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(54) REACTOR FOR OBTAINING GAS FROM BIOMASS OR ORGANIC RESIDUES AND METHOD FOR OBTAINING GAS IN SAID REACTOR

(57) The invention relates to a reactor for obtaining gas from biomass or organic residues and to a method for obtaining gas in said reactor in which the process is produced in a single rotatory horizontal reactor, wherein the stages occur in internal sections separated by helical spirals and, by analysing the synthesis gases by means of a gas chromatograph positioned at the output of the reactor, it is possible to vary the method parameters.

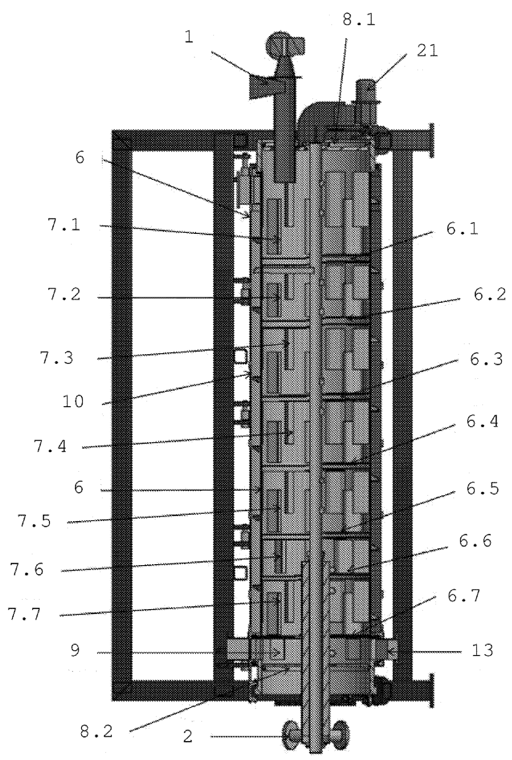

FIG. 3

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Description

Technical field of the Invention

[0001] The present invention relates to a reactor for obtaining a gas, which may be called "synthesis gas" or "syngas", through the gasification of biomass or other organic residues, where all stages of the process occur in inner sections separated by helical coils, and the method for obtaining said gas in the reactor, said process comprising the stages of drying, pyrolysis, partial oxidation of the biomass or organic residues and typical gasification reactions in the last thermal phase of the gasification reactor.

State of the Art

[0002] Gasification is a process of transformation, by means of partial oxidation at high temperature, of a raw material into a gas with a moderate heat and which can be used in a boiler, in a gas turbine or in an internal combustion engine. Its advantages are the following:

- Flexible supply: All raw materials containing carbon, such as hazardous waste, municipal solid waste, industrial waste, sewage sludge, biomass, etc. can be gasified;
- Low-cost power supply (potentially negative cost). It is the most appropriate technology for many industrial applications;
- Increased efficiency and lower environmental impact compared to combustion systems when producing low-cost electricity from solid materials;
- The gasification process can be adapted to incorporate advanced technologies for the concentration of carbon dioxide with reduced impact in respect of cost and thermal efficiency. This characteristic is one of the most important factors when selecting technology in future power plants;
- It is easier to eliminate emissions of sulphur and nitrogen oxides in gasification products. In general, the volume of fuel gas processed in a gasification plant for cleaning is a third of that which would correspond to a conventional power plant. This has implications in respect of cost reduction in pollution prevention equipment. Gasification plants can also be set up, if necessary, to achieve zero emissions;
- The ashes can be deposited in a landfill, with no added processing costs, used as building materials or be further processed to obtain value-added products, leading to a zero discharge plant, without producing solid waste.

[0003] Depending on the gasification processes used, the biomass is subjected to a high temperature process for obtaining a gas mainly composed of carbon monoxide (CO) carbon dioxide (CO_2), hydrogen (H_2) and methane (CH_4), Nitrogen (N_2) when air is used as a gasifying agent, and other substances. The objective of gasifying the biomass is to utilize the gases produced for use in the production of electric power in boilers, gas turbines or internal combustion engines. According to another application, the gasification process can be configured to produce fuels and/or recoverable chemicals for use as raw materials in other processes in the chemical industry.

[0004] Usually the process is performed with an oxygen supply defect, i.e below the stoichiometric value necessary for complete oxidation. This characteristic distinguishes gasification from other thermochemical processes such as combustion (full oxidation, usually with excess oxygen) and pyrolysis (thermal decomposition in the absence of oxygen).

[0005] Both CO and H_2 mostly as CH_4, and to a lesser extent C_2H_4, are responsible for conferring the syngas its heat output as they can react with oxygen.

[0006] The gasification of organic residues takes place in four stages:

1. Drying: the moisture evaporation phase of the moisture contained in the raw materials;
2. Pyrolysis: the thermal decomposition phase in the absence of oxygen. It occurs at about 300 to 500°C.
   The more volatile components are released therein. Due to the amount of oxygen in the reactor being insufficient, some of these volatile components may not be able to be removed, resulting in contaminant tars;
3. Combustion: partial oxidation of fixed carbon (char) that remains after pyrolysis. This occurs at an average temperature of 1200°C.
4. Gasification: reactions from which the desired amount of fuel gases produced is increased.

[0007] The process described is typically an endothermic process, therefore energy input is necessary in order for it to take place. Said energy supply can be conducted from either an external source or by oxidation of one part of the solid to be gasified.

[0008] In the latter case, in which both endothermic and exothermic reactions occur inside the reactor, it is important to control the solid/air ratio to ensure that the heat supplied by one is equal to that absorbed by the others. This process is called an autothermal process.

[0009] In a complete gasification process, basically the following reactions take place:

Oxidation (exothermic reactions)

[0010]

Complete: $C + O_2 \rightarrow CO_2$ (reaction 1)

Incomplete: $\rightarrow C + 1/2\ O_2\ CO$ (reaction 2)

Gasification

[0011]

$C + CO_2 \rightarrow 2CO$ (reaction 3)

$C + 2H_2 \rightarrow CH_4$ (reaction 4)

$C + H_2O \rightarrow CO + H_2$ (reaction 5)

Shift reaction (exothermic)

[0012]

$CO + H_2O \rightarrow CO + H_2$ (reaction 6)

Methanisation (exothermic)

[0013]

$CO + H_2O \rightarrow CH_4 + H_2O$ (reaction 6)

[0014] The "shift" reaction is an exothermic reaction of total oxidation of carbon monoxide to carbon dioxide.

