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(71) Applicant: **José Lopes, Evandro**

80040-280 Curitiba (BR)

(72) Inventor: **José Lopes, Evandro**

80040-280 Curitiba (BR)

(74) Representative: **Petraz, Gilberto Luigi et al**

GLP S.r.l.

Viale Europa Unita, 171

33100 Udine (IT)

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(54) **INTEGRATED PROCESS OF PYROLYSIS AND GASIFICATION OF WASTE AND THE DERIVATIVES THEREOF AND APPARATUS FOR THE IMPLEMENTATION THEREOF**

(57) The process and the equipment that continuously integrates the pyrolysis processes in a Rotary kiln at average temperatures of 300 to 500°C with a gasifier on moving grates in average temperatures of 500 to 800°C, whose purpose is to produce a mixture of gases originating from the pyrolysis and gasification processes of waste and their derivatives. In this process, the gas mixture known as "Waste-Derived Combustible Gases (WDCG) is continuously drawn through a Venturi system or an exhaust system, and can be directed to a combustion system or treatment and separation of combustible fractions for subsequent energy recovery. From this process and its unprecedented processing characteristics, powdered, fine, sludge, pasty or liquid waste can be thermally treated individually or in blends with other waste such as urban, commercial or industrial solid waste, with additional energy recovery.

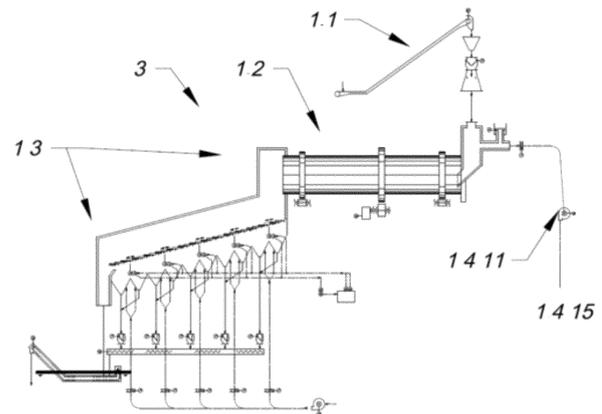


FIG. 11

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Description

Invention Technical Sector

[0001] It is a process that integrates the pyrolysis process in a rotary kiln with the gasification process on grates, in order to carry out a heat treatment with energy recovery in waste and its derivatives with characteristics that cannot be absorbed and treated in these methods individually. Using this process and its unprecedented processing characteristics, powdered, fine, sludge, pasty or liquid waste can be treated individually or in blends with other waste such as Municipal, commercial or industrial solid waste, with the additional advantage of energy recovery.

[0002] According to ABNT NBR 10004, solid waste is defined as: waste in solid and semi-solid states, which results from activities of industrial, domestic, hospital, commercial, agricultural, service and sweeping origin. This definition includes sludge from water treatment systems, those generated in pollution control equipment and installations, as well as certain liquids whose particularities make their release into the public sewage system or water bodies unfeasible, or require solutions that are technically and economically unfeasible in the face of the best available technology.

[0003] According to the ABNT NBR 16849 standard of December 2019, energy recovery or energy use is defined as: "process of using thermal energy generated from the thermal oxidation of waste intended for combustion, gasification and/or pyrolysis processes, which fundamentally uses thermal energy for industrial or electricity generation purposes, carried out under controlled conditions and with due environmental control and monitoring".

[0004] The macro operations of the process defined in the present invention are called: drying and pyrolysis, gasification and, finally, the combustion of gases derived from the previous processes.

[0005] The terms and operations used in this document are defined in the following paragraphs.

[0006] Drying is the endothermic process of removing water from waste and its derivatives, using in this process the heat resulting from the exothermic reactions of gasification processes.

[0007] Pyrolysis is an endothermic process, which requires an external source of heat. It consists of the thermal degradation of waste in the partial or total absence of an oxidizing agent (oxygen) and with process temperatures that vary, from 400°C, until the beginning of the gasification regime. Pyrolysis is used to transform polymers, or materials containing polymers, into products that at CNTP (Standard conditions for temperature and pressure) are liquid (condensable), gaseous (non-condensable) or solid (predominantly coal).

[0008] Gasification can be defined as partial oxidation of solid or semisolid carbonaceous material (biomass/wood, waste, coal, etc.), into a combustible gas (synth-

esis gas, mainly H₂, CO, N₂, CO₂), occurring at elevated temperature, that is, between 500°C and 1,400°C, and at pressures varying between atmospheric and 33 bar.

[0009] Combustion is characterized by the combustion or oxidation zone established by the entry of oxygen into a reactor. Oxygen reacts with the products of pyrolysis and gasification, releasing thermal energy (exothermic reaction), which provides heat to the other stages of the process and produces mainly CO₂, H₂O and N₂. The heat produced in the overall process covering the three operations can be used in industrial facilities, producing thermal energy for the most varied applications, such as drying or evaporation of various materials, drying of sludge, production of process steam or production of electricity in Rankine cycle.

[0010] Incineration is one of the most frequent forms of thermal processing of waste and its derivatives that can be applied to a wide variety of types of materials. It occurs when there is a surplus of oxygen for complete oxidation. During the incineration of solid Municipal waste it is possible to reduce up to 90% of the volume and 75% of the initial weight of the waste.

[0011] Incineration consists of a high-temperature thermal oxidation process, typically ranging between 800°C and 1,300°C. Facilities require additional air pollution control equipment and the energy released by combustion of waste may or may not be reused.

[0012] The performance of an incinerator is related to several factors, including variation in the composition of the waste to be incinerated, temperature, residence time of gases in the secondary chamber and swirling or excess air. Therefore, the operation of an incinerator is based on the tripod of temperature x retention time x quantity of air, necessary for the complete burning of waste, resulting in satisfactory performance of the equipment with a large reduction in the emission of polluting gases.

The State of the Art and its problems

[0013] The state of the art presents pyrolysis processes, gasification processes and waste incineration processes and their derivatives in different equipment, that is, processes or equipment dedicated to pyrolysis to obtain their by-products, processes or equipment dedicated to gasification to obtain their by-products and processes or equipment dedicated to incineration to obtain their by-products.

[0014] State of the art incinerators seek to achieve complete combustion by employing temperatures in the range of 540 to 1,090°C, to capture the heat generated, and to manage emissions through pollution controls.

[0015] The ash produced is normally landfilled, and is often treated as hazardous waste. MSW (Municipal Solid Waste) incinerators have been the target of research involving the formation of atmospheric pollutants called Polychlorinated dibenzo-p-dioxins (PCDD) and Poly-

chlorinated dibenzofurans (PCDF), commonly known as dioxins and furans, since the concentrations of these found in both fly ash and in the gas flow of these processes, present values above those permitted by environmental legislation. These types of equipment commonly require large volumes of waste and their derivatives, requiring volumes from 800 ton/day that are economically viable, this is mainly due to greater stability in the process, as all reactions (drying, pyrolysis, gasification and combustion) occur in the same chamber and same conditions of pressure, temperature, turbulence and oxidizing agent (oxygen).

[0016] Due to the fact that, in addition to normal combustion gases (CO₂, H₂O and N₂), incomplete combustion products are also produced, such as volatile organic compounds and products of organic synthesis, such as dioxins and furans, the treatment of these gases ends up making the process too costly and making it unviable for small and medium-sized facilities, considering 100 tons/day for small ones and 400 tons/day for medium-sized ones.

[0017] Also in the state of the art is the invention PI 1000573-0 B1 entitled, "INDUSTRIAL FUEL PRODUCTION PROCESS FROM MUNICIPAL SOLID WASTE", also called gasification process, which is composed of a sequence of operations that enable the generation of a mixture of combustible gases, from Municipal Solid Waste (MSW), usable in industrial facilities, producing thermal energy for the most varied applications, preserving the heavy and toxic metals present in MSW, in contact with oxidative environments and high temperatures, that is, between 1,000 and 1,400 °C, causing volatilization and chemical transformations.

[0018] As shown in the flowchart (FIGURE 1) of PI 1000573-0 B1, all thermal reactions, being endothermic (drying and pyrolysis) and exothermic (substoichiometric combustion) for the production of gases take place in the same chamber, where the Municipal Solid Waste, waste blends solids with potential combustibles, including tires, are moved "exclusively" by a system of moving grates.

[0019] In this case, where all reactions occur in the same chamber, with the same morphology of the grate, the same morphology of the top and side of this same chamber, the materials will physically change as the process passes, by the loss of surface mass caused by temperature degradation in drying and pyrolysis reactions that occur up to temperatures around 400°C and, subsequently, by the loss of mass due to the oxidation of fixed carbon by substoichiometric reactions in the gasification reactions that occur at temperatures above 400°C. For materials with different physical characteristics, such as specific weight, absolute density, compaction, humidity, volatile content, ash content, etc., different conditions are necessary and this type of reactor does not offer this possibility.

[0020] As these are surface reactions, that is, they occur preferably from the outside to the inside of the particles, if there is no distribution of this material in

contact with high temperatures, there will be no possibility for them to receive this heat in a homogeneous way, thus causing its productivity is very low. In order for the material to be processed to be able to receive heat radiation for endothermic reactions, a different model of movement through grates is necessary, with greater agitation and consequent greater productivity, as will be presented here in this document.

[0021] As shown in Figures 3, 4, 5, 6 and 7 of PI 1000573-0 B1, the individual grates that move the materials to be heat treated during the endothermic and exothermic processes have the same configuration throughout the entire length of this single chamber, with the following description in paragraph 53 "The holes (1.7.1.5 - Figure 5 and 6) in the protruding region have the function of giving uniform passage to the fluid or air coming from the air/fume mixture equalization chambers under the grate sets, which also have the function of collecting fines that eventually pass through the grates".

[0022] It turns out that the initial reactions of the process, that is, the endothermic reactions, do not require air for combustion, as they are drying and pyrolysis reactions. In this way, these holes, in addition to not being necessary, prevent materials called "fine" from being processed, that is, with a particle diameter smaller than the "holes", as they would pass or leak through these holes. Therefore, this gasifier model does not allow the processing of materials containing fines, such as sludge from an effluent treatment plant, polymeric materials in powder form from drying systems or industrial processes, powdered coal or pulverized coal, as well as materials in the liquid phase such as contaminated oils, contaminated solvents among a multitude of other possibilities. Which makes this model limited to solid-state materials with particle sizes larger than the holes in your grate.

[0023] In addition to the normal grate holes that do not allow the processing of fines, this type of cast iron grate described in paragraph 49 of PI 1000573-0 B1, once heated, it ends up expanding due to thermal expansion, causing cracks in the fittings. Also, over time of use, the natural wear of these materials due to abrasion caused by movement between the fixed part and the moving part, leads to even larger gaps, which for solid waste should not present problems, but the range of fine materials, pastes or liquids, cannot be processed, leaving the equipment even more limited.

[0024] As shown in the flowchart (FIGURE 1) of PI 1000573-0 B1 and as described in paragraph 40, the conveyor belt (1.1) raises the MSW to the intake, which is done by means of a drawer (1.2.1 - Figure 1) with a powerful hydraulic drive (1.2.1.1 - Figure 1). The intake duct (1.3.1 Figure 1) is designed to always remain full of material compacted by the drawer, preventing the entry of air and the exit of gases into the atmosphere.

[0025] This type of supply through a drawer in the process only applies to the process characteristic of that invention, other processes with material in smaller diameters, as will be presented here, do not make sense.

Another serious problem in this type of supply is the compaction of the material to prevent air passage and gas escapes, which ends up clogging the inlet mouth and preventing the process from performing well.

[0026] In invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT" another different and original method for supply will be presented.

[0027] In the Certificate of Addition No. C1 1000573-0, in paragraph 45 it is described as follows: "Although unprecedented in this addition certificate, we can verify the addition as a variant, at the exit of the gasification chamber(1.4), the unprecedented catalyst set(1.10) of corrugated metal plates(110.1), parallel and coated with nickel to trigger the Fischer Tropsch reaction. This arrangement and conformation aims to increase the contact area between the catalyst and the reacting gases, without large losses of pressure (loss of pressure) due to the passage of gases towards the chamber (120)".

[0028] This catalyst set is necessary for this process C1 1000573-0, due to the fact that this requires an increase in the calorific value of the gas generated.

[0029] In the model proposed by this document, this catalyst set will be dispensed with and will not be part of the required process, because this new model allows for better conditions for endothermic reactions, producing a gas with better calorific value compared to conventional gasifiers.

