for the solid municipal waste, a discharge portion (9) for the slag, an expulsion manifold (11) for the combustible gas and at least one principal injector (12) for the tangential injection of air.

10 27. A reactor (2) according to Claim 26, characterized in that it comprises at least one secondary injector (13) for injecting steam.

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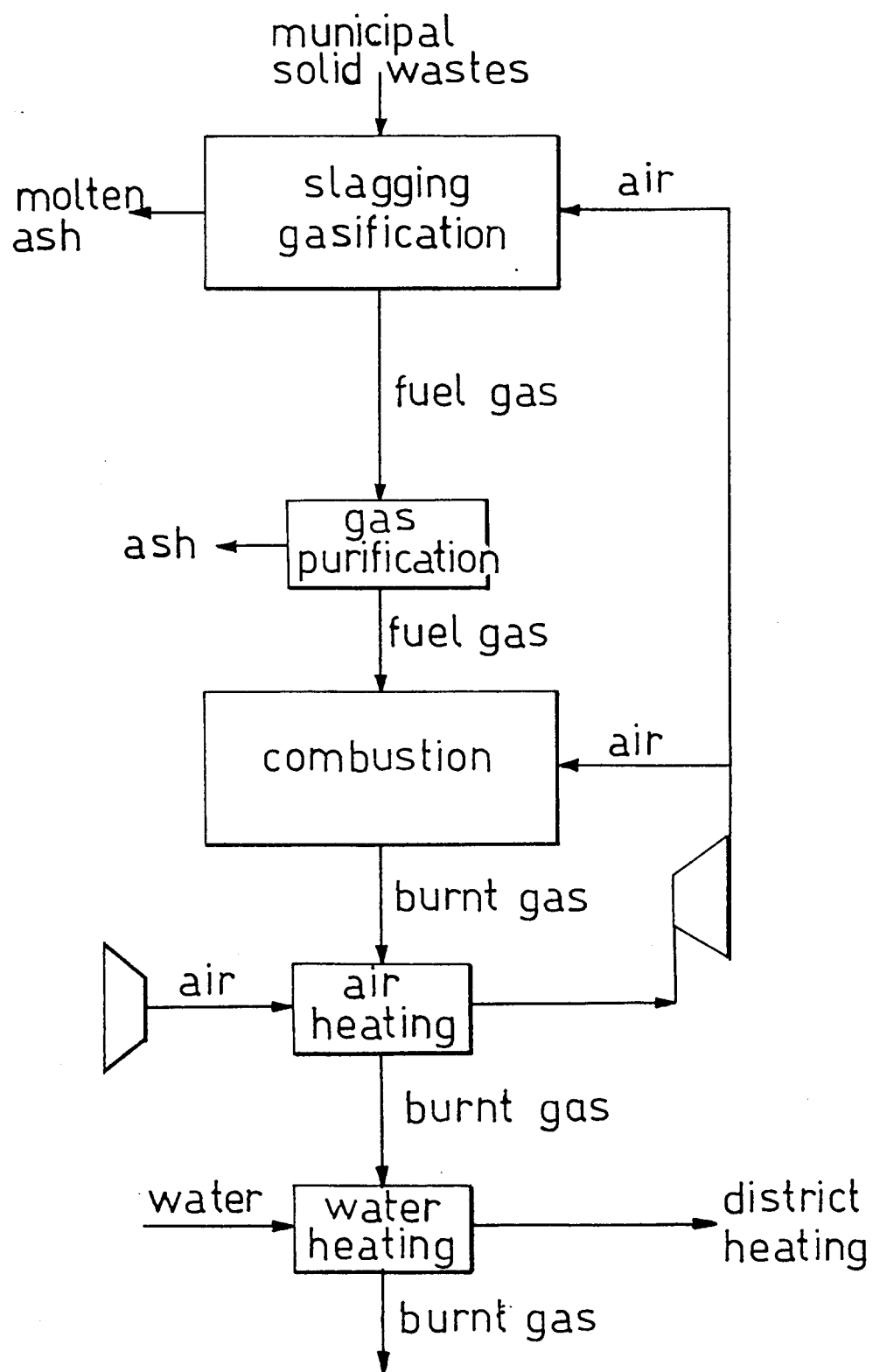


