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(71) Applicants:
• **Bordonzotti, Ivan**
6835 Morbio Superiore (CH)
• **Antonioli, Giuseppe**
6500 Bellinzona (CH)

• **Berti, Francesco**
55049 Viareggio (LU) (IT)

(72) Inventors:
• **Bordonzotti, Ivan**
6835 Morbio Superiore (CH)
• **Antonioli, Giuseppe**
6500 Bellinzona (CH)
• **Berti, Francesco**
55049 Viareggio (LU) (IT)

(74) Representative: **Fiammenghi, Alessandro**
Fiammenghi - Fiammenghi
15, Via San Gottardo
6900 Lugano (CH)

(54) **PROCESS AND PLANT FOR TRANSFORMING COMBUSTIBLE MATERIALS IN CLEAN GAS WITHOUT TARs**

(57) Plant for transforming of combustible materials in tar-free clean gas, said plant comprising:

- a pyrolysis reactor (20) suitable for being supplied on one inlet (40) by means of said combustible materials, said pyrolysis reactor (20) being at least partially installed in a first chamber (30) thermally insulated and being touched in use by gases of combustion of pyrolysis gases produced by said pyrolysis reactor (20), and wherein said pyrolysis reactor (20) outgoing produces char ;
- a flow generation chamber (140) underlying said first chamber (30) thermally insulated and communicating with it, wherein said flow generation chamber (140) has inlet nozzles (220) supplied with pyrolysis gases produced by said pyrolysis reactor (20);
- an anoxic decarburization unit (100) having first inlet means (80) supplied with said outbound char produced by said pyrolysis reactor (20) and having second inlet means, directly connected with said flow generation chamber (140); wherein in said flow generation chamber (140) takes place a stoichiometric or overstoichiometric combustion of part of said pyrolysis gases in a burner (210), wherein the resting part of said pyrolysis gases supplied with said inlet nozzles (220) is then blended with the products of said combustion thus obtaining a hot flow totally oxygen-free and wherein are completely burned the tars contained in said pyrolysis gases.

The invention comprises furthermore the associated proceeding.

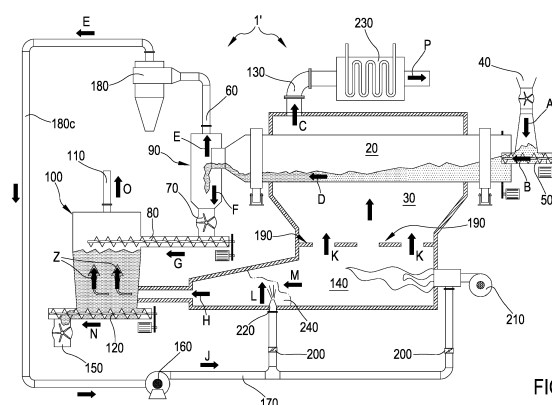


FIG.2

Description

Field of the invention

[0001] The present invention concerns the field of the transformation of combustible materials.

[0002] In detail, the present invention concerns a plant for the transformation of combustible materials in tar-free clean gas.

[0003] The present invention further concerns a proceeding for transforming of combustible materials in tar-free clean gas.

Background art

[0004] The present invention concerns the field of proceedings and of the plants used for transforming combustible materials based on molecules containing at least carbon and hydrogen (such as for example biomasses, municipal waste, plastics, tires, car fluff, ...) in clean combustible gas and inert residual.

[0005] As it is well known by field technicians, the clean combustible gas can be obtained thanks to known processes of pyrolysis, gasification or pyrogasification also if, however, the quality of products, in particular regarding the produced gas, is usually so unsatisfactory that it requires before its use complex treatment systems.

[0006] Obtaining a clean gas, therefore free from condensable substances, called by field technicians "tars" and from dusts, is a necessary condition for its use as combustible in engines or turbines, therefore for the generation of electricity, or as basic substance for the production of liquid combustibles, of synthetic natural gas or other products of the synthesis.

[0007] While the dust of the gas can be completely removed through simple filtration, the removal of tars necessitates more complex systems and usually generates underproducts of difficult and expensive disposal.