[0030] In the Certificate of Addition No. C1 1000573-0, in paragraph [52], it is described that it presents as a novelty the possibility of the gases generated in the first stage of the process, that is, from the gasification chamber(1.4), instead of being directed to the Venturi(5) of the original patent, be directed to an optional combustion chamber (120) of the torsional type that does not require a pilot flame (1.11) for activation. This is due to the fact described in paragraph [62] as follows: "The blower combustion air speed (1.6) must be higher than the gas flow speed coming from the gasification chamber (1.4) to form the Venturi effect".

[0031] The injection of combustion air only into the torsional combustion chamber does not cause the Venturi effect required to obtain a constant flow of gases, that is, it does not have the capacity to draw gases produced in the pyrolysis and gasification processes, and consequently it is not achieves adequate flow control, preventing it from operating with larger volumes of materials to be processed.

[0032] To solve this technical problem, it is presented in the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT" a new way of achieving this effect appropriately for the proposed process.

[0033] The pyrolysis process is still at the state of the art. In this thermal process, products with added values are generated, such as oil, gases and coal that can be

used as a source of fuel or in other uses related to industry. While the carbonization pyrolysis process (slow pyrolysis) is aimed specifically at the production of coal, fast pyrolysis is considered an advanced process, in which, by controlling the process parameters, considerable quantities of oil can be obtained. As it is an endothermic process, it requires quantities of heat proportional to the masses of waste and their derivatives to be consumed for their decomposition. In order for pyrolysis products to maintain their characteristics, the addition of heat is commonly done indirectly, that is, the heat conductor, whether by steam, thermal oil or even gases, which do not come into contact with the material to be processed.

[0034] In this application, this fact will not be relevant, as will be presented below, as the final product of the process will not be the same as those produced in pure pyrolysis processes, but rather a blend of gases containing the products of drying, pyrolysis and gasification. For this reason, no reference was found in patent and technology bases on the subject so that comparisons of the processes could be made.

Technical problem to be resolved

[0035] The invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT" was developed to solve the problem of treating fine, powdery, pasty, sludge and liquid waste, which can be treated individually or in blends with other waste such as Municipal, commercial or industrial solid waste. Such residues with reduced particle size cannot be processed in conventional grate gasification processes.

[0036] The present invention also offers an integral destination for waste processed by the pyrolysis technique, which generates coals that end up having no application or use when derived from waste containing heavy metals or other organic molecules.

[0037] In this way, the present invention proposes to solve both problems by integrating two distinct processes for comprehensive treatment, being able to meet a demand for waste that today basically only finds disposal in landfills and also greatly reduce the solid by-products of pyrolytic processes for waste treatment.

[0038] The integration of pyrolysis processes in a rotary kiln with gasification on grates enhances the volume of waste treatment and its derivatives per processing unit, considerably reduces the volume of waste that would go to landfills without being used, makes available to the market a process that guarantees the lack of conditions for the formation of persistent pollutants such as dioxins and furans, meets the need of waste generators for environmentally appropriate treatment that meets environmental legislation and also generates energy use of these wastes, reducing the demand for fossil fuels for generating thermal energy.

Objectives of the invention and its advantages

[0039] The invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT" aims to make waste treatment with energy recovery available to the market, through an integrated process, in an integrated equipment, with the capacity to meet waste demands which are currently sent to landfills without being used.

[0040] Also provide waste generators with a process that includes waste with characteristics that do not conform to conventional processes with additional energy use, and that fully complies with environmental laws and standards.

[0041] Make available to the market a process that effectively treats waste using energy, ensuring the non-production of pollutants such as dioxins and furans.

Novelty and technical effect achieved

[0042] The novelty of the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", comprises the integration of two distinct processes that enables the optimization of the pyrolysis technique, increasing its efficiency in terms of mass effectiveness of treated waste and also increasing the range of waste that can be treated using the grate gasification technique, offering:

- a) an integrated process that allows the treatment of waste in different particle sizes, such as fine, powdery, pasty, sludge and liquid waste that can be treated individually or in blends with other waste such as Municipal, commercial or industrial solid waste;
- b) an integrated process that allows pyrolytic gases and oils to be produced from waste, without leaving a coal liability that ends up without being used;
- c) solution for the coal produced in the pyrolysis process to be consumed in the downstream gasification process, to produce thermal energy to be consumed in the pyrolysis reactions;
- d) the operating conditions of both pyrolysis and gasification do not provide conditions for the production of dioxins and furans;
- e) the combustion of gases produced in the pyrolysis chamber and gasification chamber in an integrated combustion system, ensuring complete combustion and no generation of pollutants or being directed to a treatment and separation system for combustible fractions;
- f) a perfect combustion process, with high turbulence, temperatures on average of 1,200°C and retention time of up to 2 seconds, as is the case with the combustion chamber of the best proposed solution of the present invention, eliminating the need for

complex combustion gas treatment systems, giving greater economic and environmental viability to the process;

g) grate model that provides a gasification process that can receive materials from the pyrolysis process, because the holes for air passage in the grill are positioned transversely;

h) rotary kiln for pyrolysis reactions with rotation speed control to suit different materials, the speed being dependent on the humidity and particle size of the treated waste;

i) the grate (complete set of grates with moving and fixed grate sections) of the gasifier arranged in sections with independent speed control, in order to control the speeds according to the speed of consumption and degradation of materials on each section of the grate;

j) the extraction of ash at the end of the gasification process is carried out using a redler-type chain conveyor, which must be sealed by water or a mechanical seal, keeping the process quite airtight so that there is no false air entry, as it is a system that works at low pressure or vacuum;

k) the material supply system in the pyrolysis stage that includes a set of mechanical valves to ensure sealing for air entry or gas exit from the process, as the material entry region coincides with the gas extraction region from the process pyrolysis and gasification processes;

l) the connection between the moving parts of the rotary kiln with the material inlet and gas extraction region, as well as with the coal outlet and the gasifier inlet are designed to guarantee a seal so that there is no gas leakage or entry of false air;

m) pressure control suitable for the pyrolysis and gasification processes, by an efficient suction system, consisting of a Venturi system mounted on the duct that connects the pyrolysis kiln bringing the pyrolysis and gasification gases to the combustion face;

n) a Venturi system to control pressure in the system uses atmospheric air blown into a strategic location in the duct that enters the optional combustion chamber, and this air will already be part of the combustion air required in this chamber;

o) possibility of a variant of this invention, regarding the Venturi system, this can be replaced by a gas exhaust system with speed and flow control, thus maintaining constant pressure in the integrated pyrolysis and gasification process;

p) pressure exerted by the mixture of combustible gases and air that allows this mixture to enter under pressure into the cylindrical combustion chamber, touching the walls and thus facilitating turbulence and combustion;

q) possibility of combustion chamber for the mixture of gases from pyrolysis and gasification is of the torsional type, where the combustible gases pro-

duced are inserted tangential to the flow of blown combustion air;

r) presence of safety valves for sudden stops, consisting of a gas duct closing valve and an opening valve for the exit of gases to the safety chimney with pilot flame system.

Relationship of figures

[0043] For a better understanding of the present invention, below is a detailed description of the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", making references to the attached drawings.

Figure 1 shows the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", a general schematic drawing in side view in section of the complete set (1), in the best proposed solution, specifying its main parts.

Figure 2 shows the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", a schematic drawing in side section of the feeding set (1.1).

Figure 3 shows the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", a schematic drawing in side section of the rotating pyrolysis kiln set (1.2).

Figure 4 shows the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", a schematic drawing in side section of the gasifier set (1.3).

Figure 5 shows the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", a schematic drawing in side section of the combustor set (1.4).

Figure 6 shows the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", a schematic drawing, in side view, of the location of the sensors of the invention.

Figure 7 shows the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", a perspective of a section (1.3.1) of fixed (1.3.1.1) and moving (1.3.1.2) grates.

Figure 8 shows the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIP-

MENT TO CARRY IT OUT", a perspective of a fixed grate (1.3.1.1) or moving grate (1.3.1.2).

Figure 9 shows the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", a perspective of a fixed grate (1.3.1.1) or moving grate (1.3.1.2).

Figure 10 shows the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", a general schematic drawing in sectional side view of the complete set (1), in the composition of the 1st variant, with exhaust fan (1.4.11), specifying its main parts.

Figure 11 shows the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", a general schematic drawing in sectional side view of the complete set (1), in the composition of the 2nd variant, without the burner (1.4), specifying its main parts.

Description of the Best Proposed Solution.

[0044] The EQUIPMENT of the present invention presents its functional technical composition comprising 04 basic parts: material feeding and dosing and gas removal set (1.1), rotary pyrolysis set (1.2), gasification set (1.3) and combustion set of generated gases (1.4).

[0045] The material feeder and doser and gas removal set (1.1) comprises:

- a) feeder(1.1.1);
- b) upper hopper(1.1.2);
- c) valve (1.1.3) to control the material input volume;
- d) lower hopper(1.1.4);
- e) pyrolysis rotary kiln feeder (1.1.5) comprising:

- body(1.1.5.1), with hopper(1.1.5.1.1)
- emergency valve(1.1.5.2);
- safety chimney(1.1.5.3);
- combustible gas outlet duct (1.1.5.4);
- emergency valve (1.1.5.5);
- feeder/rotary kiln seal(1.1.5.6);

[0046] The rotary pyrolysis kiln set(1.2) comprises:

- a) rotary kiln (1.2.1) comprising:

- body(1.2.1.1);
- tracks(1.2.1.2);

- b) gear motor (1.2.2) to drive the kiln rotation;
- c) set of sensors (1.5) comprising:

- pressure transmitter (1.5.1);
- temperature transmitter(1.5.2);
- O₂ analyzer and transmitter (1.5.3), also known

as lambda probe (λ).

[0047] The gasification set (1.3) comprises:

- a) sections (1.3.1), comprising:
- fixed grates (1.3.1.1)with:
 - i) ramp(1.3.1.1.1);
 - ii) horizontal holes (1.3.1.1.2), and;
 - iii) sliding-fitting lower flap (1.3.1.1.3), and;
 - iv) sliding-fitting top flap(1.3.1.1.4);
 - moving grates (1.3.1.2) with:
 - i) ramp(1.3.1.1.1);
 - ii) horizontal holes (1.3.1.1.2), and;
 - iii) sliding-fitting lower flap (1.3.1.1.3), and;
 - iv) sliding-fitting top flap(1.3.1.1.4);
- b) hydraulic drives (1.3.2) of the moving grates (1.3.1.2) of each section (1.3.1);
- c) hydraulic power plant with pump and reservoir (1.3.3);
- d) ash collectors (1.3.4);
- e) valves for ash collection (1.3.5);
- f) ash screw conveyor (1.3.6);
- g) water seal(1.3.7);
- h) Redler type conveyor(1.3.8);
- i) blower(1.3.9);
- j) blown air damper valves (1.3.10);
- k) gasifier/rotary kiln seal(1.3.11)
- l) level sensor/switch(1.3.12);
- m)sets of sensors (1.5) on each section (1.3.1) of the grate, comprising:
- pressure transmitters (1.5.1);
 - temperature transmitters (1.5.2);
 - O₂ analyzers and transmitters (1.5.3), also known as lambda probe (λ).
 - pressure transmitters (1.5.1) under each section (1.3.1).

[0048] The combustion set of gases generated (1.4) comprises:

- a) extraction fan (1.4.1);
- b) Venturi(1.4.3);
- c) recovery gas supply line (1.4.4);
- d) pilot burner for startup (1.4.5);
- e) burner fan (1.4.6);
- f) damper valve (1.4.7);
- g) combustion chamber (1.4.8) comprising tangential inlet of produced gases (1.4.8.1);
- h) hot gas outlet (1.4.9);
- i) natural gas or LPG input line for startup (1.4.10);
- j) set of sensors (1.5) comprising:

- pressure transmitter (1.5.1);
- temperature transmitter(1.5.2);
- O₂ analyzer and transmitter (1.5.3), also known as lambda probe (λ).

[0049] During the operation of the equipment (1) there is a flow of solid, pasty and liquid fractions from the inlet set (1.1), passing to the kiln set (1.2), and, finally, to the gasifier set (1.3), where the coal residual is removed by Redler(1.3.8).

[0050] At the same time, there is a gas flow coming from the gasifier (1.3), passing through the pyrolysis set (1.2), and which is extracted through the duct (1.1.5.4) and directed to the combustor set (1.4).

[0051] As mainly seen in Figure 1, the present invention called "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", integrates the processes of pyrolysis in a rotary kiln (1.2) and gasification on moving grates in the gasifier (1.3).

[0052] The equipment components(1) are built with materials suitable for each phase of the overall process, according to temperature, humidity, electrochemical corrosivity and abrasiveness.