FIG.1

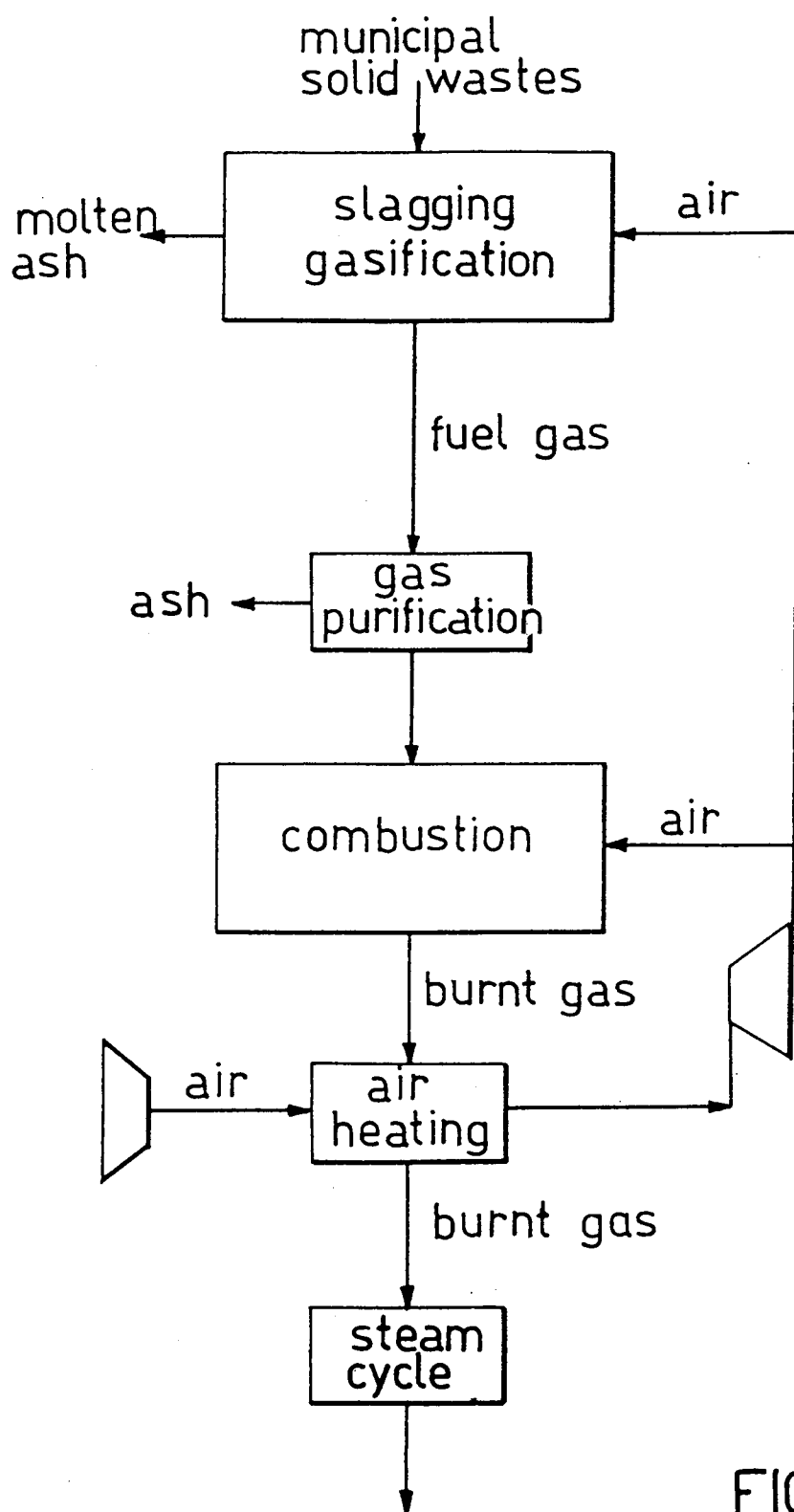


FIG.2

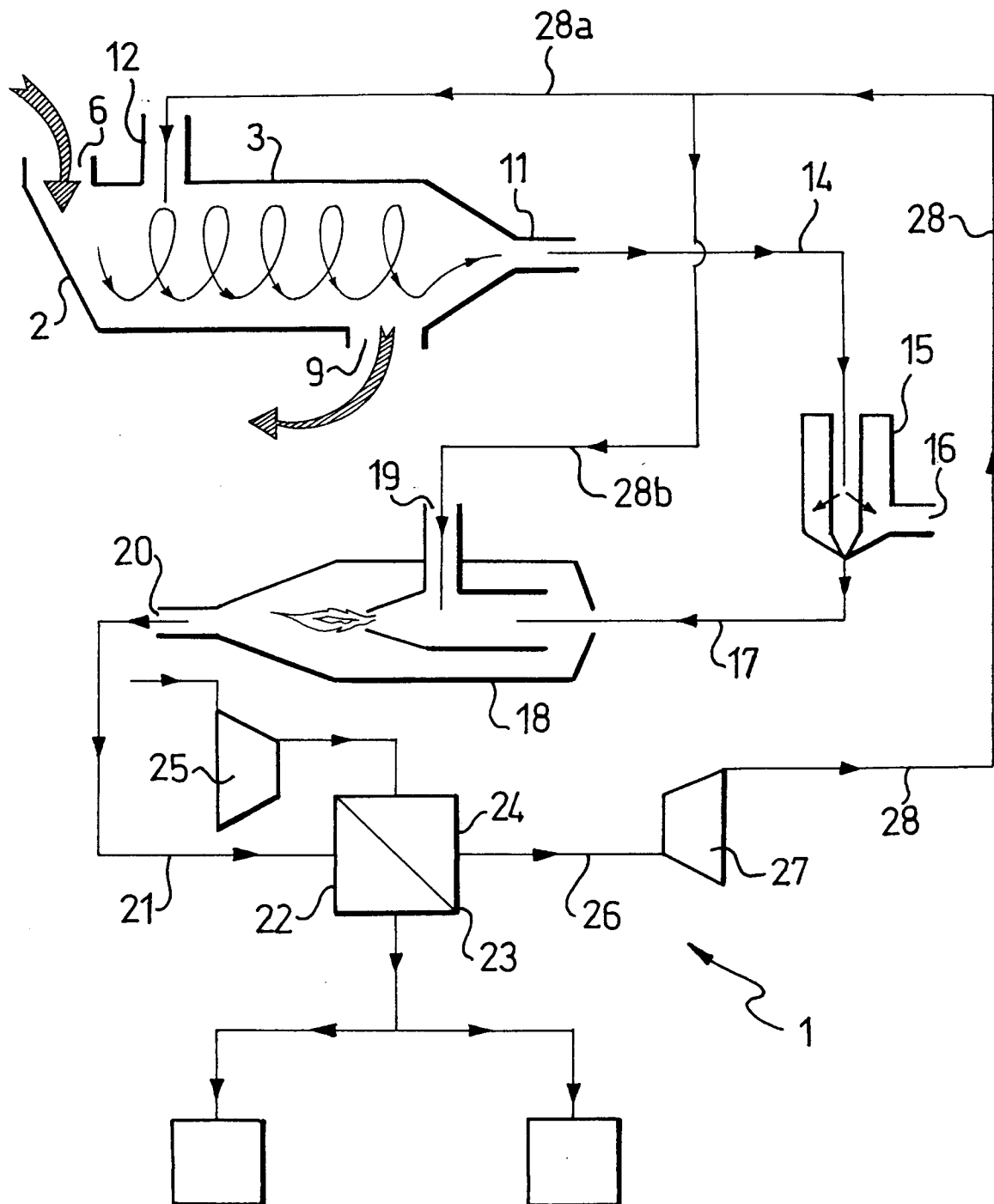


FIG. 3

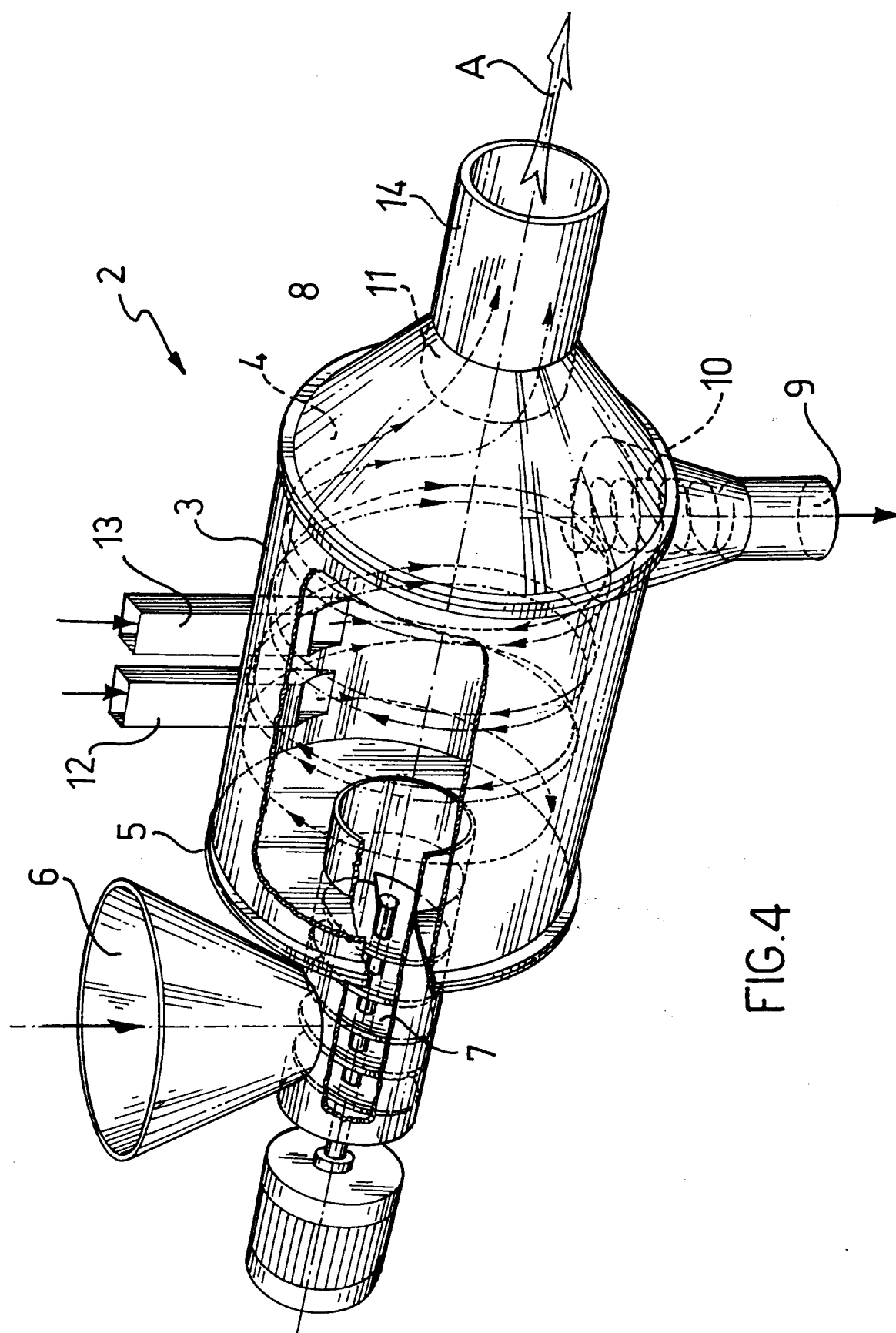


FIG. 4



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EUROPEAN SEARCH REPORT

Application Number
EP 94 83 0294

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	US-A-4 346 317 (FERNANDES) * column 2, line 14 - column 2, line 49 * * column 3, line 9 - column 3, line 16 * * column 3, line 55 - column 4, line 9 * * figure * ---	1-3,12, 15,18, 20,24	F23G5/027 F23G5/46 C10J3/46 C10J3/48
Y	PATENT ABSTRACTS OF JAPAN vol. 7, no. 211 (M-243) 17 September 1983 & JP-A-58 106 317 (NIPPON FURNACE KOGYO KK) 24 June 1983 * abstract *	1-3,12, 15,18, 20,24	
A	EP-A-0 553 019 (INSTITUT FRANCAIS DU PETROLE) * column 3, line 40 - column 4, line 2 * * column 4, line 42 - column 4, line 57 * * column 5, line 18 - column 5, line 28 * * figure 2 *	1,3,18, 20	
A	DE-A-42 00 341 (KLÖCKNER-HUMBOLDT-DEUTZ AG) * column 3, line 25 - column 4, line 9; figures 1,2 *	1,20	TECHNICAL FIELDS SEARCHED (Int.Cl.6) F23G C10J
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 72 (C-570) 17 February 1989 & JP-A-63 264 696 (HITACHI LTD) 1 November 1988 * abstract *	1,10,18	
A	GB-A-2 106 130 (FOSTER WHEELER POWER PRODUCTS LTD) * page 1, line 68 - page 1, line 90; figure *	10,18,19	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 28 November 1994	Examiner Phoa, Y
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			