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(54) Continuous-type gasifier, in particular for biomasses and urban and industrial wastes

(57) A continuous-type gasifier (1) of the "down-draft" type is described, in particular for biomasses and urban and industrial wastes, comprising at least one reaction chamber (3) divided into at least one upper portion (3a) and at least one lower exhaustion portion (3b) by at least one mobile grid (21) for withdrawing charcoal and supporting a solid bed, such reaction chamber (3) having at least one first upper end equipped with at least one opening (5) for introducing substances to be gasified inside such chamber (3), such chamber (3) being internally equipped with at least one rotary stirring shaft (13), such shaft (13) being equipped with a plurality of openings (15) for delivering inside such chamber (3) at least one comburent fluid pre-heated at a temperature sufficient to guarantee triggering oxidation reactions.

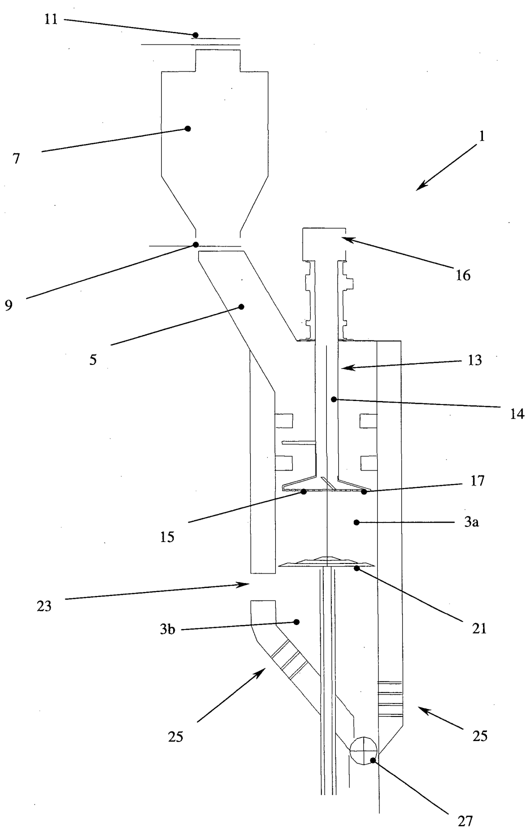

FIG. 1

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Description

[0001] The present invention refers to a continuous-type gasifier, in particular for biomasses and urban and industrial wastes.

[0002] As known, in general, gasifiers exploit a pyrolysis reaction through heating with reduced amounts of oxygen to convert the original solid fuel originario into a fuel gas (syngas) by means of partial combustion.

[0003] In particular, the gasification process always proceeds through three steps:

- pyrolysis, namely transforming, by thermal cracking, the solid material into gaseous products and carbon residuals;
- combustion of part of the pyrolysis products with an oxidising agent (air, oxygen);
- gasification of the carbon residual produced by pyrolysis at the expense of heat of the combustion products.

[0004] In the first step, there is a thermal demolition of the molecules of products to be treated, forming gaseous products with various molecular weights and carbon residuals. Combustion generates the necessary heat to perform the pyrolysis and to transform the pyrolysis products into light gases (CO, H_2, CH_4). In this step, there must also occur a thermal cracking of the gaseous pyrolysis products with high molecular weight, which, when using the gas, can give rise to condensation of liquids and tars.

[0005] In past years, many technologies have been developed for gasifying various solid fuels. For medium-small sized plants, the most commonly used technology is the moving-bed technology of the "down-draft" type. In this system, the solid is supplied from the top in the reactor in order to form a solid bed which slowly advances downwards.

[0006] The reactor, in its upper part, is airtight, in such a way as to force gases inserted or produced in the reactor itself to go out through the lower bed part, where instead openings are left. At a certain height, air or oxygen are inserted through nozzles placed on the periphery of the reactor. Inserted air implies the partial combustion of the pyrolysis gas in the neighbourhood of points for introducing air. The developed heat causes the pyrolysis of the material present immediately above the area for introducing air. Volatile pyrolysis products flow downwards, crossing the area where combustion occurs and taking part therein.