[0053] It is a process that can be operated electronically through responses to pressure sensors (1.5.1), temperature (1.5.2), and oxygen content (1.5.3), acting to control the speed of the gearmotor (1.2.2) of rotation of the rotary kiln (1.2.1), speed of advance and retreat of the moving grates (1.3.1.2) of the sets of grates (1.3.1) of the gasifier, timer of the mechanical valves (1.1.3) of input of materials, speed of the ash extraction Redler(1.3.8), speed/flow of air blower(1.4.1) in the Venturi system(1.4.3), speed/flow of air in the gasification system(1.3) by control of the blower (1.3.9) and valves (1.3.10), air flow in the blower (1.4.6) of the combustion chamber (1.4), the entire process being linked to the safety valve system (1.1.5.1), (1.1.5.2) and (1.4.7).

[0054] As better described later in the 1st variant of the equipment (1), instead of controlling the blower (1.4.6), control is carried out over the gas exhaust fan (1.4.11).

[0055] The basic instrumentation, seen in Figure 6, comprises:

- a) pressure transmitter (1.5.1);
- b) temperature transmitter(1.5.2);
- c) O₂ analyzer and transmitter (1.5.3), also known as lambda probe (λ).

[0056] Such sensors will be controlled by a control loop that will control the frequency inverters of the fans and exhaust fans (1.4.1), (1.4.11), (1.3.9) and (1.4.6), the frequency inverter of the gearmotor (1.2.2) that drives the rotation of the kiln (1.2.1), valves (1.1.3), (1.1.5.3), (1.1.5.5), (1.3.5), (1.3.10) and (1.4.7), and the movement of the moving grates (1.3.1.2) by the hydraulic unit (1.3.3) managing the entire operation of the equipment (1).

[0057] In the material feeder and doser and gas re-

moval set (1.1) the feeder (1.1.1); It can be of different types, such as the belt represented in the figures, or claws, or mugs, among others.

[0058] The upper hopper (1.1.2) acts as a funnel receiving the material to be processed, which then meets the valve (1.1.3) to control the material input volume.

[0059] The lower hopper (1.1.4) directs the dosed material to the feeder inlet of the rotary pyrolysis kiln (1.1.5).

[0060] The feeder of the rotary pyrolysis kiln (1.1.5) has the body (1.1.5.1) of several functions, which are to offer the material to be processed the path to the set (1.2) or through the hopper (1.1.5.1.1), and the path of counter-flow gases to the outlet (1.1.5.4) through the valve (1.1.5.5).

[0061] Attached to the body (1.1.) is also the safety valve (1.1.5.2), which directs, in cases of emergencies/abrupt stops, the gases to the chimney (1.1.5.3).

[0062] The feeder/rotary kiln seal (1.1.5.6) in the region of separation between the moving part of the kiln (1.2.1) and the fixed part of the body (1.1.5.1) prevents false air from entering the system.

[0063] In the heat production process of this invention, two distinct methods of treating waste and their derivatives are continuously incorporated, namely, pyrolysis and gasification, generating gases to be burned in a combustion chamber(1.4).

[0064] In this way, it is possible to solve the problems that limit such processes to a comprehensive treatment of waste and its derivatives with energy recovery. The simple pyrolysis process is limited by the high coal content it produces in addition to the gases and oils it produces in the gaseous state.

[0065] In the integrated process given by the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT" the gaseous fraction of the pyrolytic processes in set (1.2) and gasification in set (1.3) are pulled, by the action of the Venturi (1.4.3), to the duct (1.1.5.4), and then directed to the combustion chamber set (1.4), with the coal being directed to the gasification chamber set (1.3).

[0066] Through the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", in the pyrolysis process in a rotary kiln(1.2) it is possible to process and pyrolyze fine materials, powders, sludges, pastes and liquids, including blends of these materials with municipal, commercial and industrial solid waste.

[0067] The rotary kiln set (1.2) performs the function of pyrolysis of the material in process, which, for this purpose, has its body (1.2.1.1) rotated, by the gear motor (1.2.2), on the tracks (1.2.1.2).

[0068] As shown in Figure 6, providing data for equipment automation(1), internally in the kiln(1.2.1), there is a set of sensors (1.5) comprising a pressure transmitter(1.5.1), temperature transmitter(1.5.2), O₂ analyzer and transmitter(1.5.3), also known as lambda probe (λ).

[0069] In the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", the dosing feeder (1.1) feeds the rotary kiln (1.2) for the pyrolysis reactions, where the seal (1.1.5.6) of the feeder/doserset (1.1) and the sealing (1.3.11) of the gasifier set (1.3) guarantee the absence of false air passage and gas leakage between moving parts of the rotary kiln (1.2) and those fixed on both sides of it.

[0070] The gear motor (1.2.2) determines the rotation speed of the rotary kiln (1.2.1) which provides the revolving and movement of the material so that good pyrolysis occurs and the material is sent to the gasifier set (1.3).

[0071] Conventional gasification processes using moving grates do not allow processing certain materials due to their physical forms, such as fine materials, powders, sludges, pastes and liquids.

[0072] However, in the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT" the gasification process on moving grates given in the gasification set (1.3) can process the ashes from the pyrolysis process on grates with transverse holes.

[0073] In this way, the processes complement each other by taking on tasks not performed by the other.

[0074] The gasification set (1.3) comprises sets of grate sections (1.3.1), where, in the direction of material flow, the odd lines are with fixed grates (1.3.1.1) and the even lines are with moving grates (1.3.1.2).

[0075] The number of grates lines (1.3.1.1) and (1.3.1.2) for each independent section (1.3.1), as well as the number of grates per even or odd line, depends on the processing capacity or size of each equipment.

[0076] In the present invention, it is possible to control, individually for each section (1.3.1) of grates, both the advance and retreat speed of the moving grates (1.3.1.2), as well as the time between each activation, according to the responses to the data from the sensor sets(1.5) located on each set.

[0077] The movement of the grate sets(1.3.1.2) is done by hydraulic actuators(1.3.2), these can be cylinders or hydraulic motors, where propulsion is offered by the hydraulic unit with pump and reservoir(1.3.3).

[0078] The moving grates (1.3.1.2) move with the upper sliding-fitting flaps (1.3.1.1.4) sliding over the adjacent lower sliding-fitting flaps (1.3.1.1.3), providing the necessary sealing.

[0079] During movement, the material descends over the grates, mainly through the ramps (1.3.1.1.1), while it is blown by the air injected through the holes (1.3.1.1.2).

[0080] Also in the gasification set (1.3) there are ash collectors (1.3.4) residual from the process, which, like hoppers, direct such ash to the ash collection valves (1.3.5), ash conveyor screw (1.3.6), and finally, using a Redler-type conveyor (1.3.8), out of the equipment (1).

[0081] The Redler type conveyor (1.3.8) has its lower part covered by a water seal (1.3.7) preventing false air

from entering the equipment (1).

[0082] The air blown into the gasifier (1.3) is controlled by a frequency inverter that operates the blower (1.3.9) and drives the blown air damper valves (1.3.10).

[0083] The gasifier/rotary kiln seal (1.3.11) prevents false air from entering.

[0084] The level sensor/switch (1.3.12) maintains the seal level at such a height that it does not allow false air to enter through the gasifier Redler (1.3.8) (1.3).

[0085] As shown in Figure 7, providing data for equipment automation (1), internally of the gasifier (1.3), above each grate section (1.3.1), there is a set of sensors (1.5) comprising a pressure transmitter (1.5.1), temperature transmitter (1.5.2), O₂ analyzer and transmitter (1.5.3), also known as lambda probe (λ).

[0086] Below each grate section (1.3.1) there is a pressure sensor (1.5.1), also providing data for equipment automation (1). Based on the signals from these sensors, the blown air damper valves (1.3.10) are opened, the purpose of which is to maintain constant pressure at these points.

[0087] In the present invention, the endothermic pyrolysis process that occurs in set (1.2), and the consequent thermal decomposition of waste and its derivatives will be thermally fed with the heat of the gases produced in the exothermic gasification reactions of set (1.3).

[0088] This is possible by passing the gasification gas flow, which is heated to an average temperature of 650°C (between 500 and 800°C), through the rotary kiln (1.2.1), which, when rotating, promotes contact between the materials to be processed with this heated gas.

[0089] To make this possible, the gas removal duct (1.1.5.4), best seen in Figure 2, will be arranged next to the material inlet in the rotary kiln (1.2.1), so that the flow of gases is countercurrent in relation to solid, pasty and liquid material.

[0090] Controlling the rotation speed of the kiln (1.2.1) and controlling the amount of material to be processed must maintain the temperature of the mixture of gasification gases from set (1.3) plus pyrolytic gases from set (1.2) at an average value 400°C (between 300 and 500°C), to avoid condensation of pyrolytic gases.

[0091] The O₂ measuring cell by lambda probe (1.5.3) interconnected to the operating system, allows control and guarantees that there will be no oxygen available for complete combustion in the pyrolysis chamber (1.2).

[0092] The internal working temperature of the rotary kiln (1.2.1) for pyrolysis reactions should be around 400°C on average, in the gasifier (1.3) the average internal working temperature will be around 650°C.

[0093] The control of substoichiometric reactions takes place by blower air insufflation(1.3.9), which is controlled by the temperature, pressure and oxygen concentration given by the sensors(1.5) above each grate section(1.3.1) and by the pressure(1.5.1) below each section(1.3.1) of grate.

[0094] The control of the gas flow in the gasifier and in the rotary kiln will be done by the air blower frequency

inverter (1.4.1) coupled to the duct so that the Venturi effect is created in the Venturi (1.4.3).

[0095] The control will be done by the pressure above the grates (1.3.1) of the gasification chamber, which must be below atmospheric pressure to guarantee a vacuum process.

[0096] The Venturi effect guarantees the flow of gases and pressure throughout the process, as well as providing the torsional combustor(1.4) with a mixture of combustible gases from the pyrolysis and gasification processes plus the oxidizing atmospheric air from the blower (1.4.6).

[0097] The blower (1.4.6) is controlled by the valve (1.4.7) together with a frequency inverter.

[0098] In the invention called "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES", a residue is generated which is called process ash.

[0099] These ash contain the inorganic fraction present in the waste and its derivatives. The composition of the ash and its quantity will depend on the type of waste to be processed and must be characterized/classified and disposed of appropriately.

[0100] The gasifier (1.3) has the function of conditioning the material from the rotary kiln (1.2) for substoichiometric reactions to produce gas operating at average temperatures of 650°C, and, for this purpose, it is coated with ceramic material to maintain conditions at these temperatures and not be attacked by corrosive gases.

[0101] The fixed (1.3.1.1) and moving (1.3.1.2) grates of the gasifier (1.3) are made of cast iron with special alloys and have the function of pushing the materials.

[0102] According to Figure 7, the odd rows of grates are fixed (1.3.1.1) and the even rows are moving (1.3.1.2) with forward and backward movement in the direction of material flow.

[0103] As shown in Figures 7, 8 and 9, the individual grates that move the materials to be heat treated during the exothermic processes, have on their upper face a recess (1.3.1.1.1) in the form of a descending ramp, outside the travel area, that is, outside the contact area between the moving and fixed grate during the movement of the grate set.

[0104] This recess (1.3.1.1.1) allows transverse holes (1.3.1.1.2) to be made in the direction of passage of materials, reducing the possibility of passage of fine materials to the bottom of the gasifier (1.3) and/or obstruction of the holes, and also benefiting the control of the air flow given by the blower (1.3.9) for the oxidation reactions on the grate.

[0105] As shown in Figures 8 and 9, the individual grates have flaps and recesses on the side edges of the male (1.3.1.1.3) and female (1.3.1.1.4) type, in order to prevent the passage of fine materials through the gaps and also do not allow air flow.

[0106] In Figure 7 it is possible to see the assembly of the grate set (1.3.1), with the individual grates side by side and the side flaps (1.3.1.1.3) and (1.3.1.1.4) over-

lapping.

[0107] As previously stated, the number of grate lines (1.3.1.1) and (1.3.1.2) for each independent section (1.3.1), as well as the number of grates per even or odd line, depends on the processing capacity or size of each equipment, therefore, each section (1.3.1) of grates can be activated individually, according to the responses to the sets of sensors (1.5.) located on each set of grates.

[0108] The movement of the moving grates (1.3.1.2) of each section can be varied in terms of the speed of advancement and retreat as well as the time between movement activations.

[0109] The ash collectors (1.3.4) of the gasifier (1.3) have the purpose of removing ash, directing it to valves (1.3.5) that control the ash output flow.

[0110] When the valves (1.3.5) are opened, the ash falls onto a collector (1.3.6) with a screw conveyor, which directs it to the entrance of a Redler-type conveyor (1.3.8) submerged by a water seal with a level (1.3.7).