[0008] On the market there are different processes and plants of conversion of a combustible or more generally of a solid material containing at least carbon and hydrogen into useful gas.

[0009] There are direct proceedings of conversion of a solid combustible into gas, such as for example the gasification or the sole pyrolysis, but here are not examined since, if necessary, they represent only a part of the overall proceeding object of the patent application.

[0010] Into the majority of cases the best proceeding carried out according to the known technique consists in a first phase of pyrolysis followed by a phase of gasification and/or of combustion. The punctually required heat in the process is generated through combustion (oxidation) of a part of the combustible (material) to be treated or of a part of products generated by it.

[0011] Sometimes different proceedings use similar equipments also if the proceedings together evaluated as a whole are different among them.

[0012] The process of pyrolysis, globally used, is a val-

id example of what has been assessed before.

[0013] From document EP0976806 it is known a plant of production of syngas, which shows that the material to be treated, typically municipal waste, is pushed through a press through a conduit in which it is compressed. This conduit is externally heated by hot fumes of combustions burning part of the gas produced by the process. The material that finds itself here, at least in part, undergoes the pyrolysis.

[0014] The vapors and the gas produced by this partial pyrolysis exit then from the ending part of the conduit together with the partially charred material ("pyrolyzed"). This conduit, horizontally positioned is directly connected to a vertical chamber. The scope of this chamber is the complete gasification and combustion of the partially charred material deriving from said conduit. This process takes place by injecting oxygen into the chamber in under-stoichiometric quantities (lower than what is necessary to burn all the material). The gas produced by the gasification is blended with the pyrolysis gases and the vapors exiting from the conduit of pyrolysis. This gas mix is extracted to the top of the chamber of gasification.

[0015] Therefore, the plant aforementioned does not allow to obtain a process of creation of gas without the production of tars.

[0016] The incombustible part of gasified material, due to the high temperatures that exist into the zone (1800°C and more), blend and collect on the bottom of the chamber of gasification where they are then extracted, always in the liquid state, through a siphon that has the scope of keeping insulated the inner from the environment. The inert liquids that exit from the siphon are then vitrified through water hardening.

[0017] From document CH697942 the material to be treated is directed through an inlet 4 provided with means suitable for ensuring its watertight integrity respective to the surrounding environment. Downstream to said inlet 4 is installed a supply equipment 5 that conveys the material (arrow B) toward the inner of a pyrolysis reactor, constituted by a sheathed rotating drum 2, walls thereof are touched by fumes of combustion that go through the space comprised between said rotating drum 2 and a chamber 3 thermally insulated that contains it, exiting (arrow C) through an exhaust conduit 13. These fumes release much of their heat to the pyrolysis reactor 2, within which the material to be treated, reaching temperatures around 400-500°C, undergoes a process of pyrolysis transforming itself into into gas and char.

[0018] While the pyrolysis gases exits (arrow E) through an outlet conduit 6 the char displaces (arrow D) towards a chamber of gasification 9 wherein deposits (arrow F) and wherein, blowing comburent gas (oxygen, air, air enriched of oxygen and/or vapor), is obtained the partial combustion with relative partial gasification of said char of pyrolysis.

[0019] While the syngas produced exits together with pyrolysis gases (arrow E) through the already described outlet conduit 6, the not gasified char moves (also for

gravity) through a by-pass plant 7, provided with means of extraction 8 that deposit it (arrow G) on a post-combustion grid 10 located into the zone lower than said thermally insulated chamber 3 containing the pyrolysis reactor 2 wherein it is burned generating the fumes necessary for the heating of the rotating drum 2 and ashes then removed by means of an extraction equipment 12 of a known type, for example of auger-type as shown in the drawing.

[0020] Also the plant described in the patent CH697 942 does not allow to obtain a gas production without non-oxidized solid residuals and free from unburned materials.