[0015] In the presence of oxygen, the raw material undergoes oxidation (reaction 1).

[0016] As the oxygen fed into the reactor is insufficient for complete oxidation, the presence of CO (reaction 2) is favoured. Excess organic material reacts with the gases that are present (primarily CO_2 and H_2O, reactions 3 and 5). Reactions 5 and 6 are favoured by the presence of water vapour, which in turn favours the production of H_2. The formation of methane (reaction 7) is favoured by high pressures.

[0017] Therefore, during the gasification process, a large portion of the chemical energy contained in the solid concentrates as chemical energy contained in a gas. This gas can be used in a much more flexible way (as raw material for chemical processes or as fuel in boilers, internal combustion engines or gas turbines).

[0018] The residues of the gasification process are the ashes. Depending on the type of ash, these can be used as raw material for construction materials, fertilizers, manufacture of glass or as accessory loads, for example in the manufacture of plastics, including others. If it cannot be used, the resulting residue is minimal, therefore the costs of processing and/or transport will also be minimal.

[0019] Those materials with a high carbon content, like any type of coal, biomass and organic residues can be gasified.

[0020] Therefore, one aspect of the present invention is the optimization of the gasification process by a gasification reactor designed for that purpose.

Description of the Invention

Description of the Method

[0021] The invention herein relates to a method for obtaining gas from biomass or organic residues, which comprises the following stages:

1. Supply and Drying

- The biomass or organic residue is transported to the inside of the reactor.
- Temperatures between 25°C and 250°C.
- The dehydration process occurs.
- The water vapour obtained will be used in later phases.

2. Pyrolysis:
There are four sub-steps:

2.1 Deoxygenation and desulfurization:

- Temperatures between 250°C and 340°C.
- Unwanted acid gases such as HCl and H_2S are produced.
- The acid gases are extracted so they are not mixed in subsequent phases and cause undesirable imbalances.

2.2 Polymer degradation 1.

- Temperatures between 340°C and 400°C.
- Gases such as methane and light aliphatic hydrocarbons are produced.

2.3 Pyrolysis:

- Temperatures between 400°C and 500°C.
- Volatile compounds and gases are produced.

2.4 Polymer degradation 2:

- Temperatures between 500°C and 600°C.
- Gases such as CO_2, H_2 and CO are produced.
- Facilitates better control of the subsequent oxidation phase.

3. Partial Oxidation:

- Oxidation reactions (exothermic) occur mainly in the solid organic matter (char) that has reached this stage after thermal degradation in the earlier stages with an oxidizing agent, preferably O_2, where a peak temperature of 1,200°C is reached.
- The oxidizing agent is introduced directly into this zone of the reactor where the partial oxidation takes place in a proportion less than the stoichiometric amount required for the total oxidation.
- The high temperature ensures the thermal cracking of the volatile components, which would give rise to condensable hydrocarbons (tars), which reduces the amount of condensates in the gas, facilitating the subsequent gas conditioning process and ensuring the use of gas as fuel in combustion engines.

4. Gasification

- Temperature of 850°C.
- Heterogeneous reactions (solid-gas) are produced between the carbon that has not transformed (char) and gases such as CO_2, H_2 or H_2O (water vapour) wherein H_2, CO and CH_4 is generated.
- Water vapour is introduced from step 1, which increases the heating value of the gas produced as the concentration of H_2 is increased.

[0022] The process also comprises the control of various parameters, in particular:

- Mass flow of supply of organic matter;
- Mass flow of supply of oxidizing agent to the gasification reactor, which is preheated by means of a heat exchanger

of the gas produced;

- Mass flow rate of water vapour supplied during the gasification stage;
- Temperatures in each thermal zone of the reactor;
- Analysis of the gases obtained from the gasification process; according to the gas obtained the flow or the proportion of the supplies of oxidizing agent and combustion and water vapour to the reactor. Based on these values, the supply of organic matter and the rotation speed of the reactor may vary.

[0023] The process described here allows for greater efficiency in reducing pollutants, such as dioxins and furans, relative to other gasification processes.

Description of the reactor

[0024] The reactor according to the invention herein has internal sections separated by helical spirals positioned in the inner cylindrical surface of the cylinder which define a supply and drying section, a number of pyrolysis sections, a partial oxidation section and a gasification section.

[0025] The gasification reactor comprises a cylinder arranged in a horizontal position, which has a number of pathways for perimeter rolling at the ends thereof which are supported on a number of rollers fixed to the support structure of the reactor assembly. The rollers are part of a drive system consisting of two synchronized drive motors having variable speed which facilitates controlled angular movement in both directions, being able to form a speed-controlled rotary movement. This movement facilitates homogenization of the process and helps the product feed through to each of the areas. Perimeter roller pathways are suitably dimensioned to absorb the different expansions along the reactor.

[0026] It has an assembly of angled blades having a special profile inside, which act as buckets in both directions of rotation and which are connected to the inner body. The blades are arranged on the inner perimeter of the reactor at different positions and angles to facilitate transport of the solid material and mixing and homogenization, thereby improving thermochemical processes.

[0027] Additionally, it has a number of helical spirals joined to the inner body located such that the product moves forward and separates the internal sections of the reactor in thermal zones wherein the different thermochemical processes are produced. The spirals have a certain configuration in respect of sizing and in the length of the pitch in order to adjust the retention times of the matter in each zone.

[0028] The gasification reactor has a number of fixed heads at its ends wherein the ducts are placed which enable the organic matter, the oxidizing agent and the gasifying agent to be supplied.

[0029] A fixed pipe centred along the axial axis and fixed on the fixed heads of the ends are arranged inside the reactor. The different temperature probes for each section are placed in said pipe and ducts are places inside in order to vent unwanted gases from the desulfurization zone and deoxygenation to the outside during the pyrolysis stage.

[0030] In the initial section for drying the waste, the water vapour generated is extracted and transported by means of a pipe along the outside of the reactor to the gasification section, where it is added, favouring the production of H_2.