[0111] In this way, the sealing of the ash extraction is done by a water seal, ensuring that there is no false air entry.

[0112] The blower (1.3.9) is located below the grate (1.3.1), and ensures the appropriate amount of air in each section of the grate through the damper valves (1.3.10), in order to maintain controlled substoichiometric reactions in each section of the gasifier (1.3).

[0113] The gas removal duct (1.1.5.4) carries gases from the pyrolysis and gasification processes towards the combustion set (1.4).

[0114] For this flow to occur properly, the air blower (1.4.1) is controlled by a frequency inverter.

[0115] The air from the blower (1.4.1) goes to a Venturi (1.4.3) that drags the gases from the duct (1.5.5.4) towards the combustion set (1.4).

[0116] The duct closing safety valve (1.1.5.5) acts to close the duct (1.1.5.4) in case of sudden stop/emergency. In these cases of sudden stop, the safety chimney (1.1.5.3) has the purpose of evacuating the pyrolysis and gasification chambers, with the concomitant action of the chimney opening safety valve (1.1.5.2).

[0117] The combustion set (1.4) aims to condition perfect combustion of gases produced in the pyrolysis and gasification processes. It is coated with ceramic material in order to withstand temperature conditions of up to 1,400°C.

[0118] The pilot burner (1.4.5) operates only for initial heating of the chamber (1.4.8) or to act in the event of a flame extinguishing emergency.

[0119] The air blowers (1.4.6) serve to supply the concentration of air necessary for combustion, this concentration being controlled by the valve (1.4.7) and frequency inverters.

[0120] The gases produced (from pyrolysis and gasification) have a tangential entry (1.4.8.1) into the combustion chamber (1.4.8), which has this arrangement so that such gases are directed to the internal walls of the combustor in a torsional movement or swirl and, conse-

quently, increase turbulence to increase burning efficiency.

[0121] The hydraulic control unit (1.3.3) has the purpose of activating the moving grates, a set of registers with pneumatic actuators.

[0122] The valves (1.3.10) have the function of opening and closing the upward air flow in each section of the gasifier.

[0123] Therefore, the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT" receives waste and its derivatives, carries out the pyrolysis and gasification process sequentially, producing a mixture of gases with combustible contents, which we can now call "Derived Combustible Gases of Waste" (DCGW).

[0124] These gases can be submitted directly to the combustion set (1.4) and produce hot gases at temperatures around 1,200°C.

[0125] To control combustion reactions in the combustion chamber (1.4.8), pressure (1.5.1), temperature (1.5.2), and oxygen content (1.5.3) sensors are used.

[0126] The combustion chamber (1.4) is sized in terms of diameter and length so that it obtains a minimum retention time of 1.5 seconds for the gases inside the chamber at temperatures between 1,000°C and 1,400°C.

[0127] These combustion gases can be used in different ways, the most common being in industrial dryers, in industrial steam production, in Rankine cycle electrical energy production, or others that can be compatible with these characteristics.

[0128] The integrated pyrolysis and gasification **PROCESS** of waste and its derivatives is characterized by comprising the following steps:

- a) **step 1:** feed the dosing feeder process (1.1) with waste and/or its derivatives;
- b) **step 2:** dose the waste and its derivatives to be inserted into the rotary kiln set (1.2);
- c) **step 3:** by action of gases from the exothermic reactions of the gasifier set (1.3) at a temperature of around 650 °C carry out the endothermic processes of pyrolysis of waste and its derivatives in the rotary kiln set (1.2);
- d) **step 4:** direct materials that were not pyrolyzed under the conditions imposed in the rotary kiln (1.2) to the gasifier (1.3) by rotary the kiln (1.2.1);
- e) **step 5:** move the material in process in the gasifier (1.3) by the advancing and retreating action of the moving grate sets (1.3.1.2), so that they are subjected to the partial oxidation reaction with atmospheric air, used as a gasifying agent, blown by the air blower(1.3.9) in an upward flow that passes through the holes in the grates(1.3.1.1) and (1.3.1.2) to carry out the substoichiometric gasification combustion reactions, undergoing control of the predominantly substoichiometric reactions, pressure sen-

sors are used (1.5.1), temperature (1.5.2), and oxygen content (1.5.3);

f) **step 6:** concomitant with step 6, the non-gasified materials in the gasification chamber (1.3) will be pushed through the moving grates (1.3.1.2) of the grate sections (1.3.1) to the ash extractor (1.3.8), as well as The fine materials passing through the holes in the grates go through the valves (1.3.5), through the screw conveyor (1.3.6), joining the rest of the ash in the conveyor (1.3.8), passing through the water or mechanical seal (1.3.7) go outside the gasifier (1.3) avoiding false air entering the gasifier (1.3);

g) **step 7:** the gases produced in the gasifier(1.3) by the gasification reactions from the substoichiometric oxidation reaction of waste and its derivatives, will be drawn through the gas removal duct (1.1.5.4), passing through the interior of the rotary kiln(1.2.1), collaborating with the reaction in step 3 above;

h) **step 8:** the gases produced in the rotary kiln set (1.2) by pyrolytic reactions from the decomposition of waste and their derivatives, together with the gases derived from the gasification processes carried out in the gasifier (1.3) are sucked into the waste removal duct gases(1.1.5.4);

i) **step 9:** flow of the gas removal duct (1.1.5.4) which is caused by the system composed of the air blower (1.4.1), Venturi (1.4.3), which generate a Venturi effect pulling the gases;

j) **step 10:** direct the gases drawn by the Venturi effect (1.4.3) to the entrance of the combustion chamber (1.4.8.1) tangentially to the chamber (1.4.8);

k) **step 11:** concomitantly with step 10, inflate air flow, through a blower (1.4.6) and valve control (1.4.7), in the same rotational direction of the combustible gases derived from waste that enter tangentially into the combustion chamber (1.4.8) offering a minimum retention time of 1.5 seconds for gases inside the chamber at temperatures between 1,000°C and 1,400°C;

l) **step 12:** make use of the thermal energy generated.

Description of the 1st solution variant (process)

[0129] The 1st variant of the process is characterized by the fact that it comprises:

a) **step 1:** feed the dosing feeder process (1.1) with waste and/or its derivatives;

b) **step 2:** dose the waste and its derivatives to be inserted into the rotary kiln set (1.2);

c) **step 3:** by action of gases from the exothermic reactions of the gasifier set (1.3) at a temperature of around 650°C carry out the endothermic processes of pyrolysis of waste and its derivatives in the rotary kiln set (1.2);

d) **step 4:** direct materials that were not pyrolyzed

under the conditions imposed in the rotary kiln (1.2) to the gasifier (1.3) by rotary the kiln (1.2.1);

e) **step 5:** move the material in process in the gasifier (1.3) by the advancing and retreating action of the moving grate sets (1.3.1.2), so that they are subjected to the partial oxidation reaction with atmospheric air, used as a gasifying agent, blown by the air blower(1.3.9) in an upward flow that passes through the holes in the grates(1.3.1.1) and (1.3.1.2) to carry out the substoichiometric combustion reactions of gasification, undergoing control of the predominantly substoichiometric reactions, pressure sensors are used (1.5.1), temperature (1.5.2), and oxygen content (1.5.3);

f) **step 6:** concomitant with step 6, the non-gasified materials in the gasification chamber (1.3) will be pushed through the moving grates (1.3.1.2) of the grate sections (1.3.1) to the ash extractor (1.3.8), as well as The fine materials passing through the holes in the grates go through the valves (1.3.5), through the screw conveyor (1.3.6), joining the rest of the ash in the conveyor (1.3.8), passing through the water or mechanical seal (1.3.7) go outside the gasifier (1.3) avoiding false air entering the gasifier (1.3);

g) **step 7:** the gases produced in the gasifier(1.3) by the gasification reactions from the substoichiometric oxidation reaction of waste and its derivatives, will be drawn through the gas removal duct (1.1.5.4), passing through the interior of the rotary kiln(1.2.1), collaborating with the reaction in step 3 above;

h) **step 8:** the gases produced in the rotary kiln set (1.2) by pyrolytic reactions from the decomposition of waste and their derivatives, together with the gases derived from the gasification processes carried out in the gasifier (1.3) are sucked into the waste removal duct gases(1.1.5.4);

i) **step 9:** flow of the gas removal duct (1.1.5.4) which is caused by the exhaust fan (1.4.11) pulling the gases;

j) **step 10:** direct the gases drawn by the exhaust fan (1.4.11) to the combustion chamber entrance (1.4.8.1) tangentially to the chamber (1.4.8);

k) **step 11:** concomitantly with step 10, blow the only air flow into the combustion chamber (1.4) through a blower (1.4.6) and valve control (1.4.7), in the same direction as the rotation of the combustible gases derived from waste that enter tangentially into the combustion chamber (1.4.8);

l) **step 12:** make use of the thermal energy generated.

Description of the 1st solution variant (equipment)

[0130] Figure 6 shows the first variant of the invention "INTEGRATED PYROLYSIS AND GASIFICATION PROCESS OF WASTE AND ITS DERIVATIVES AND THE EQUIPMENT TO CARRY IT OUT", here called equipment(2).

[0131] In the 1st variant, equipment (2), replacing the system with Venturi (1.4.3) and blower (1.4.1), a system is used with the hot gas exhaust fan (1.4.11) with speed and flow control by frequency inverters

[0132] The exhaust fan (1.4.11) maintains constant pressure in the integrated pyrolysis and gasification processes. In this case, the combustion air injection will be made exclusively at the combustion chamber inlet, by the blower (1.4.6).

Description of the 2nd solution variant (process)

[0133] The 2nd variant of the process is characterized by the fact that it comprises:

- a) **step 1:** feed the dosing feeder process (1.1) with waste and/or its derivatives;
- b) **step 2:** dose the waste and its derivatives to be inserted into the rotary kiln set (1.2);
- c) **step 3:** by action of gases from the exothermic reactions of the gasifier set (1.3) at a temperature of around 650°C carry out the endothermic processes of pyrolysis of waste and its derivatives in the rotary kiln set (1.2);
- d) **step 4:** direct materials that were not pyrolyzed under the conditions imposed in the rotary kiln (1.2) to the gasifier (1.3) by rotary the kiln (1.2.1);
- e) **step 5:** move the material in process in the gasifier (1.3) by the advancing and retreating action of the moving grate sets (1.3.1.2), so that they are subjected to the partial oxidation reaction with atmospheric air, used as a gasifying agent, blown by the air blower(1.3.9) in an upward flow that passes through the holes in the grates (1.3.1.1) and (1.3.1.2) to carry out the substoichiometric combustion reactions of gasification, undergoing control of the predominantly substoichiometric reactions, pressure sensors are used (1.5.1), temperature (1.5.2), and oxygen content (1.5.3);
- f) **step 6:** concomitant with step 6, the non-gasified materials in the gasification chamber (1.3) will be pushed through the moving grates (1.3.1.2) of the grate sections (1.3.1) to the ash extractor (1.3.8), as well as The fine materials passing through the holes in the grates go through the valves (1.3.5), through the screw conveyor (1.3.6), joining the rest of the ash in the conveyor (1.3.8), passing through the water or mechanical seal (1.3.7) go outside the gasifier (1.3) avoiding false air entering the gasifier (1.3);
- g) **step 7:** the gases produced in the gasifier(1.3) by the gasification reactions from the substoichiometric oxidation reaction of waste and its derivatives, will be drawn through the gas removal duct(1.1.5.4), passing through the interior of the rotary kiln(1.2.1), collaborating with the reaction in step 3 above;
- h) **step 8:** the gases produced in the rotary kiln set (1.2) by pyrolytic reactions from the decomposition of waste and their derivatives, together with the gases

derived from the gasification processes carried out in the gasifier (1.3) are sucked into the waste removal duct gases(1.1.5.4);

i) **step 9:** flow of the gas removal duct (1.1.5.4) which is caused by the exhaust fan (1.4.11) pulling the gases;

j) **step 10:** direct the gases drawn by the exhaust fan (1.4.11) to the treatment and separation system for combustible fractions, and sent to various energy use processes.

Description of the 2nd solution variant (equipment)

[0134] As shown in figure 7, the second variant is configured by the equipment(3) not combusting gases directly at the system outlet with Venturi(1.4.3) of the best proposed solution or at the exhaust fan outlet(1.4.11) of the first variant.

[0135] In the 2nd variant, equipment (3), combustible gases derived from waste will be sent to the outlet (1.4.15) by an exhaust fan (1.411) controlled by a frequency inverter.

[0136] These combustible gases derived from waste must be used in a treatment and separation system for combustible fractions, and sent to various energy recovery processes.