[0007] The pyrolysis gas combustion therefore brings about the formation of high amounts of CO_2 and H_2O. In the combustion area, the temperature can locally get to exceed 1200-1300°C.

[0008] Hot gases, in order to go out of the reactor, must therefore cross the lower bed part, composed of the carbon residual. Under such situation, the following endothermal gasification reactions occur for carbon:

$$C+CO_2={}_2CO \qquad (1)$$

$$C+H_2O=CO+H_2 \qquad (2)$$

[0009] Other reactions which bring about the formation of light hydrocarbons (natural gas, for example), both for kinetic and for thermodynamic reasons, have a more limited effect.

[0010] Carbon residuals, partly gasified, are withdrawn together with ashes through a grid placed at the reactor base. Through the same grid, also gases produced by the gasifier are withdrawn, which therefore go out at a temperature of at least 800°C.

[0011] The above described known reactor, however, still suffers from a series of limitations, such as the following:

- air is generally inserted from the reactor sides, in an area occupied by the bed of fuel material. Its penetration into the bed is therefore limited and consequently also the combustion area remains limited. A relatively cold area therefore can be created next to the gasifier axis, such area being able to be crossed by gases and tars produced by pyrolysis without subjecting them to cracking, thereby partly finding them in the final gas. The importance of such critical aspects highly increases when the plant sizes increase. Ofter the gasifiers, downstream of entering air, have a smaller section to make it easier to mix gas, but at the same time a smaller section favours the creation of solid bridges which block the downward flow of the bed;
- carbon residuals react according to above reactions (1) and (2) quickly reducing the gas temperature. In the lower bed areas, such temperature is often too low to allow the reactions (1) and (2) to occur quickly enough, taking to the complete exhausting of the residuals. In addition to this, always in the lower bed area, gas often reaches conditions which are near the thermodynamic balance, and anyway does not succeed in converting carbon into CO, apart from kinetic aspects.

[0012] Consequence of the previous considerations is that normally a relevant amount of carbon residual is withdrawn from the reactor together with ashes. This aspect, in addition to impairing the process efficiency, does not allow reaching the specific requests of EC legislations (Directive 200/76 CE) in terms of maximum content of carbon in ashes produced by the thermal treatment of wastes. Also under the most favourable working conditions, the amount of produced tar is on the order of 0.5-1 g/Nm^3 of gas.

[0013] Moreover, in case of materials producing a fragile and fine carbon residual like the one originated by pyrolysis of wastes or very subdivided biomasses (straw, cutting, etc.), a bed of very fine solid particles is formed at the gasifier base, which makes the flow of outgoing gases, in the gasification phase, very problematic.

[0014] The most relevant prior art documents for the present invention are NL-A-8 200 417 and CA-A1-2 432 202.

[0015] NL-A-8 200 417 provides for an upper stirrer from which air is entered and a lower grid supporting the solid. Below the grid ashes accumulate, and are then withdrawn from the opening 20 (figure 1). The exhausting section 9 is not crossed by any gas which can favour the actual exhausting. In the present invention, pre-heated air is entered, whose purpose is enabling the esothermal gasification reactions of the whole exhausting section.

[0016] In addition to this, pre-heated air is entered from the bottom in order to impair the bad packing.

[0017] In addition to this, in the present invention, between exhausting section and grid, an empty area from solid is always created, which can allow the possible movement of the bed in the exhausting area. In the present invention it is further specified that fluid entered by the stirrer is pre-heated, and the stirrer blades must be coated with a refractory material to allow using pre-heated air. Such features are not mentioned in NL-A-8 200 417.

[0018] Like in the previous case, in patent CA-A1-2 432 202, in the exhausting section (figure 1, 44) nothing is entered which can favour the charcoal exhaust. The described exhausting section therefore is nothing but the common gasifying area, always present in downdraft gasifiers. Between area 44 and upper area 38, the empty space which is provided in the present invention is instead not present. Nor CA-A1-2 432 202 mentions methods to make the combustion more stable, such as air pre-heating and following protection of blades with thermal insulation.