[0031] Oxidizing agent is injected into a specific heat zone in the partial oxidation section, this injection system being composed of different ducts that transport the oxidant and which are adjustable for controlling both the position and the angles of incidence of the flows of injection of the oxidizing agent in respect of the axial axis of the reactor.

[0032] At the end of the outlet, the contour of the reactor has a set of window-like perforations. A gas exhaust hood is placed over the set of windows for guiding them and a hopper is placed on the bottom and for collecting the ashes.

[0033] In the outer cylindrical surface of the reactor, a duct is placed in the form of a spiral that runs from one end to the other, forming a continuous helicoid along which the backflow of gases produced in the reactor circulates to promote the exchange of heat, help maintain the thermal balance and achieve a high thermochemical efficiency of the different processes.

[0034] A fixed cylinder or liner is arranged outside the cylindrical body, which acts as a raceway for the gases, together with the coil located outside the cylindrical body of the reactor. Said outer liner of the gasification reactor is divided into two parts, upper and lower, to facilitate assembly and maintenance.

[0035] Because the temperatures along the cylinder of the reactor and liner vary, so does the expansion of both elements and to this end, provided at the far end, where temperatures are equal, is a system of rollers that fix the position of the reactor and the liner, in the area containing common outlets, therefore both expansions are in the longitudinal direction towards the beginning of the reactor. Closing elements have been arranged at that point, which guarantee NO gas leaks and allow for freedom of expansion.

[0036] Also the transverse or peripheral expansions, and thus the diametrical expansions, are different, therefore the outer liner is provided such that a number of adjustable, sliding rods are hung, initially enabling distances to be adjusted and enabling freedom of expansion when in operation.

[0037] All these measurements allow all elements to function properly, thus ensuring longer service life.

[0038] All parts mentioned, allow easy access to enable effective monitoring and maintenance.

[0039] In the area of the reactor where the partial oxidation phase occurs, a number of refractory bricks are arranged to enable the temperature to exceed 1,000°C guaranteeing durability of the reactor and extending the service life.

[0040] The reactor body and most of its structural elements are manufactured using refractory steel.

[0041] Therefore, the following advantages are obtained:

- Separation of the different thermochemical stages of gasification in one single reactor.
- The moisture from the residue, in the form of water vapour, can be utilised in order to to promote the gasification process, thereby increasing the calorific value of the gas obtained and therefore improving the overall efficiency of the process thus reducing water consumption in a total balance.
- Control thermal equilibrium throughout the reactor by recirculation through the outer liner of the gases produced and at an elevated temperature.
- High efficiency in the thermal destruction of tars as the partial oxidation zone, where there is a maximum temperature point above 1,000°C, is located between stages of pyrolysis and the final gasification, unlike rotary furnaces. However, the portion of tars produced will be separated and condensed in the later stage of gas purification and recirculated directly to the area of maximum temperature.
- Good response in heterogeneous organic residues processing, unlike static furnaces.
- A wide variety of organic materials can be worked with regardless of their content of volatile components, inert components and metal salts, which is not feasible in static furnaces.
- The rotation speed can be varied, by means of the gear motor group, fed by an inverter; this means residence times of the material can be varied according to their kinetic and thermodynamic behaviour.
- Supports the reduction of dioxins and furans as the reactor can allow the exposure time necessary for degradation (more than 2 seconds at a temperature above 800°C) to be exceeded.

[0042] The designed system considers the possibility of incorporating more water if the organic matter is in deficit and can also vent water vapour if required to regulate the gasification process.

[0043] The gasification reactor incorporates an industrial gas chromatograph positioned at the output of the reactor which provides information on the composition of the gas at short intervals of time (between a few seconds and several minutes). Based on this data, and depending on the concentration of carbon monoxide and hydrogen, the oxidizing agent flow rate, the rotation speed of the reactor, the speed of the inlet valve of the organic matter and the flow rate of the water vapour entering the reactor is modified, thereby regulating the gasification process in its entirety. This corrects a high percentage of the fluctuations in the gas composition and calorific value due to the heterogeneity of the processed organic matter.

Description of the figures

[0044]

Figure 1: shows two perspectives of the whole reactor.
Figure 2: shows two perspectives of the whole reactor without insulation panels
Figure 3: cylinder section of the reactor
Figure 4: top view of the reactor
Figure 5: elevation of the reactor
Figure 6: left and right side views of the reactor
Figure 7: Cross-section of the reactor

List of references used

[0045]

1. feeding fuel by means of dosing thread
2. feeding oxidizing agent via blowing ducts
3. central pipe for temperature probes and outlet for unwanted gases
4. extraction of water vapour
5. water vapour injection in the reduction zone
6. reactor body

6.1 to 6.7 separation of spirals process zones
7.1 to 7.7 angled blades
8.1 fuel inlet seal cover

8.2 end closure cover with oxidizing agent and water vapour intake
9. outlet opening for gases and ash
10. coil distributor for hot gases
11. gas channelling outer liner
12. Gas outlet hood
13. ash outlet hopper
14. reactor gas outlet mouth exit to particle separation
15. inlet mouth for treated gases
16. gas outlet to energy recovery, for heating oxidizing agent 20. reactor support structure
21. gear reducer reactor drive
22.1, 22.2. traction rollers with room for expansion
25 23.1, 23.2. support rollers with wheels to secure expansion
24. support plate for manifold oxidant injection
25. outer liner supports
26. insulation panels

Preferred embodiment of the invention

[0046] A preferred embodiment of the invention is shown in the accompanying figures attached to the present descriptive memory.
[0047] The method and the reactor represented in the figure are described above in sufficient detail for clarity such that a person skilled in the art can make them.
[0048] In this preferred embodiment, the reactor and most of its structural elements are manufactured using refractory steel.

Claims

1. Reactor for obtaining gas from biomass or organic residues comprising a support structure for the reactor and a cylinder arranged in a horizontal position **characterised in that** all the stages of the gasification process occur in internal sections separated by helical spirals located in the inner cylindrical surface of the cylinder which defines at least one supply and drying section, one pyrolysis section, one partial oxidation section and one gasification section.