[0021] The documents US2007/0163176 (only reactor of combustion and gasification) and WO 95/21903, show a plant and a process of production of gas, wherein provides for a first phase of transformation of the material to be treated in char and gas containing tars through pyrolysis in a specific reactor and then the subsequent gasification of the char in a special gasifier of bed type displaced using as gasification medium the fumes obtained by the combustion in under-stoichiometric conditions of all the pyrolysis gas obtained into the previous phase and using pure oxygen as comburent. The reaction between the fumes of combustion and the char generates the syngas.

[0022] The use of oxygen as comburent allows reaching very high fumes temperatures that should melt the inert materials contained in the char that are then extracted in the form of melted slag. In detail, it is to be noted that in the original patent (WO 95/21903) the sensible heat contained in the produced syngas (with temperature between 800-900°C) is retrieved for supplying the heat necessary to the drying and to the pyrolysis of the material to be treated.

[0023] Also these two documents show the drawback of producing oxidized melted slags.

[0024] In particular, if applied to biomasses, municipal waste and similar, the indicated proceeding in the last two cited documents above mentioned, is not practically realizable since:

- the sensible heat retrieved from the warm syngas exiting from the bed size reactor displaced is not sufficient to allow the drying and the pyrolysis of the material to be treated and furthermore the temperature relatively low of the thermal flow used for said two operations affects the performance (it is then necessary much more heat respective to what should be needed with a warmer flow) and requires very wide exchange surfaces on the dryer and on the pyrolyser for compensating the lower available thermal shift;
- the quantity and composition of pyrogas and char obtainable from the pyrolysis at low temperature depends mainly by the features of the treated material and only secondarily by the temperature and times set for the process. The quantity of fumes required

for the gasification of the char obtained by the previous pyrolysis depends instead mainly by the composition and quantity of the char. Also the composition of fumes would play an important role but, having to operate in lack of oxygen (as required by the patented proceeding) and having to ensure at the same time temperatures of fumes enough high, said composition is little influencable. The high temperatures of fumes require furthermore having to operate in lack of air near to 1 (quasi stoichiometric combustion) that makes less adjustable the flow and composition of fumes;

- the process of gasification results in a series of chemical reactions that require a precise stoichiometry and that therefore precise quantities of reagents and of composition known for obtaining the desired products. Since, as of the previous point, the involved quantities and related compositions of char, pyrogas and fumes are effectively not adjustable, it results the impossibility to obtain the desired products. Considering for example the case of wood treatment, it would be the generation of a quantity of pyrolysis gases and therefore of fumes of combustion significantly higher than what is required for gasifying the available char. The syngas obtained would be therefore very warm and with a very low heating value.

[0025] In conventional proceedings of combustion and of gasification of the char, the energy and the flows necessary to their realization are directly generated by the reactions that involves the char itself: for example into the combustion there is the complete oxidation of the carbon into carbon dioxide while into the gasification there is the partial oxidation of the carbon to carbon monoxide.

[0026] As it is known by the experts in the art, is very difficult and sometimes impossible to realize these proceedings on so-called poor carbons (= with low heating value), in particular in the case of proceedings of gasification, since the level of self-support of the involved chemical reactions is not reached. Failing to burn all the available carbon, it is obtained a final residual that still contains unburned materials with the already previously described consequences.

[0027] Having a final residual with the lowest possible oxidation degree, is fundamentally important. In fact, many metals contained in the solid residual should remain at the pure metallic state no oxidized, as happens instead in the incineration or into the air or oxygen gasification, allowing for an efficient and safe retrieval. In detail, from the final residual is possible to obtain iron, copper or aluminum.

[0028] The formation of oxides in the final residual is dangerous because some metals if oxidized transform into toxic composants; for example the chrome, that if oxidized, can transform in hexavalent chrome.

[0029] Furthermore, the contact between char and oxygen, further than generating a little recyclable oxidized

residual, results in many other problems known to the experts in the art and resulting from the fact that the oxidizing events are quick and strongly exothermic.