[0019] With respect to these prior documents, the present invention discloses the lower gasifier part, which must behave like a counter-current gasifier: it is therefore of the utmost importance that, in its lower part, air is entered: this allows the exhausting section to operate. The arrangement for which the gas outlet is below the grid but above the exhausting section (not inside it, like in NL-A-8 200 417) allows withdrawing gas without compelling it to cross the exhausted and very fine solid.

[0020] Therefore, object of the present invention is solving the above prior art problems by providing a continuous-type gasifier, in particular for biomasses and urban and industrial wastes, which is more efficient with respect to what is proposed by the prior art, allowing, in particular, a better exploitation of carbon residuals, substantially reducing their amount present in ashes.

[0021] Another object of the present invention is providing a continuous-type gasifier, in particular for biomasses and urban and industrial wastes, in which, also next to the axial area of the reaction chamber, an adequate temperature is kept for guaranteeing the cracking of gas and of tars produced by pyrolysis which cross such area.

[0022] Moreover, an object of the present invention is providing a continuous-type gasifier, in particular for biomasses and urban and industrial wastes, able to guarantee the complete exhaustion of the carbon residual due to esothermal combustion reactions, reaching, in the hottest bed areas, temperatures much greater than 1000 °C.

[0023] The above and other objects and advantages of the invention, as will appear from the following description, are obtained with a continuous-type gasifier, in particular for biomasses and urban and industrial wastes, as claimed in claim 1. Preferred embodiments and non-trivial variations of the present invention are the subject matter of the dependent claims.

[0024] It is intended that all enclosed claims are an integral part of the present description.

[0025] It will be immediately obvious that numerous variations and modifications (for example related to shape, sizes, arrangements and parts with equivalent functionality) could be made to what is described, without departing from the scope of the invention as appears from the enclosed claims.

[0026] The present invention will be better described by some preferred embodiments thereof, provided as a non-limiting example, with reference to the enclosed drawings, in which:

- Figure 1 shows a schematic, side sectional view of a preferred embodiment of the gasifier according to the present invention; and
- Figure 2 shows a schematic diagram illustrating the flows of material/energy in a plant equipped with a gasifier according to the present invention.

[0027] With reference to Figure 1, it is possible to note that a preferred embodiment of the continuous-type gasifier 1 of the "down-draft" type, in particular for biomasses and urban and industrial wastes, according to the present invention comprises at least one reaction chamber 3 divided into at least one upper portion 3a and at least one lower exhaustion portion 3b by at least one mobile grid 21 for withdrawing charcoal and supporting the solid bed, such reaction chamber 3 having at least one first upper end equipped with at least one opening 5 for introducing substances to be gasified inside such chamber 3, such chamber 3 being internally equipped with at least one rotary stirring shaft 13, having a substantially vertical rotation axis, such shaft 13 being equipped with a plurality of delivery openings 15 inside such chamber 3 for at least one comburent fluid like, for example, air or air enriched with technical oxygen, suitably pre-heated at such a temperature as to guarantee triggering oxidation reactions.

[0028] Preferably, such shaft 13 is equipped with at least one internal axial duct 14 communicating such openings 15 with at least one source means of such comburent fluid through, for example, at least one opening 16 for introducing such comburent fluid inside such duct 14. Preferably, the shaft 13 is equipped with internal thermal protecting means in such a way as not to disperse sensitive heat of the pre-heated fluid which passes therein. Still more preferably, the shaft 13 is equipped, at least at the bottom, with a stirring end 17 equipped with a plurality of such openings 15.

[0029] Preferably, the stirring ends 17 are externally equipped with at least one layer of refractory, thermally protecting material whose purpose is protecting the internal metallic parts from high temperatures generated due to oxidation reactions and the use of a strongly pre-heated comburent fluid.

[0030] The gasifier 1 according to the present invention further comprises at least one mobile grid 21 for withdrawing charcoal and supporting the solid bed, such grid 21 being arranged below the lower end of such shaft 13.