2. Reactor for obtaining gas from biomass or organic residues according to claim 1 **characterised in that** a plurality of blades is provided on the inner surface of the cylinder, and a number of fixed heads are positioned at the ends of the cylinder wherein the ducts supplying the raw material, oxidizing agent and gasification agent are located.

3. Reactor for obtaining gas from biomass or organic residues according to claim 2 **characterised in that** the cylinder has a number of pathways for perimeter rolling at the ends thereof, which are supported on a number of bearings fixed to the support structure of the reactor, designed such that any expansion along the reactor are absorbed.

4. Reactor for obtaining gas from biomass or organic residues according to claim 3 **characterised in that** it has a drive system which transmits a rotational speed-controlled movement in both directions to the cylinder.

5. Reactor for obtaining gas from biomass or organic residues according to claim 1 **characterised in that** a fixed pipe is arranged along the axial axis of the cylinder in which the temperature probes of each section of the cylinder and ducts that enable unwanted gases produced in the pyrolysis section to be vented to the outside.

6. Reactor for obtaining gas from biomass or organic residues according to claim 1 **characterised in that** an outer duct to the cylinder carries the water vapour produced in the supply and drying section and to the gasification section.

7. Reactor for obtaining gas from biomass or organic residues according to claim 1 **characterised in that** an oxidizing agent injection section is provided in the partial oxidation system comprising different conduits that are adjustable to control both the position and angles of incidence of injection flows of the oxidizing agent relative to combustion the axial shaft of the reactor.

8. Reactor for obtaining gas from biomass or organic residues according to claim 1 **characterised in that** on one end of the cylinder, the contour of the reactor has a set of perforations as windows, an extraction hood for gases is positioned on the set of windows for guiding thereof and a hopper is fitted at the bottom for collecting ashes.

9. Reactor for obtaining gas from biomass or organic residues according to claim 1 **characterised in that** on the surface of the outer cylinder of the reactor a spiral-shaped conduit is positioned, such that it crosses it from one end to the other, forming a continuous helix through which the backflow of gases produced in the reactor circulates in order to promote the exchange of heat.

10. Reactor for obtaining gas from biomass or organic residues according to claim 1 **characterised in that** externally to the cylindrical body of the reactor, a fixed cylinder or liner is arranged, which acts as a channel for feeding the gases, together with the spiral located on the outer cylindrical surface of the reactor, said outer liner of the gasification reactor is divided into two parts, top and bottom, to facilitate assembly and maintenance.

11. Reactor for obtaining gas from biomass or organic residues according to claim 10 **characterised in that** a roller system has been provided at the rear end which fixes the position of the reactor and the liner in the area where there are common outputs, wherein at said point closing elements have been arranged which ensure no leakage of gases and which enable freedom of expansion.

12. Reactor for producing gas from biomass or organic residues according to claim 10 **characterised in that** the outer liner is provided such that a number of adjustable, sliders are hung, initially enabling distances to be adjusted and enabling freedom of expansion when in operation.

13. Reactor for obtaining gas from biomass or organic residues according to claim 1 **characterised in that** a number of refractory bricks are arranged in the partial oxidation section to enable a temperature exceeding 1,000°C.

14. Reactor for obtaining gas from biomass or industrial waste according to claim 1 **characterised in that** an industrial gas chromatograph is installed at the outlet for synthesis gases.

15. Method for obtaining gas using the reactor according to the preceding claims from biomass or organic residues, comprising the stages:

a) Supply of the biomass or organic residue to the inside of the reactor.
b) Drying at temperatures between 25°C and 250°C.
c) Pyrolisis: comprising deoxygenation and desulfurization, polymer degradation, pyrolysis and polymer degradation
d) Partial oxidation.
e) Gasification.

characterised in that the water vapour produced in the supply and drying stage is used in the gasification stage, the acid gases generated in the pyrolysis stage are extracted to the outside and the oxidant, preheated by the gas, is introduced directly in the partial oxidation stage.

16. Method for obtaining gas from biomass or organic residues according to claim 14 **characterised in that** the following parameters are controlled:

a) Mass flow rate of supply of biomass or organic residues;
b) Mass flow rate of supply of oxidizing agent to the gasification reactor;
c) Mass flow rate of water vapour supplied during the gasification stage;
d) Temperatures in each thermal zone of the reactor;
e) Analysis of the gasification.

17. Method for obtaining gas from biomass or organic residues according to claim 15 **characterised in that** depending on the results of the gas analysis, the flow rate of the supplies of oxidizing agent, water vapour to the reactor, biomass or organic residues and the rotation speed of the reactor varies.