[0137] This is another possibility of using "Combustible Gases Derived from Waste" (CGDW), where they are subjected to treatment and separation processes into combustible fractions such as oils and gases. The treatment must be in accordance with the uses, such as burning in engines, direct burning in gas turbines, obtaining fuel oils, among others.

Industrial application

[0138] The present invention is from the waste treatment and energy recovery industry sector.

Claims

1. Integrated pyrolysis and gasification **PROCESS** of waste and its derivatives **characterized by** comprising the following steps:

- a) **step 1:** feed the dosing feeder process (1.1) with waste and/or its derivatives;
- b) **step 2:** dose the waste and its derivatives to be inserted into the rotary kiln set (1.2);
- c) **step 3:** by action of gases from the exothermic reactions of the gasifier set (1.3) at a temperature of around 650 °C carry out the endothermic processes of pyrolysis of waste and its derivatives in the rotary kiln set (1.2);
- d) **step 4:** direct materials that were not pyrolyzed under the conditions imposed in the rotary kiln (1.2) to the gasifier (1.3) by rotating the kiln

(1.2.1);

e) **step 5:** move the material in process in the gasifier (1.3) by the advancing and retreating action of the moving grate sets (1.3.1.2), so that they are subjected to the partial oxidation reaction with atmospheric air, used as a gasifying agent, blown by the air blower(1.3.9) in an upward flow that passes through the holes(1.3.1.1.2) of the grates(1.3.1.1) and (1.3.1.2) to carry out the substoichiometric gasification combustion reactions, undergoing control of the predominantly substoichiometric reactions, pressure (1.5.1), temperature (1.5.2), and oxygen content (1.5.3) sensors are used;

f) **step 6:** concomitant with step 6, the non-gasified materials in the gasification chamber (1.3) will be pushed through the moving grates (1.3.1.2) of the grate sections (1.3.1) to the ash extractor (1.3.8), as well as the fine materials that pass through the holes(1.3.1.1.2) in the grates go through the valves(1.3.5), through the screw conveyor(1.3.6), joining the rest of the ash in the conveyor(1.3.8), passing through the water or mechanical seal (1.3.7) to the outside of the gasifier (1.3) avoiding false air entering the gasifier (1.3);

g) **step 7:** the gases produced in the gasifier(1.3) by the gasification reactions from the substoichiometric oxidation reaction of waste and its derivatives, will be drawn through the gas removal duct (1.1.5.4), passing through the interior of the rotary kiln(1.2.1), collaborating with the reaction in step 3 above;

h) **step 8:** the gases produced in the rotary kiln set (1.2) by pyrolytic reactions from the decomposition of waste and their derivatives, together with the gases derived from the gasification processes carried out in the gasifier (1.3) are sucked into the waste removal duct gases(1.1.5.4);

i) **step 9:** flow of the gas removal duct (1.1.5.4), which is caused by the system composed of the air blower (1.4.1) and Venturi (1.4.3), generating a Venturi effect pulling the gases;

j) **step 10:** direct the gases drawn by the Venturi effect (1.4.3) to the entrance of the combustion chamber (1.4.8.1) tangentially to the chamber (1.4.8);

k) **step 11:** concomitantly with step 10, inflate air flow, through a blower (1.4.6) and valve control (1.4.7), in the same rotational direction of the combustible gases derived from waste that enter tangentially into the combustion chamber (1.4.8) offering a minimum retention time of 1.5 seconds for gases inside the chamber at temperatures between 1,000°C and 1,400°C;

l) **step 12:** use the thermal energy generated at the output (1.4.9).

2. **EQUIPMENT(1)** integrated for pyrolysis and gasification of waste and its derivatives, for carrying out the process described in claim 1, **characterized by** the fact that it comprises the set for feeding and dosing material and removing gases (1.1), rotary pyrolysis set (1.2), the gasification set (1.3) and the combustion set of the gases generated (1.4).

3. **Material feeder and doser and gas removal set (1.1)**, according to claim 2, **characterized by** comprising:

- a) feeder(1.1.1);
- b) upper hopper(1.1.2);
- c) valve (1.1.3) to control the material input volume;
- d) lower hopper(1.1.4);
- e) pyrolysis rotary kiln feeder (1.1.5) comprising:

- body(1.1.5.1), with hopper(1.1.5.1.1)
- emergency valve(1.1.5.2);
- safety chimney(1.1.5.3);
- combustible gas outlet duct (1.1.5.4);
- emergency valve (1.1.5.5);
- feeder/ rotary kiln seal(1.1.5.6);

4. **Rotary pyrolysis kiln set (1.2)**, according to claim 2, **characterized by** comprising:

a) rotary kiln (1.2.1) comprising:

- body(1.2.1.1);
- tracks(1.2.1.2);

b) gear motor (1.2.2) to drive the kiln rotation;

c) set of sensors (1.5) comprising:

- pressure transmitter (1.5.1);
- temperature transmitter(1.5.2);
- O₂ analyzer and transmitter (1.5.3).

5. **Gasification set (1.3)** according to claim 2, **characterized by** comprising:

a) sections (1.3.1), comprising:

- fixed grates (1.3.1.1) with:

- i) ramp(1.3.1.1.1);
- ii) horizontal holes (1.3.1.1.2), and;
- iii) sliding-fitting lower flap (1.3.1.1.3), and;
- iv) sliding-fitting top flap(1.3.1.1.4);

- moving grates (1.3.1.2) with:

- i) ramp(1.3.1.1.1);
- ii) horizontal holes (1.3.1.1.2), and;

- iii) sliding-fitting lower flap (1.3.1.1.3),
and;
iv) sliding-fitting top flap(1.3.1.1.4);
- b) hydraulic activation of the moving grates (1.3.2) of the moving grates (1.3.1.2) of each section (1.3.1); 5
- c) hydraulic power plant with pump and reservoir (1.3.3);
- d) ash collectors (1.3.4); 10
- e) valves for ash collection (1.3.5);
- f) ash screw conveyor (1.3.6);
- g) water seal(1.3.7);
- h) Redler type conveyor(1.3.8);
- i) blower(1.3.9); 15
- j) blown air damper valves (1.3.10);
- k) gasifier/ rotary kiln seal(1.3.11)
- l) level sensor/switch(1.3.12);
- m) Sensor sets (1.5) on each section (1.3.1) comprising: 20
- pressure transmitters (1.5.1);
 - temperature transmitters (1.5.2);
 - O₂ analyzers and transmitters (1.5.3);
 - pressure transmitters (1.5.1) under each set of grates (1.3.1). 25
- 6. Generated gas combustion set (1.4)**, according to claim 2, **characterized by** comprising: 30
- a) extraction fan (1.4.1);
- b) Venturi(1.4.3);
- c) recovery gas supply line (1.4.4);
- d) pilot burner for startup (1.4.5);
- e) burner fan(1.4.6); 35
- f) damper valve(1.4.7);
- g) combustion chamber (1.4.8) comprising tangential inlet of produced gases (1.4.8.1);
- h) hot gas outlet (1.4.9);
- i) natural gas or LPG input line for startup (1.4.10); 40
- j) set of sensors (1.5) comprising:
- pressure transmitter (1.5.1);
 - temperature transmitter(1.5.2); 45
 - O₂ analyzer and transmitter (1.5.3).
- 7. Integrated PROCESS** for pyrolysis and gasification of waste and its derivatives, according to claim 1, **characterized by** presenting the first variant of the process comprising the following steps: 50
- a) **step 1:** feed the dosing feeder process (1.1) with waste and/or its derivatives;
- b) **step 2:** dose the waste and its derivatives to be inserted into the rotary kiln set (1.2); 55
- c) **step 3:** by action of gases from the exothermic reactions of the gasifier set (1.3) at a tempera-

ture of around 650°C carry out the endothermic processes of pyrolysis of waste and its derivatives in the rotary kiln set (1.2);

d) **step 4:** direct materials that were not pyrolyzed under the conditions imposed in the rotary kiln (1.2) to the gasifier (1.3) by rotating the kiln (1.2.1);

e) **step 5:** move the material in process in the gasifier(1.3) by the advancing and retreating action of the moving grate sets(1.3.1.2), so that they are subjected to the partial oxidation reaction with atmospheric air, used as a gasifying agent, blown by the air blower(1.3.9) in an upward flow that passes through the holes in the grates(1.3.1.1) and (1.3.1.2) to carry out the substoichiometric combustion reactions of gasification, undergoing control of the predominantly substoichiometric reactions, pressure sensors are used (1.5.1), temperature (1.5.2), and oxygen content (1.5.3);

f) **step 6:** concomitant with step 6, the non-gasified materials in the gasification chamber (1.3) will be pushed through the moving grates (1.3.1.2) of the grate sections (1.3.1) to the ash extractor (1.3.8), as well as the fine materials passing through the holes in the grates go through the valves (1.3.5), through the screw conveyor (1.3.6), joining the rest of the ash in the conveyor (1.3.8), passing through the water or mechanical seal (1.3.7) go outside the gasifier (1.3) avoiding false air entering the gasifier (1.3);

g) **step 7:** the gases produced in the gasifier(1.3) by the gasification reactions from the substoichiometric oxidation reaction of waste and its derivatives, will be drawn through the gas removal duct(1.1.5.4), passing through the interior of the rotary kiln(1.2.1), collaborating with the reaction in step 3 above;

h) **step 8:** the gases produced in the rotary kiln set (1.2) by pyrolytic reactions from the decomposition of waste and their derivatives, together with the gases derived from the gasification processes carried out in the gasifier (1.3) are sucked into the waste removal duct gases(1.1.5.4);

i) **step 9:** flow of the gas removal duct (1.1.5.4) which is caused by the exhaust fan (1.4.11) pulling the gases;

j) **step 10:** direct the gases drawn by the exhaust fan (1.4.11) to the combustion chamber entrance (1.4.8.1) tangentially to the chamber (1.4.8);

k) **step 11:** concomitantly with step 10, blow the only air flow into the combustion chamber (1.4) through a blower (1.4.6) and valve control (1.4.7), in the same direction as the rotation of the combustible gases derived from waste that enter tangentially into the combustion chamber

- (1.4.8);
 l) **step 12**: make use of the thermal energy generated.
8. **EQUIPMENT (2)** integrated for pyrolysis and gasification of waste and its derivatives, for carrying out the process described in claim 7, **characterized by the fact that** it is presented as the first variant of the equipment (1) given in claim 2, comprising replacing the system with Venturi (1.4.3) and blower (1.4.1) by an exhaust fan (1.4.11) of hot gases with speed and flow control by frequency inverters, with combustion air being injected exclusively at the inlet of the combustion chamber, through the blower (1.4.6).
9. Integrated **PROCESS** for pyrolysis and gasification of waste and its derivatives, according to claim 1, **characterized by** presenting the second variant of the process comprising the following steps:
- a) **step 1**: feed the dosing feeder process (1.1) with waste and/or its derivatives;
 b) **step 2**: dose the waste and its derivatives to be inserted into the rotary kiln set (1.2);
 c) **step 3**: by action of gases from the exothermic reactions of the gasifier set (1.3) at a temperature of around 650°C carry out the endothermic processes of pyrolysis of waste and its derivatives in the rotary kiln set (1.2);
 d) **step 4**: direct materials that were not pyrolyzed under the conditions imposed in the rotary kiln (1.2) to the gasifier (1.3) by rotating the kiln (1.2.1);
 e) **step 5**: move the material in process in the gasifier(1.3) by the advancing and retreating action of the moving grate sets(1.3.1.2), so that they are subjected to the partial oxidation reaction with atmospheric air, used as a gasifying agent, blown by the air blower(1.3.9) in an upward flow that passes through the holes in the grates (1.3.1.1) and (1.3.1.2) to carry out the substoichiometric combustion reactions of gasification, undergoing control of the predominantly substoichiometric reactions, pressure sensors are used (1.5.1), temperature (1.5.2), and oxygen content (1.5.3);
 f) **step 6**: concomitant with step 6, the non-gasified materials in the gasification chamber (1.3) will be pushed through the moving grates (1.3.1.2) of the grate sections (1.3.1) to the ash extractor (1.3.8), as well as the fine materials passing through the holes in the grates go through the valves (1.3.5), through the screw conveyor (1.3.6), joining the rest of the ash in the conveyor (1.3.8), passing through the water or mechanical seal (1.3.7) go outside the gasifier (1.3) avoiding false air entering the gasifier (1.3);
 g) **step 7**: the gases produced in the gasifier(1.3) by the gasification reactions from the substoichiometric oxidation reaction of waste and its derivatives, will be drawn through the gas removal duct (1.1.5.4), passing through the interior of the rotary kiln (1.2.1), collaborating with the reaction in step 3 above;
 h) **step 8**: the gases produced in the rotary kiln set (1.2) by pyrolytic reactions from the decomposition of waste and their derivatives, together with the gases derived from the gasification processes carried out in the gasifier (1.3) are sucked into the waste removal duct gases(1.1.5.4);
 i) **step 9**: flow of the gas removal duct (1.1.5.4) which is caused by the exhaust fan (1.4.11) pulling the gases;
 j) **step 10**: direct the gases drawn by the exhaust fan (1.4.11) to the treatment and separation system for combustible fractions, and sent to various energy use processes.
10. **EQUIPMENT (3)** integrated for pyrolysis and gasification of waste and its derivatives, for carrying out the process described in claim 9, **characterized by** the fact that it is presented as a second variant of the equipment (1) given in claim 2, comprising exhaust fan (1.4.1) and absence of a combustion chamber (1.4) and direction of the gases drawn by the exhaust fan (1.4.11) to the treatment and separation system for combustible fractions, and sent to various energy use processes.