[0031] Advantageously, the mobile grid 21 and the shaft 13 can have wholly independent mutual movements: in particular, the movement of the grid 21 can be both alternate vertical and rotary, and, when it is rotary, preferably the grid 21 and the shaft 13 will have an opposite rotation direction.

[0032] The gasifier 1 according to the present invention further comprises at least one opening 23 for outputting the fuel gas produced inside the reaction chamber 3, such opening 23 being preferably arranged below such grid 21.

[0033] The lower exhaustion portion 3b is therefore arranged below the grid 21 and preferably has its perimeter walls equipped with means 25 for introducing at least one fluid for exhausting the charcoal (for example air) pre-heated at a temperature of at least 450-500 °C, so that, due to the combustion reactions, peak temperatures greater than 1200 °C are reached, following its combustion, such lower portion 3b being coated with at least one layer of a refractory material and having preferably a tapered shape towards a lower end equipped with means for withdrawing ashes 27.

[0034] Obviously, entering substances to be gasified inside the reaction chamber 3 can occur through suitable loading means known in the art, such as, for example, at least one hopper or, still more preferably, at least one loading chamber 7 connected to such opening 5 by interposing at least one first valve means 9 cooperating with at least one second valve means 11 placed as closure of at least one loading opening of such loading chamber 7, such valve means 9, 11 having an alternate opening/closing operation, in order to guarantee the necessary tightness to force gases entered or produced in the reaction chamber 3a to go out through the grid 21 openings.

[0035] Therefore, due to the features of the gasifier 1 according to the present invention as described above, it is possible to advantageously obtain the following technical results:

- the part of solid bed affected by pyrolysis and therefore softening of plastics possibly present therein is continuously moved by the shaft 13 to avoid forming bridges and agglomerates due to the plastic material being present;
- the comburent fluid is uniformly distributed inside the reaction chamber 3 through the openings 15 in order to make it useless to employ the restriction generally adopted in prior art down-draft gasifiers, and to make the hot combustion area wider. It must be noted that pre-heating of the comburent fluid is necessary to obtain a stable combustion, since the points for inserting the comburent are mobile and a continuous bed ignition is therefore required: moreover, the entered amount of comburent fluid, not having to wholly gasify the residual, is lower with respect to prior art systems with the same potentiality, and therefore also generated heat is lower: from this, a further pre-heating of the comburent fluid is needed. Finally, heating allows recovering energy;

- under the combustion area (which occurs mostly with pyrolysis gas) a bed of carbon residual is formed, which is only partly consumed by gasification reactions with CO_2 and H_2O and which is supported by the mobile grid 21 that, through its movement, drops the solid with a fixed flow-rate;
- carbon residual and ash falling through the grid 21 accumulate in the lower exhaustion portion (3b) below, where they are completely exhausted due to the insertion of exhausting fluid from below, such fluid being preferably pre-heated air at a temperature of at least 450-500°C: in this way, Directive 2000/76/CE is complied with, which strongly limits the presence of carbon residual in ashed.

[0036] As application example of the gasifier 1 according to the present invention, herein below some performances are given for a plant like the one in Figure 2, such plant comprising in line:

- at least one system 101 for crushing supplied wastes;
- at least one de-ironing device 103;
- at least one means 105 for storing the sterilised wastes;
- at least one supplying means 107 for wastes from such storage means 105 to the loading chamber 7 of the gasifier 1;
- at least one gasifier 1 according to the present invention;
- at least one means 109 for washing gas with an organic liquid phase for removing residual tars and one washing

means 110 with a basic acqueous solution for removing acid gases;

- at least one gas-meter 111;
- at least one motor 113 supplied by such fuel gas with exhausting means.

[0037] The above plant 100 has been supplied with wastes at 515 Kg/h (the gasifier 1 is therefore supplied with the de-ironed wastes equal to 500 kg/h) having the properties included in the following Table 1.