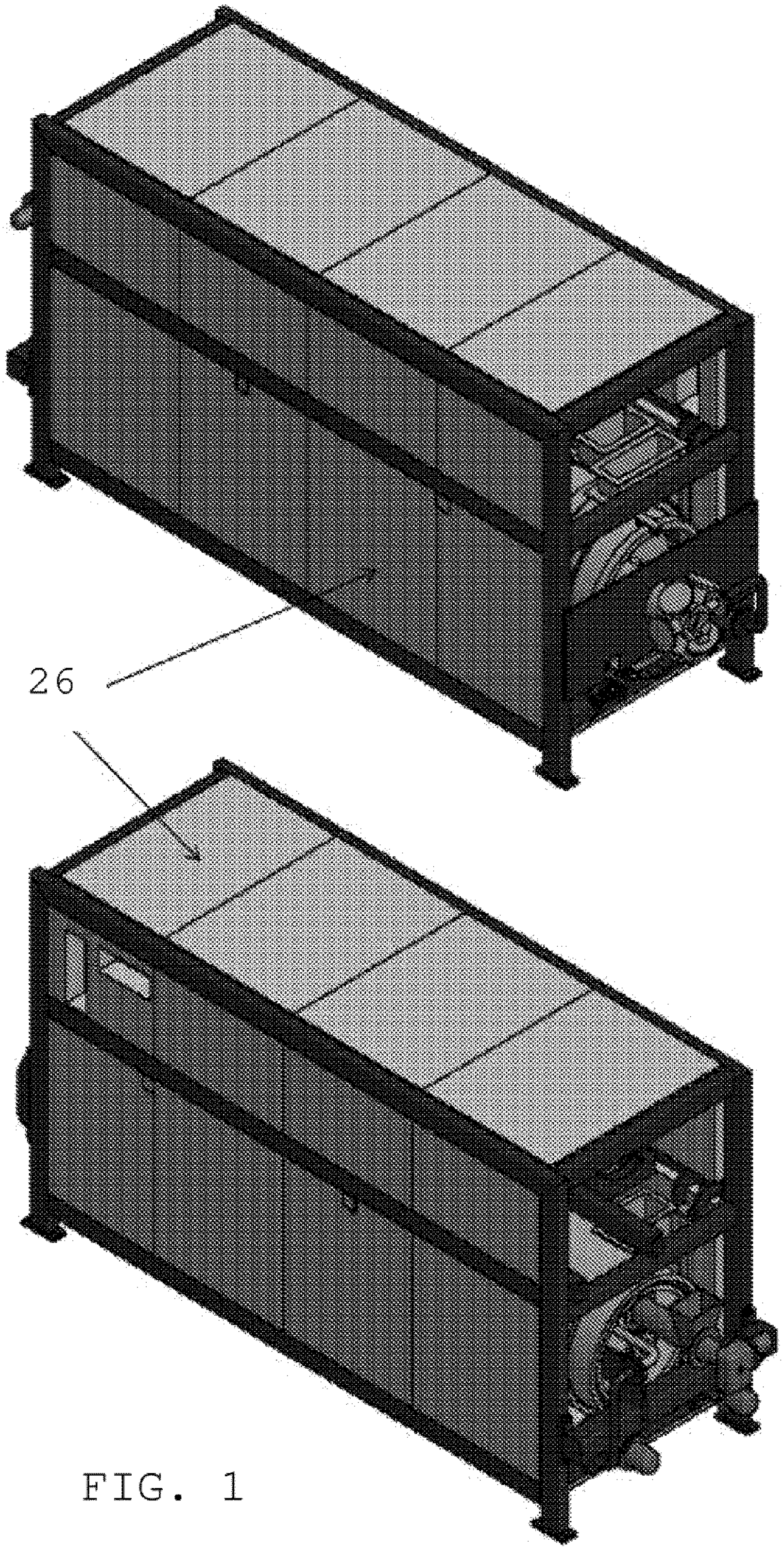

FIG. 1

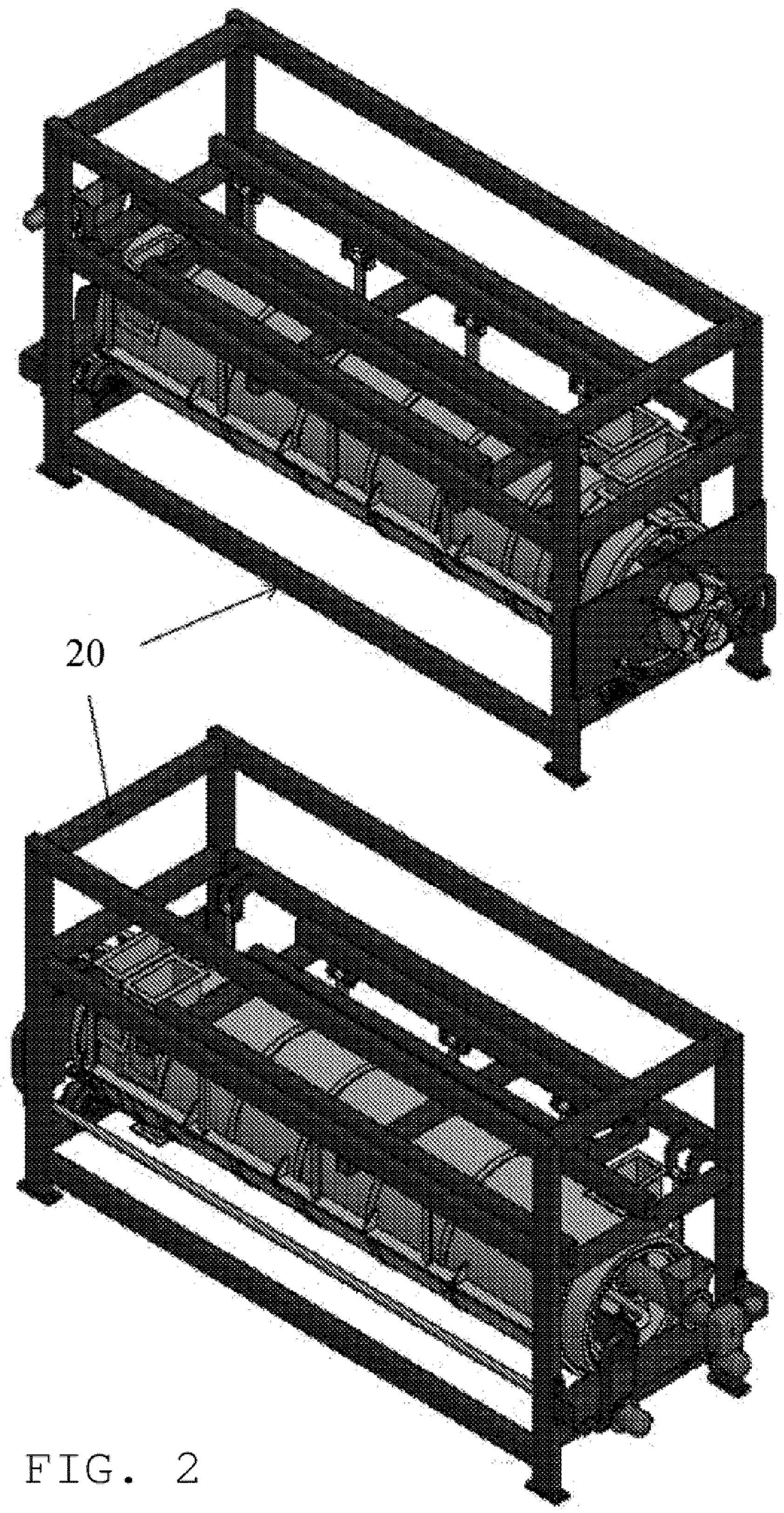

FIG. 2

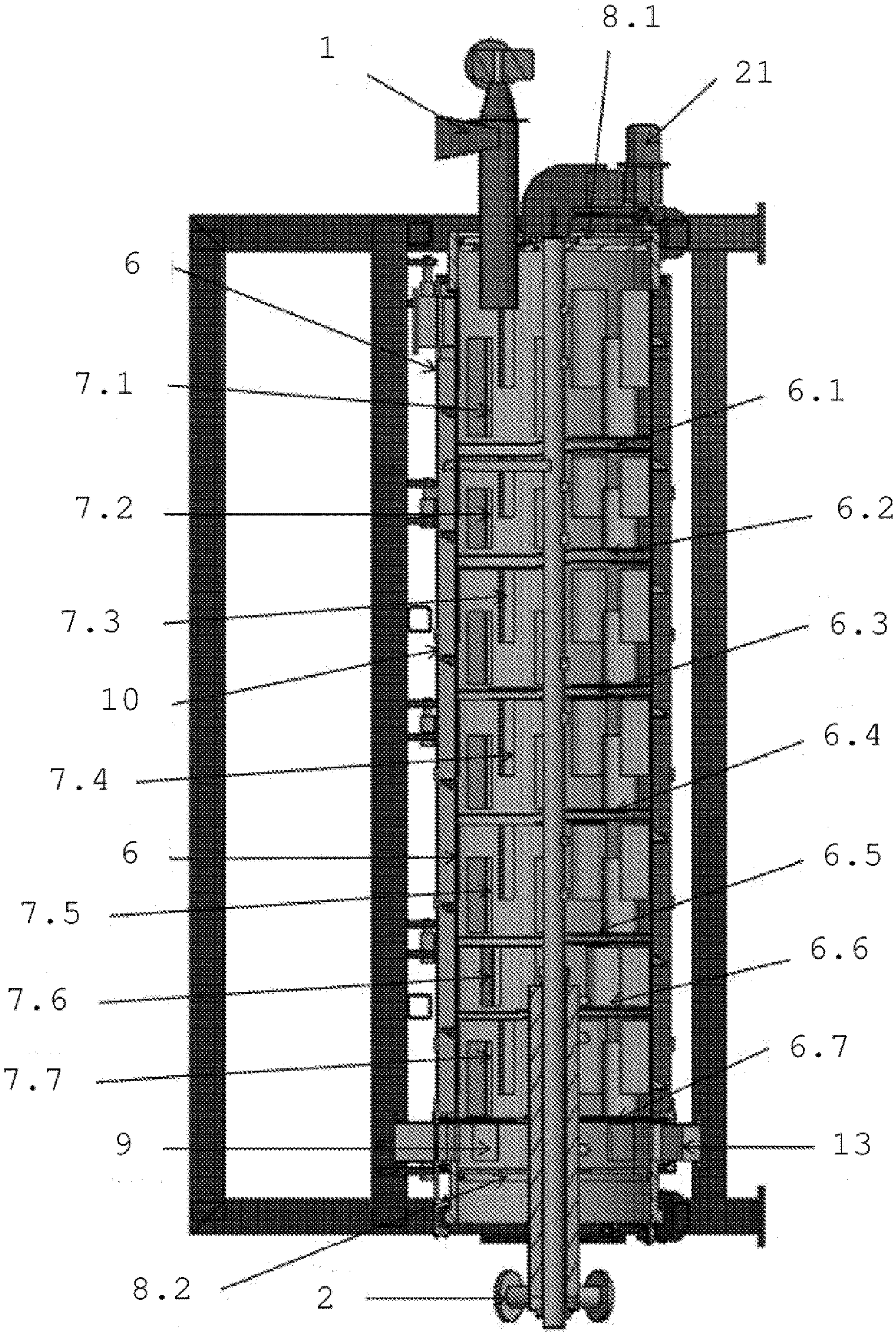

FIG. 3

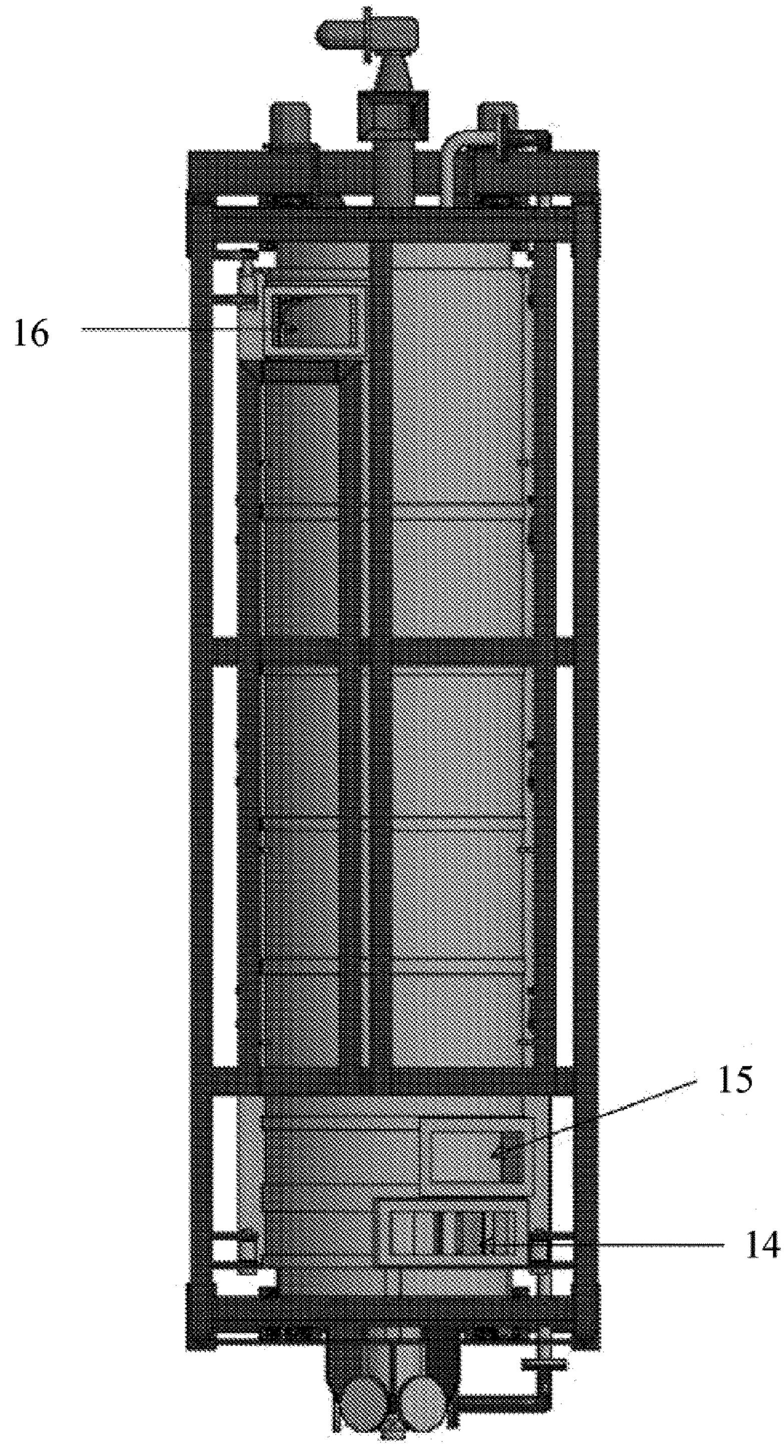

FIG. 4

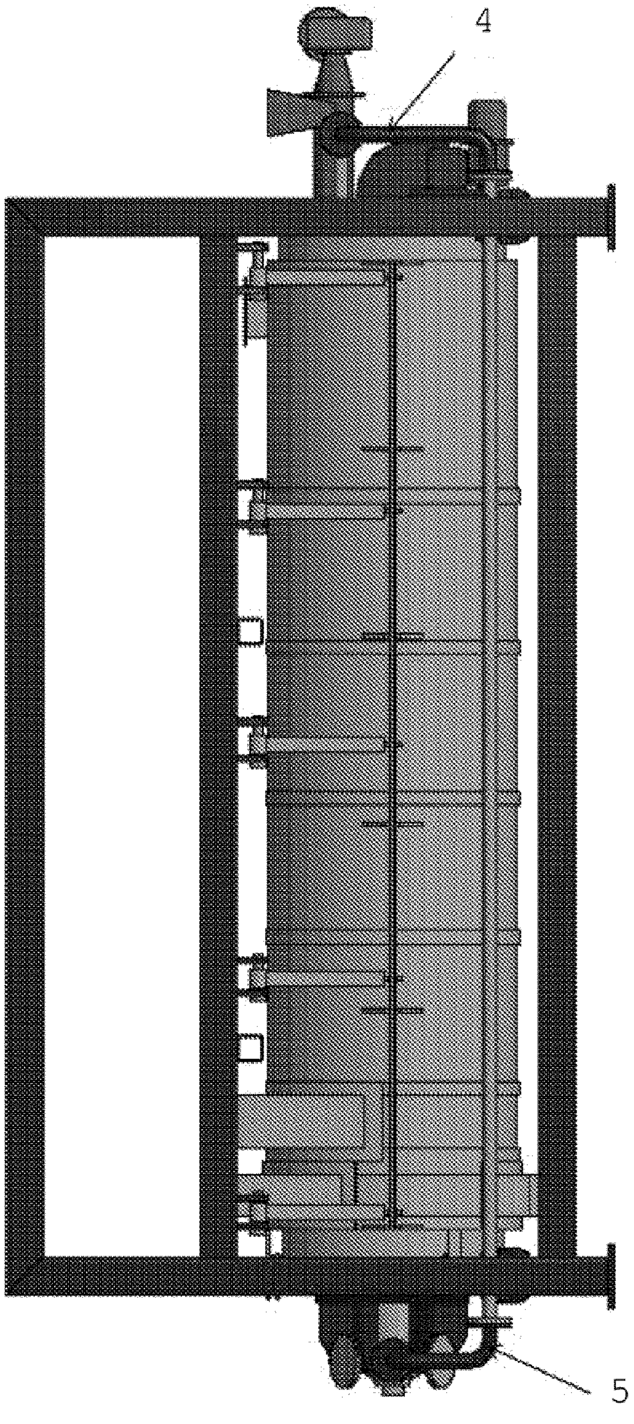

FIG. 5

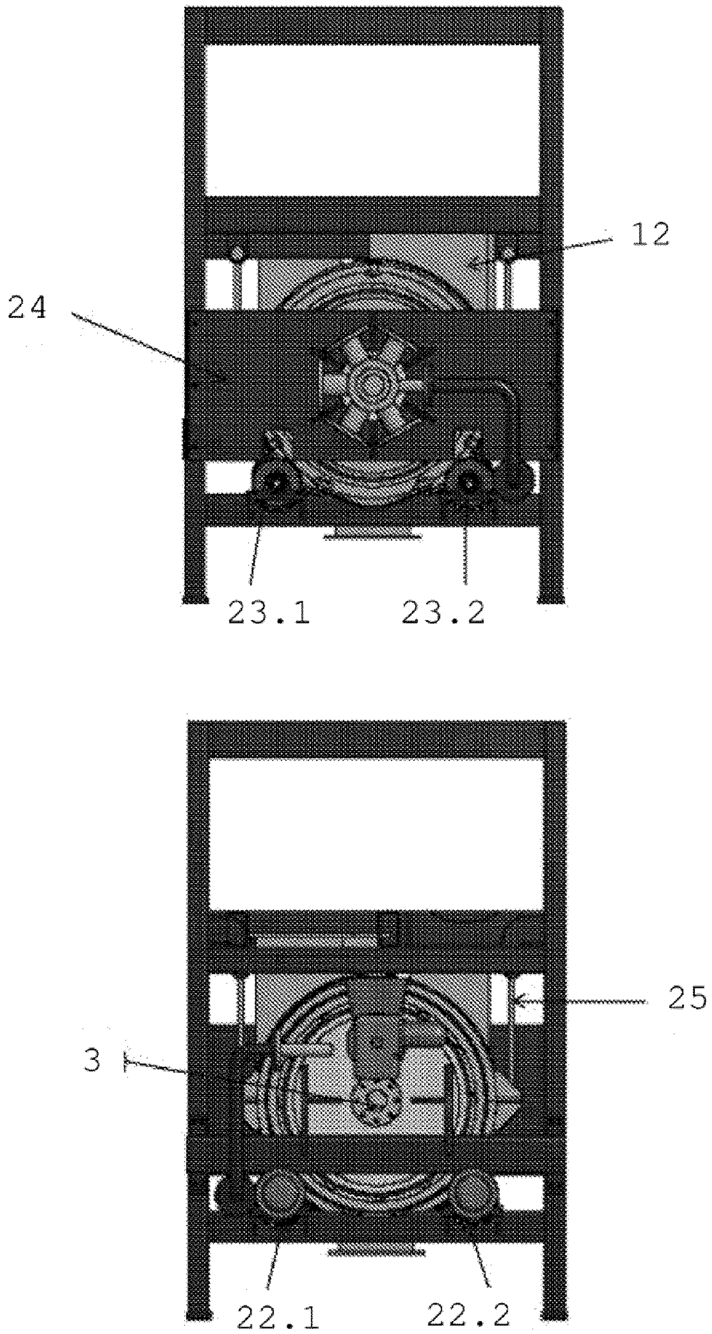

FIG. 6

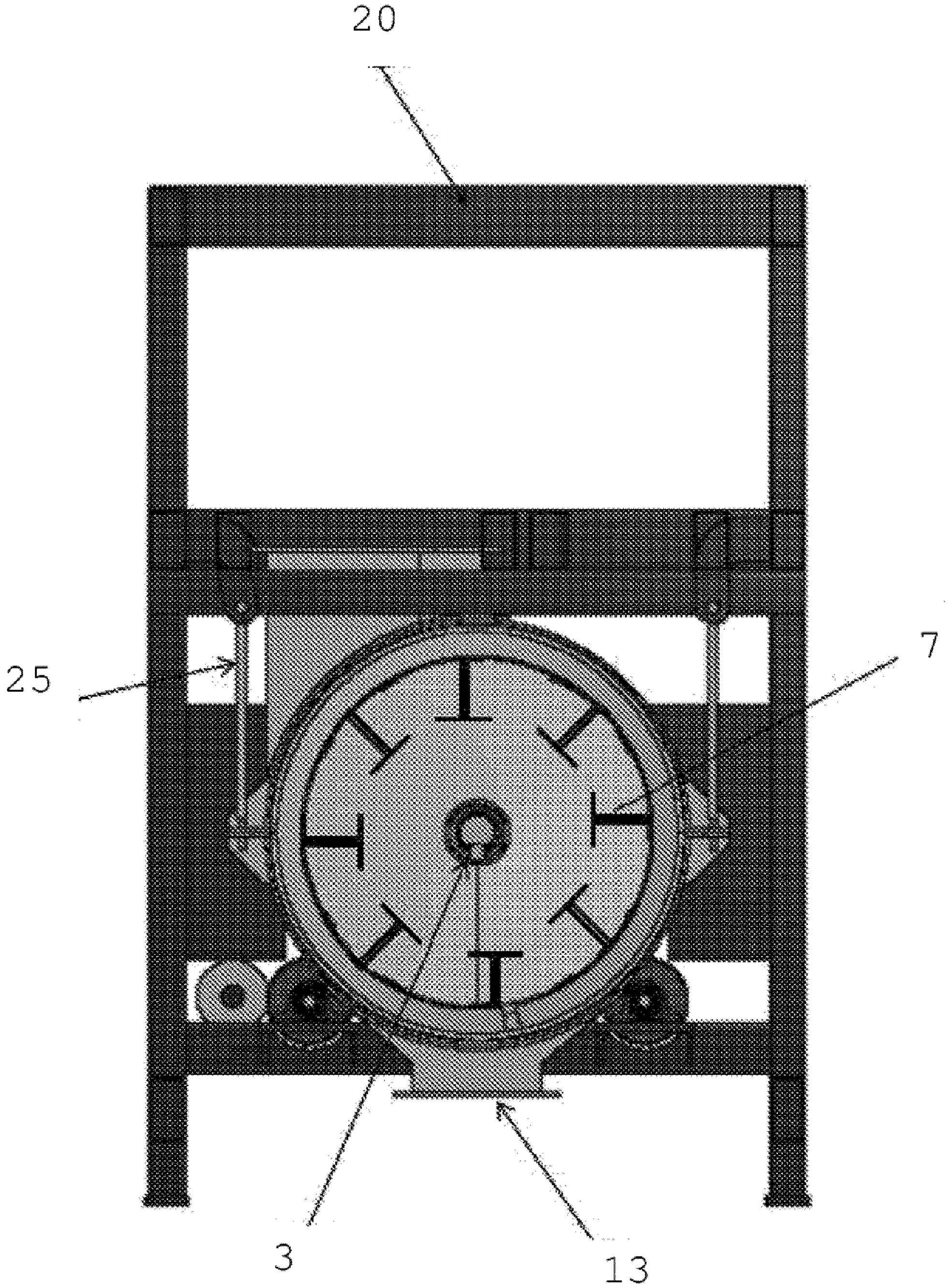

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/ES2012/070607

A. CLASSIFICATION OF SUBJECT MATTER

C10J3/00 (2006.01)
C10J3/72 (2006.01)
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)
C10J

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, INVENES, WPI, TXTUS, TXTEP1, TXTGB1, XPESP

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	WO 2007123510 A1 (ZIA METALLURG PROCESSES INC ET AL.) 01/11/2007, paragraph [0007] and fig. 1	1-17
A	WO 2011044943 A1 (JENEY PETER ET AL.) 21/04/2011, fig. 1	1-17
A	US 4318713 A (LEE GEORGE T ET AL.) 09/03/1982, fig. 1	1-17

☐ 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
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"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 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
16/01/2013	**(18/01/2013)**
Name and mailing address of the ISA/ OFICINA ESPAÑOLA DE PATENTES Y MARCAS Paseo de la Castellana, 75 - 28071 Madrid (España) Facsimile No.: 91 349 53 04	Authorized officer I. González Balseyro Telephone No. 91 3496881

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
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