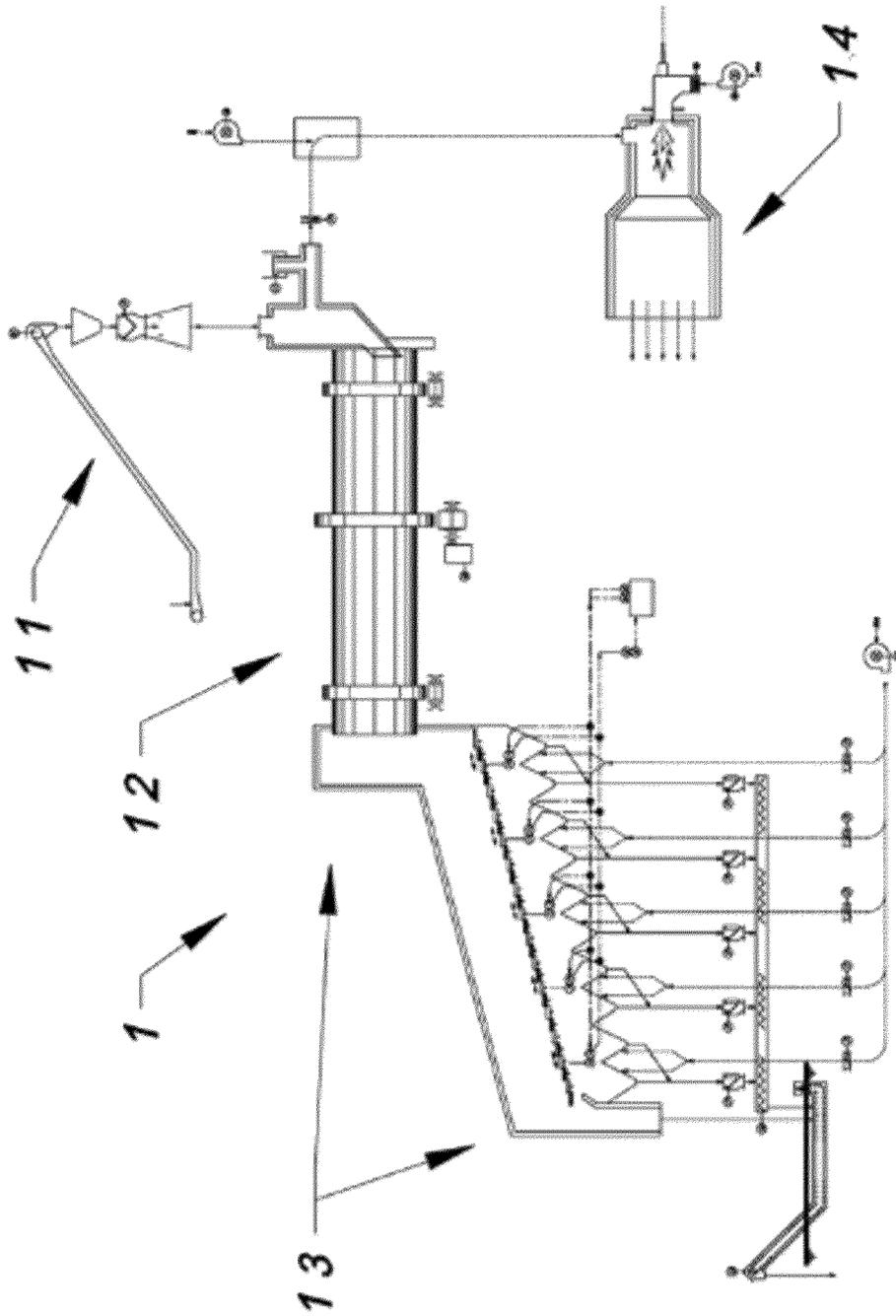


FIG. 1

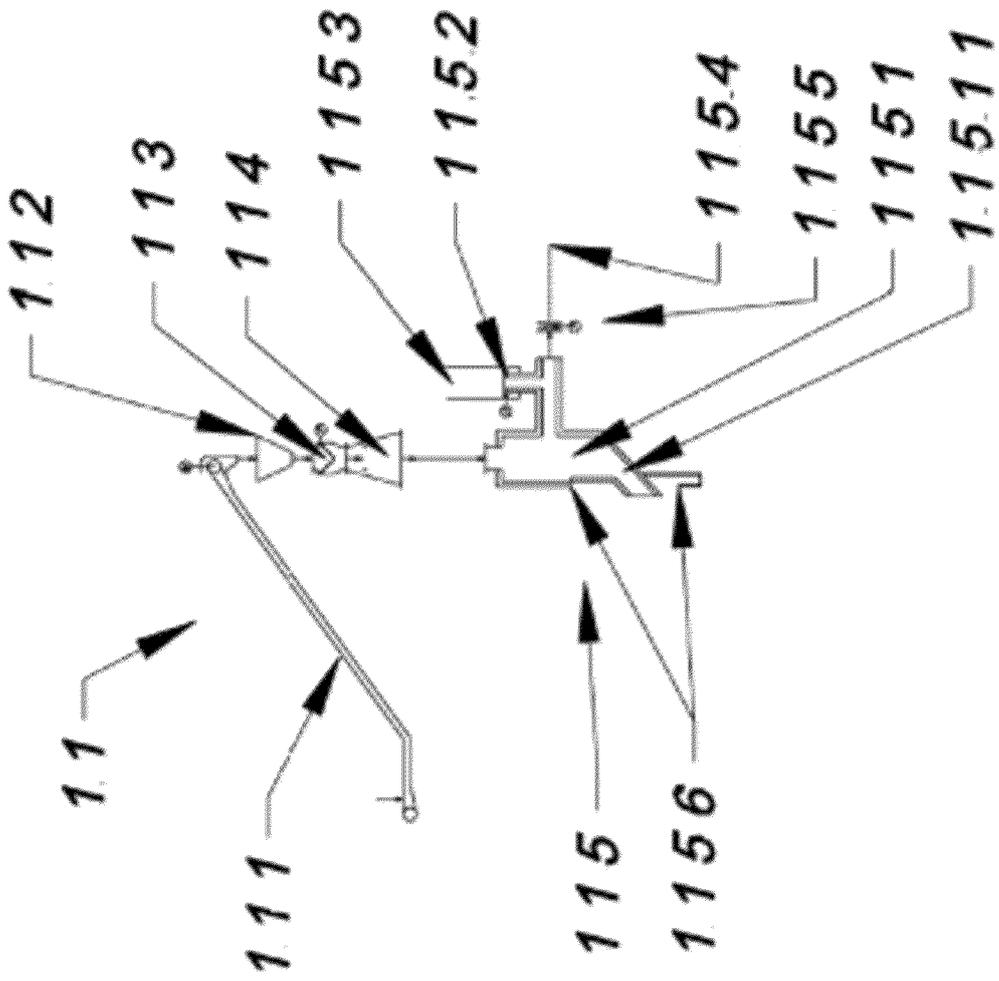


FIG. 2

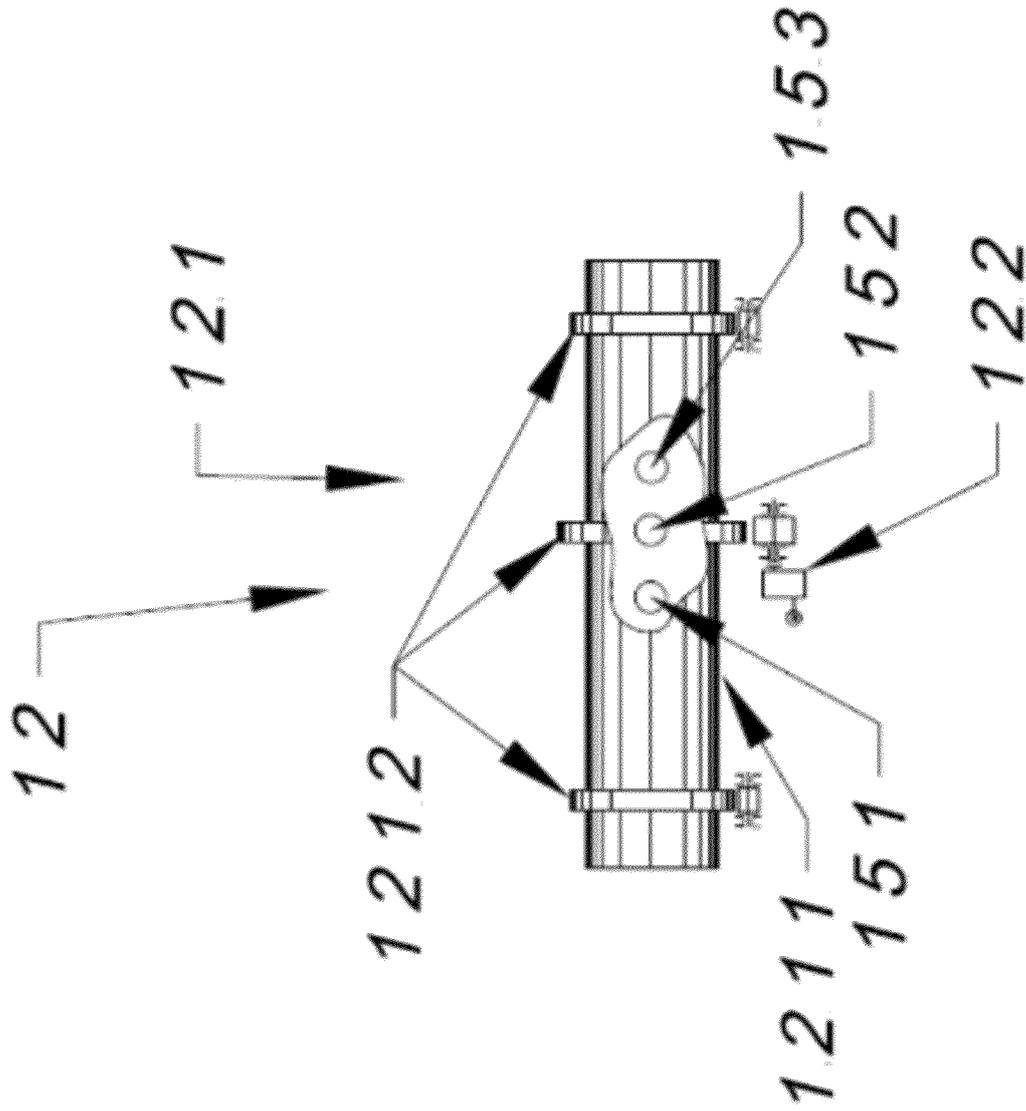


FIG. 3

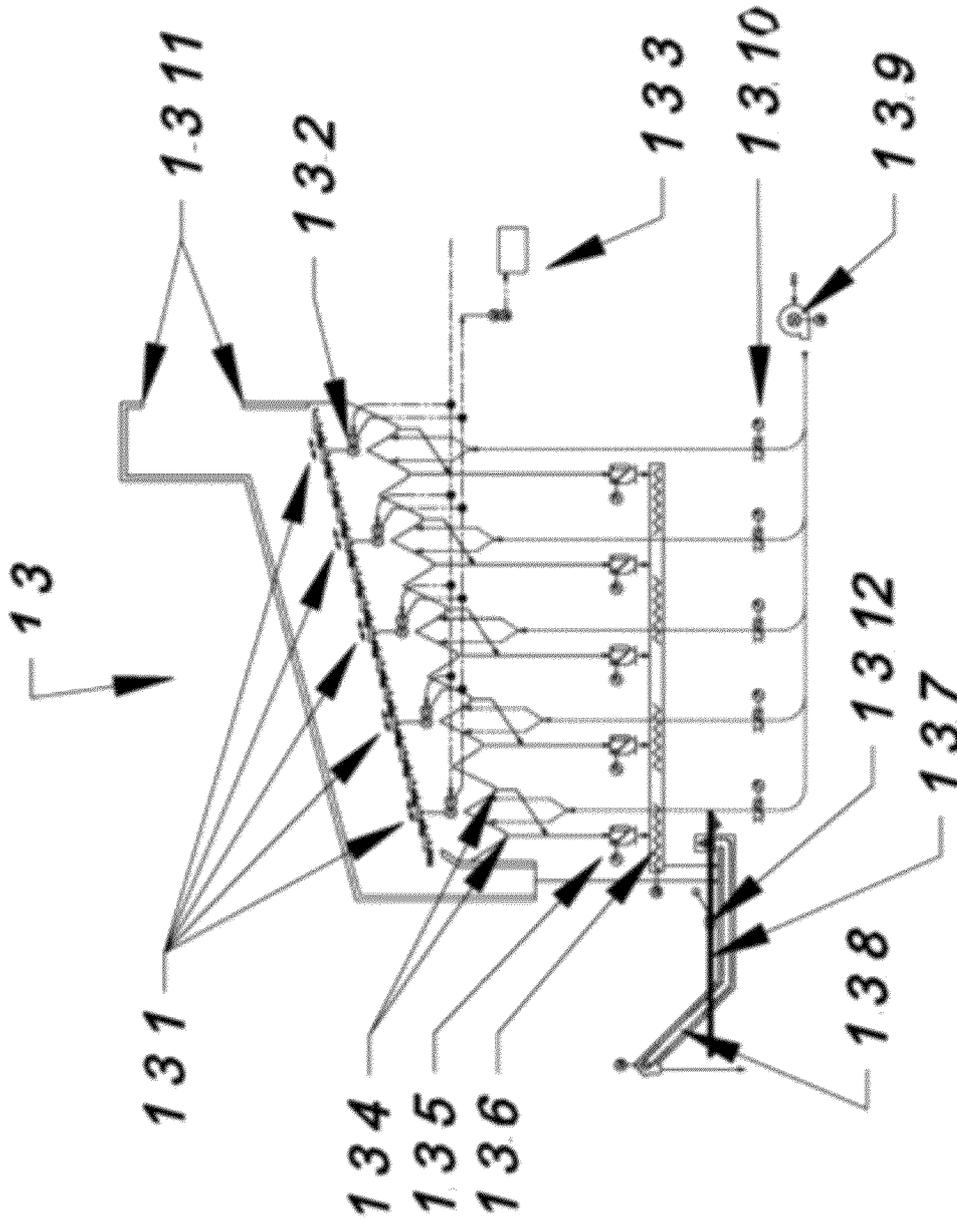


FIG. 4

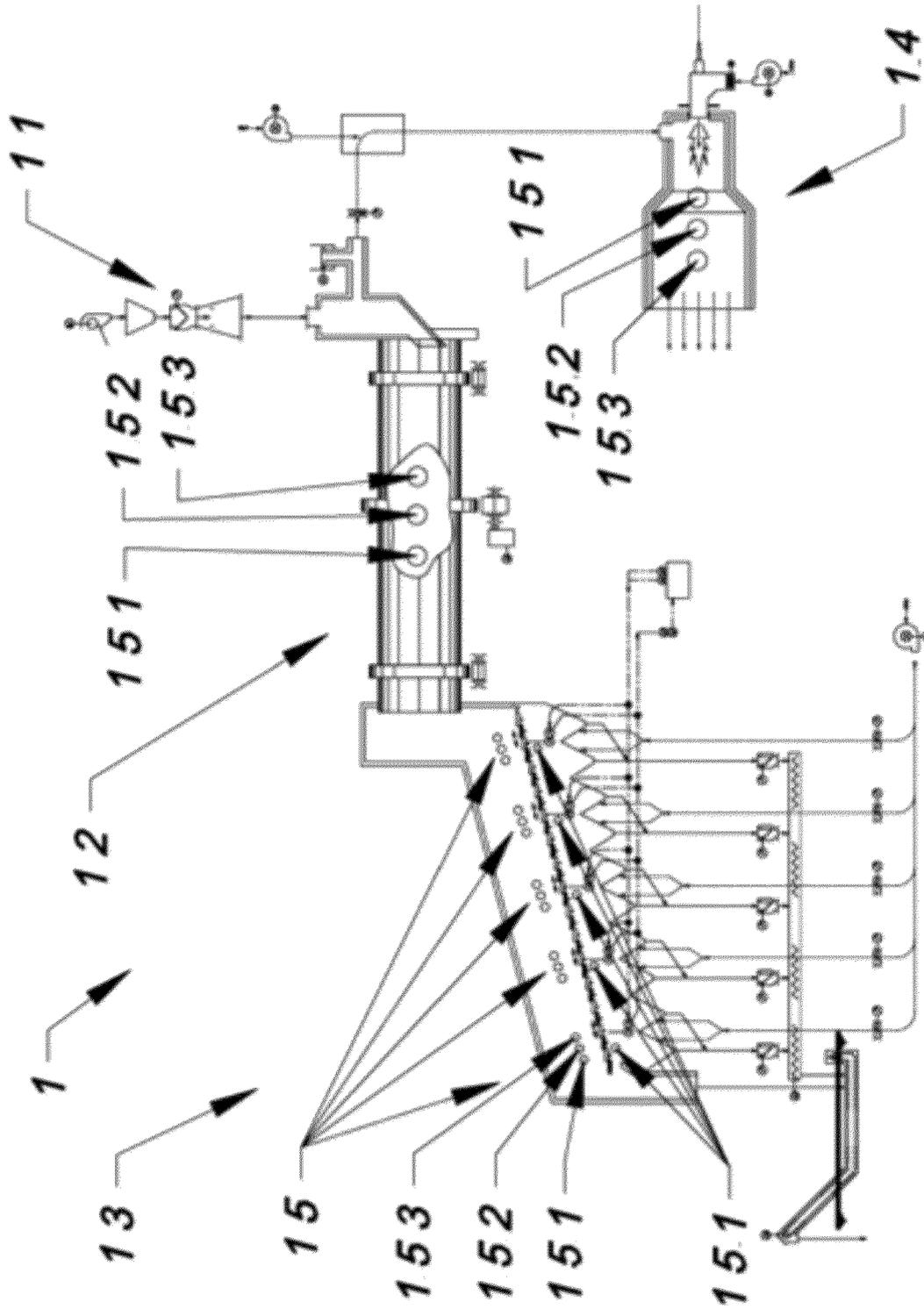


FIG. 6

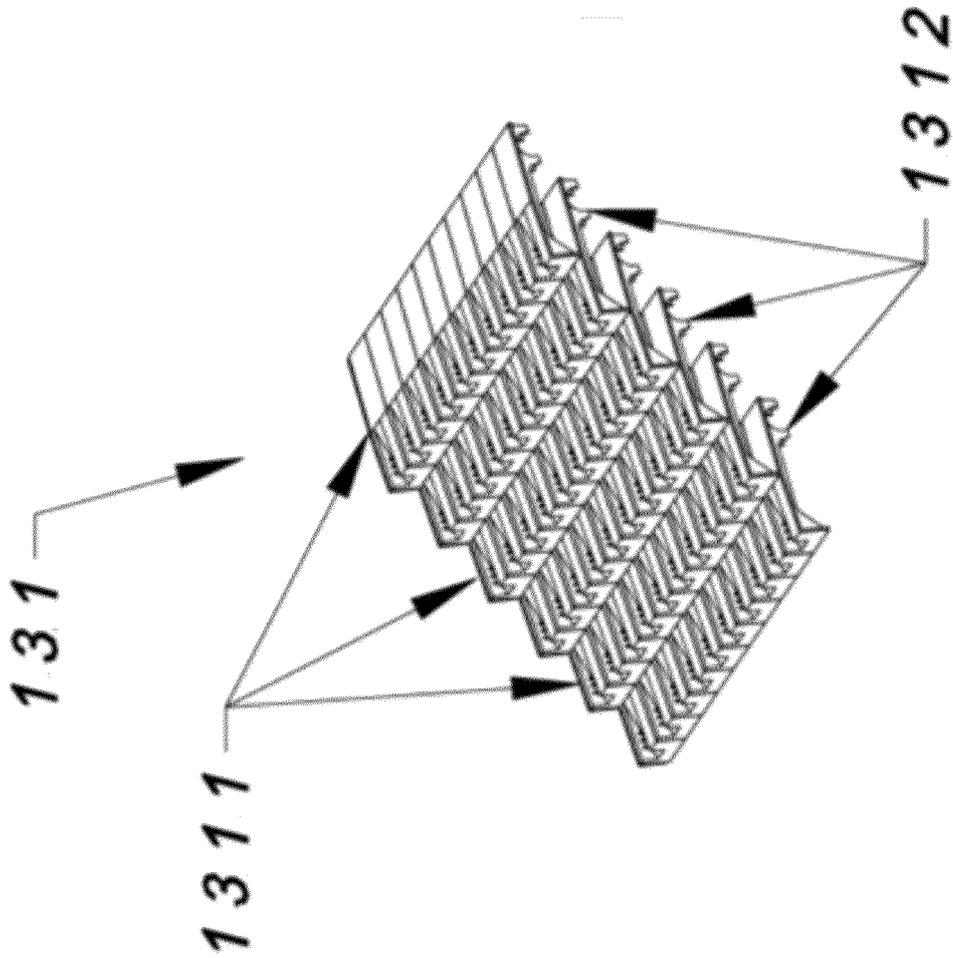


FIG. 7

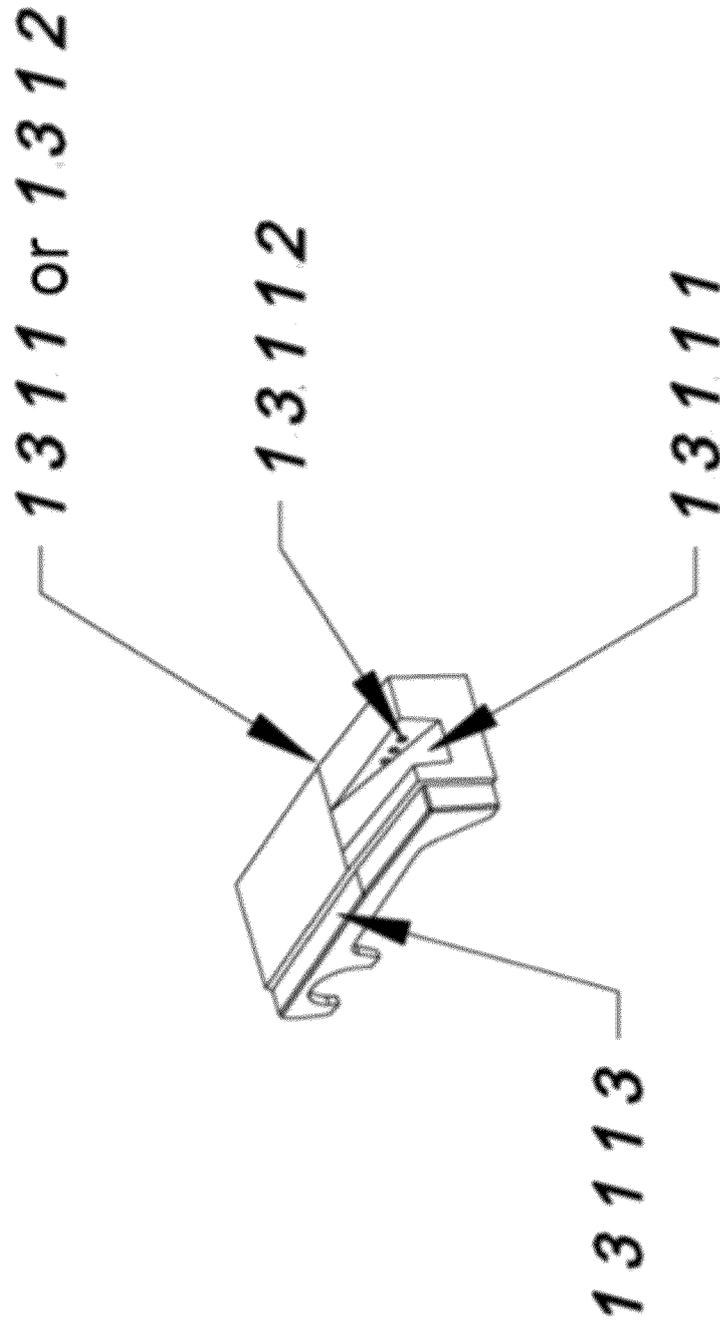


FIG. 8

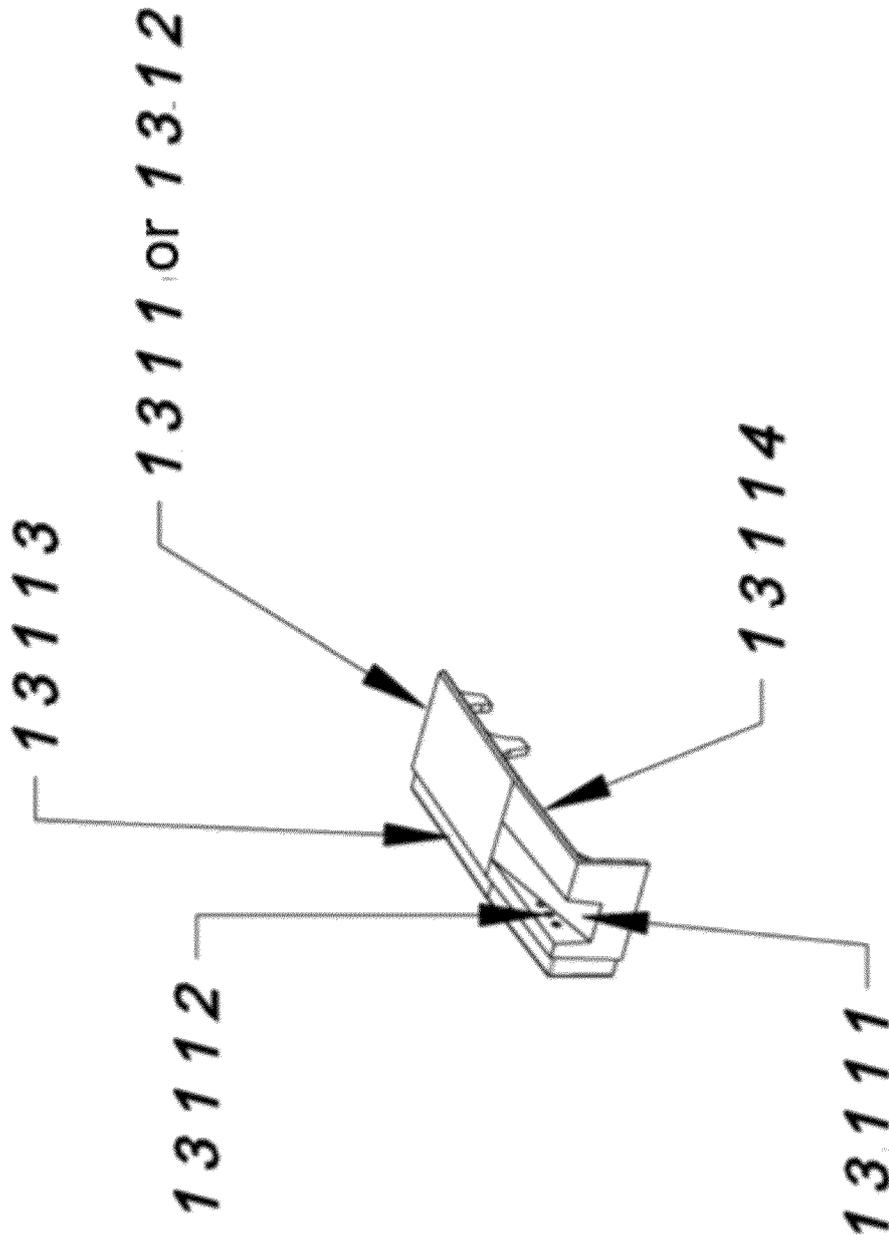


FIG. 9

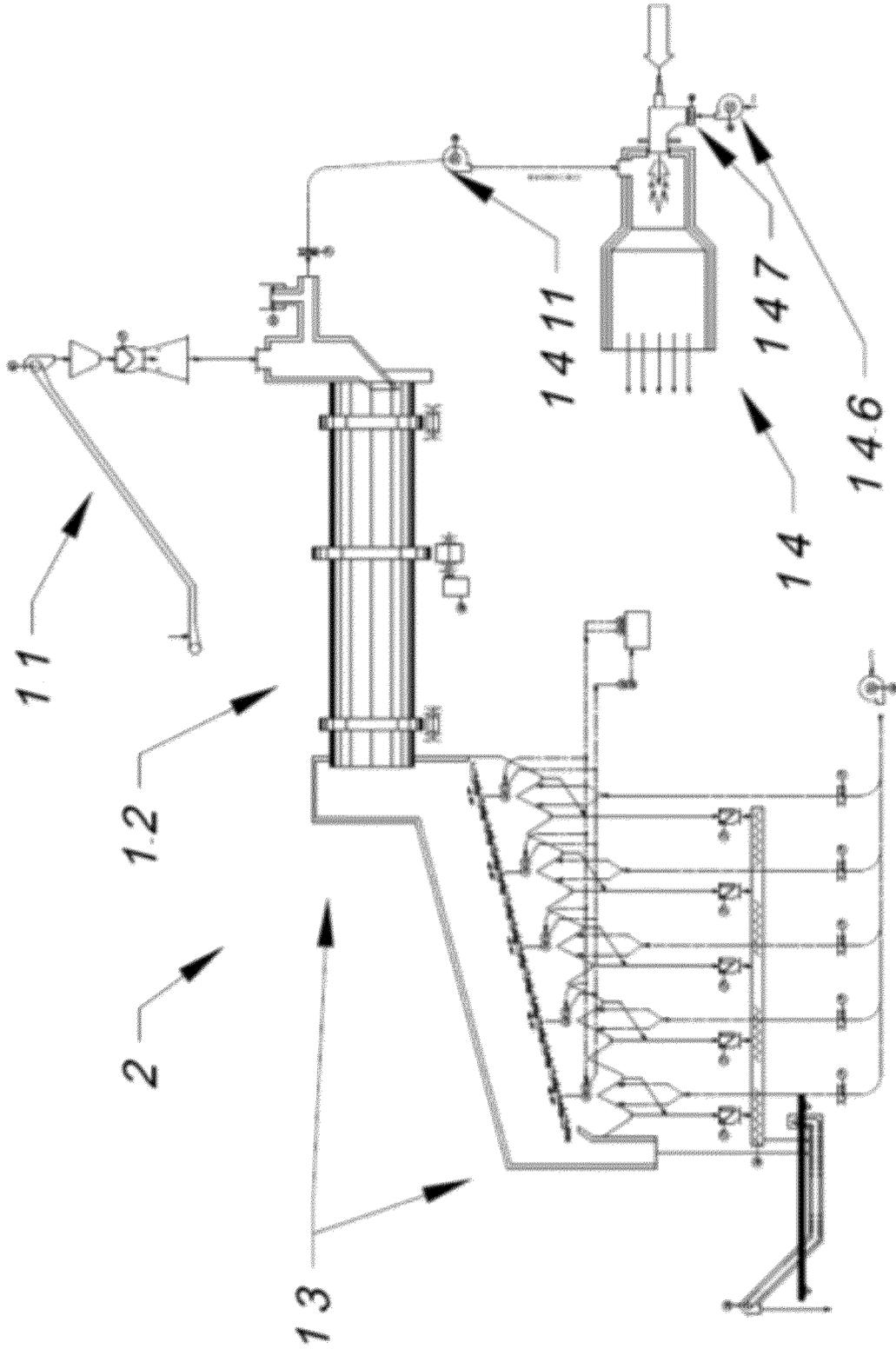


FIG. 10

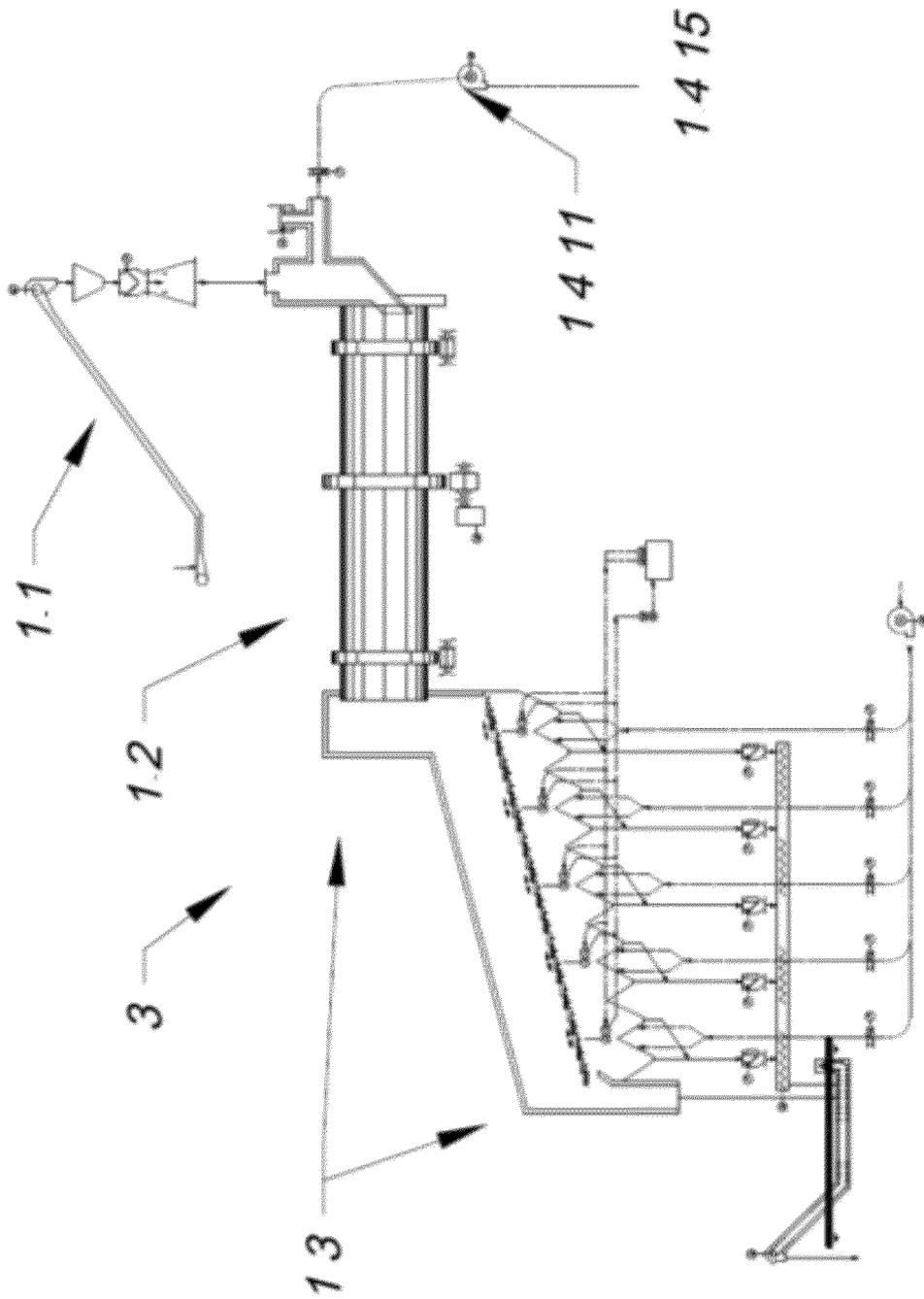


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/BR2023/050030

5	A. CLASSIFICATION OF SUBJECT MATTER	
	C10B 31/04 (2006.01)i; C10B 47/30 (2006.01)i; C10B 51/00 (2006.01)i; C10B 53/07 (2006.01)i; C10B 57/02 (2006.01)i CPC: C10B31/04; C10B47/30; C10B51/00; C10B53/07; C10B57/02;	
10	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) C10B CPC: C10B	
15	Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Banco de Patentes do INPI - BR, Portal CAPES	
	Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) STN (CNFULL, CAPLUS, USPATFULL, SCISEARCH, PCTFULL, COMPENDEX), DERWENT	
20	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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40	<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.	
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45	"A" document defining the general state of the art which is not considered to be of particular relevance	"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
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	"P" document published prior to the international filing date but later than the priority date claimed	
50	Date of the actual completion of the international search 24 April 2023	Date of mailing of the international search report 05 May 2023
55	Name and mailing address of the ISA/BR National Institute of Industrial Property (Brazil) Rua Mayrink Veiga, 9, 6º andar, CEP 20.090-910 Rio de Janeiro – RJ Brazil	Authorized officer Rosana Marques Amorim
	Telephone No. (55 21) 3037-3742, 3037-3984	Telephone No. +55 21 3037 4528 - 3037 3319

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Information on patent family members

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