Table 1: elementary composition and PCI of wastes

Heat power (kcal/kg) as it is	4000
INERTS/metals	16.8%
Total humidity	10.4%
Elementary composition (dry ash free), percentage in weight	
C	57.6 %
H	7.4 %
OR	34.2 %
N	0.8 %

[0038] In this way, it is possible to obtain a fuel gas with a heat power lower at least by 1250 kcal/ Nm^3 (on humid gas).
[0039] The following Table 2 includes the major features of the various flows of material/energy in the sections of plant 100 designated with related letter-type references A to I:

Table 2

Currents	**A**	**B**	**C**	**D**	**E**	**F**
Composition						
H2O % vol	0	0	0	0	6.3	6.3
O2 % vol	21	90	21	0.21	0	0
N2 % vol	79	10	79	0.79	44	44
H2 % vol	0	0	0	0	20.5	20.5
CH4 % vol	0	0	0	0	0	0
CO % vol	0	0	0	0	23.3	23.3
CO2 % vol	0	0	0	0	5.5	5.5
Flow-rate kg/h	950	0	125	845	1400	1400
Temperature °C	25	25	500	500	880	620

[0040] The following Table 3 instead includes the major parameters linked to the energy balance of the plant 100:

Table 3

Balances at massification section		
Power given by direct waste combustion	2340	kW
Lost heat with hot ashes	25	kW
Dissipated heat for gas cooling down to 25°C	260	kW
Miscellaneous losses	55	kW
Thermal power from direct gas combustion	2000	kW

Claims

1. Continuous-type gasifier (1) of the "downdraft" type, in particular for biomasses and urban and industrial wastes, comprising at least one reaction chamber (3) divided into at least one upper portion (3a) and at least one lower exhaustion portion (3b) by at least one mobile grid (21) for withdrawing charcoal and supporting a solid bed, said reaction chamber (3) having at least one first upper end equipped with at least one opening (5) for introducing substances to be gasified inside said chamber (3), said chamber (3) being internally equipped with at least one rotary stirring shaft (13), said shaft (13) being equipped with a plurality of openings (15) for delivering inside said chamber (3) at least one comburent fluid pre-heated at a temperature sufficient to guarantee triggering oxidation reactions, **characterised in that** it comprises at least one opening (23) for outputting a fuel gas produced inside said reaction chamber (3), said opening (23) being arranged below said grid (21), and **in that** said lower exhaustion portion (3b) arranged below said grid (21) has perimeter walls equipped with means (25) for introducing a comburent fluid for exhausting said charcoal in order to reach, due to combustion reactions, peak temperatures greater than 1200 °C, said lower portion (3b) being coated with at least one layer of a refractory material and having a tapered shape towards a lower end equipped with means for withdrawing ashes (27).

2. Gasifier (1) according to the previous claim, **characterised in that** said comburent fluid is air or air enriched with technical oxygen.

3. Gasifier (1) according to claim 1, **characterised in that** said shaft (13) is equipped with at least one internal axial duct (14) communicating said openings (15) with at least one source means of said pre-heated comburent fluid through at least one opening (16) for introducing said comburent fluid inside said duct (14).

4. Gasifier (1) according to claim 1, **characterised in that** said shaft (13) is equipped at least on its bottom with a stirring end (17) equipped with a plurality of said openings (15), said stirring end (17) being externally equipped with at least one layer of refractory material for thermal protection.

5. Gasifier (1) according to claim 1, **characterised in that** said mobile grid (21) is arranged below a lower end of said shaft (13).

6. Gasifier (1) according to the previous claim, **characterised in that** said grid (21) and said shaft (13) have mutually independent movements.

7. Gasifier (1) according to the previous claim, **characterised in that** said movement of said grid (21) is alternate vertical or rotary.

8. Gasifier (1) according to the previous claim, **characterised in that** also said shaft (13) has a rotary movement but with a rotation direction opposite to the rotation direction of said grid (21).

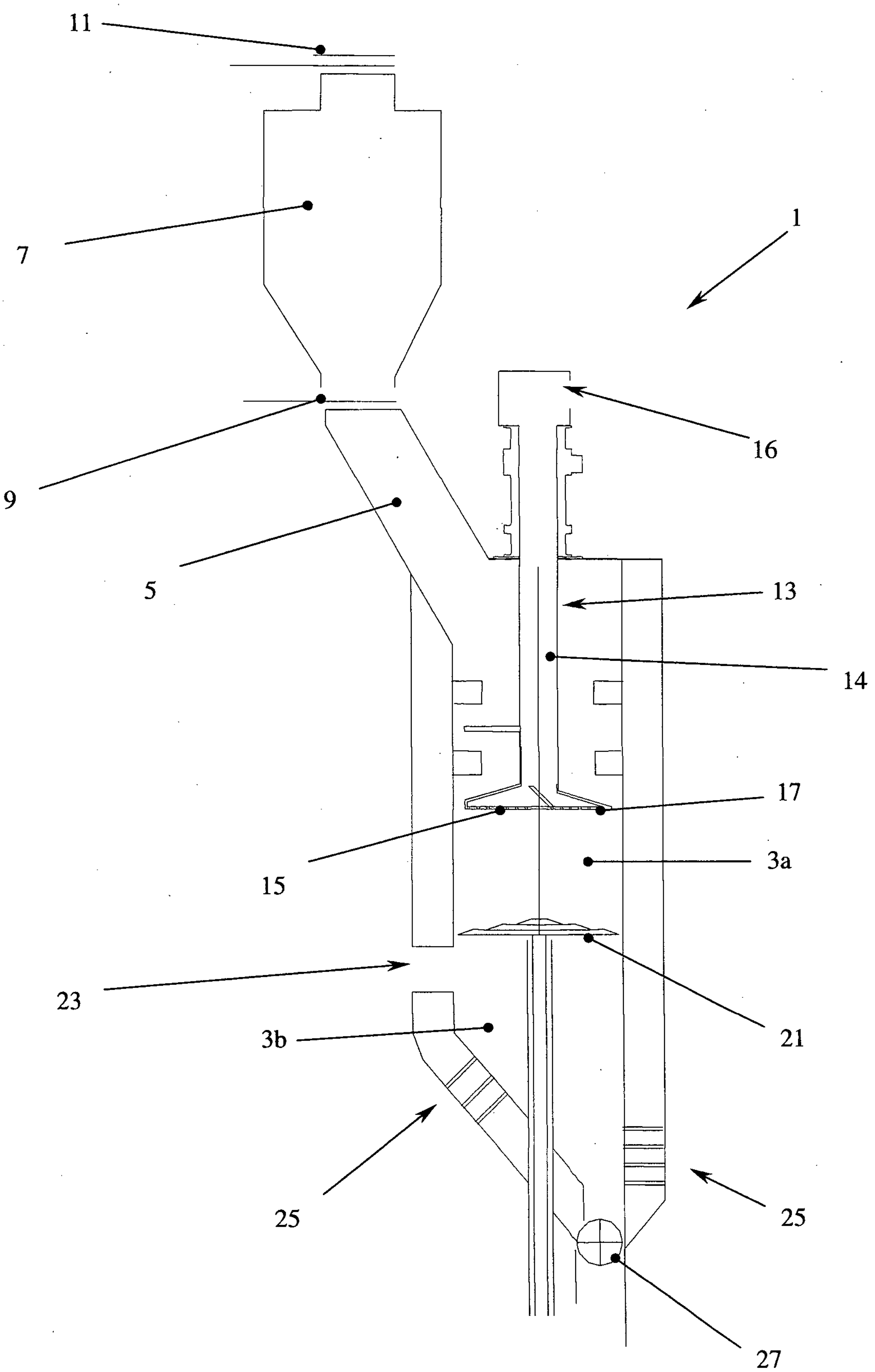

FIG. 1

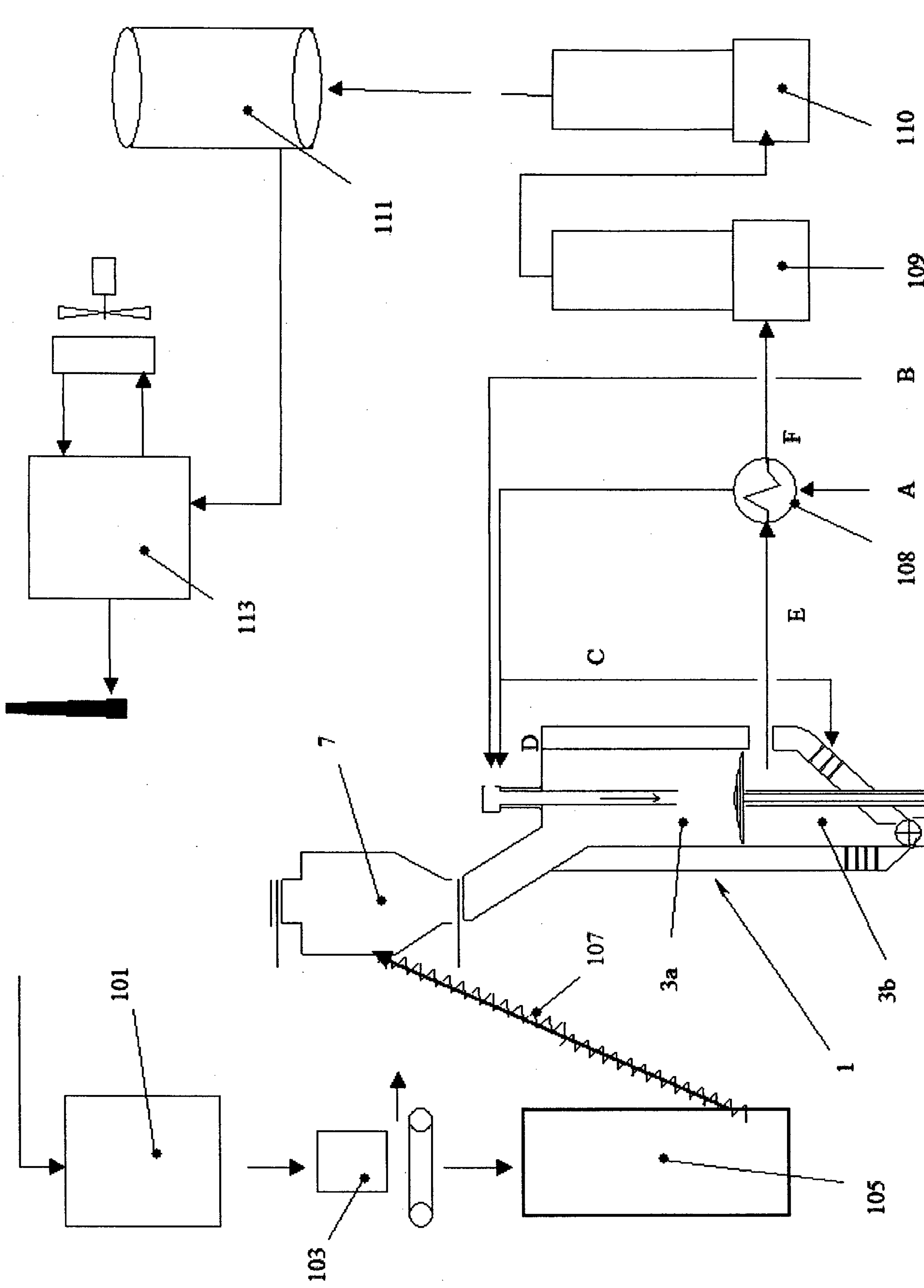

FIG. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 13 00 4693

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 4 583 992 A (ROGERS CHESTER D [US]) 22 April 1986 (1986-04-22) * column 2, line 35 - column 3, line 55; figure 1 * -----	1,3-8	INV. C10J3/26 C10J3/32 C10J3/42 F23B30/04 F23G5/26 F23G5/28 C10J3/24 C10J3/80
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A	EP 0 532 901 A1 (TOMADINI GINO & C [IT]) 24 March 1993 (1993-03-24) * the whole document * -----	1-8	

TECHNICAL FIELDS SEARCHED (IPC)

C10J
F23B
F23G

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	13 November 2013	Iyer-Baldew, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
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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

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 00 4693

13-11-2013

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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