[0030] One of these problems is the fusion of the ashes, due to the high temperatures reached by the process of oxidation and that causes damages, premature wear or malfunctions of the involved equipments. The fusion of the ashes typically takes place in combustion processes, wherein the quantity of oxygen introduced in the process is equal (=stoichiometric) or slightly higher than what is theoretically required for burning all the char, but can happen also in gasification processes since, even if the quantity of oxygen inserted in the process in them is not enough to burn all the char, there are anyway at local level, normally in correspondence of the injection point of the comburent (air or oxygen) in the system, zone with stoichiometric concentrations of oxygen or higher with consequent high local temperatures and oxidation of the residual.

[0031] Furthermore, as it is known by the experts in the art, the presence of oxygen promotes the fusion of the ashes also thanks to its participation to the formation of low-melting substances such as glass starting from sodium, potassium and silica.

[0032] Further documents of known art are the documents WO 2015/049659 and WO2015084193.

[0033] The document WO 2015/049659 shows a device with rotating chamber of gasification wherein in the process there are two additions of oxidizing agents: a mix of gasifying agents in the gasifier and air of combustion in the burner. It is therefore a plant with indirect pyrolysis. It is excluded the direct contact between the fumes of combustion and the char to be gasified. This causes a less clean production of combustible gases, and affects therefore the overall efficiency of the plant.

[0034] Similarly, also the document WO 2015/084193 shows that the solid fraction of material is gasified with air. The document US 4,881,947 shows a plant of gasification with conical rotating reactor heated through radiant tubes, wherein pyrolysis and gasification take place at the same time in the reactor itself. In the plant described in US 4,881, 947 it is produced a waste material that does not undergo a further gasification. Said waste material still has significant carbon rates and does not have the possibility to further react with the gas, reducing therefore the overall efficiency of conversion of combustible materials into tar-free gas. Moreover, in the US document here described, the residual product is still a char, and not an ash.

[0035] The scope of the present invention is to describe a plant and a process that permit to solve the aforementioned drawbacks.

Summary of the invention

[0036] The scope of the present invention is realized by means of a plant and a process that are totally without oxidative processes both of solid material at the inlet of

the plant, and of any other flow of material solid created during the process of working in the plant.

[0037] In detail, the plant of the present invention can advantageously operate also on poor coals, at low heating value, operating a complete gasification of the carbon in carbon dioxide and a partial oxidation of the carbon in carbon monoxide.

[0038] According to the present invention it is therefore realized a plant for transforming combustible materials into clean tar-free gas, said plant comprising:

- a pyrolysis reactor suitable for being supplied on one of its inlet by means of said combustible materials, said pyrolysis reactor being at least partially installed in a first chamber thermally insulated and being touched in use by gas of combustion of pyrolysis gases produced from said pyrolysis reactor, and wherein said pyrolysis reactor produces exiting from the char;
- a flow generation chamber underlying said first chamber thermally insulated and communicating with it, wherein said flow generation chamber has inlet nozzles supplied with pyrolysis gases produced from said pyrolysis reactor;
- a fixed anoxic decarburization unit having first inlet means supplied with said char produced exiting from said pyrolysis reactor and having second inlet means, directly connected with said flow generation chamber;

wherein in said flow generation chamber takes place a stoichiometric or over-stoichiometric combustion of part of said pyrolysis gases

and takes place the mixing of the resting part of said pyrolysis gases supplied with said inlet nozzles with the product of said combustion thus obtaining, in said chamber and exiting from itself, a hot flow totally free from oxygen and completely burn the tars contained in said pyrolysis gases.

[0039] According to an aspect of the present invention, said plant comprises furthermore a supplying hopper positioned exiting from said pyrolysis reactor and wherein said first inlet means comprise a supplying auger of char, positioned to a height lower than said supplying hopper.

[0040] In detail, said second inlet means of said chamber of anoxic decarburization are positioned to a height lower than said first inlet means of said chamber of anoxic decarburization.

[0041] According to a preferred and non-limiting aspect of the present invention, at least said first inlet means are configured for insulating an inlet of said chamber of anoxic decarburization.

[0042] According to an aspect of the present invention, said flow generation chamber has the particularity of geometrically being an extension of the first chamber sharing with it the external walls and being separated from it through a septum partition.

[0043] According to an aspect of the present invention,

said plant comprises furthermore a dust eliminating filter installed in correspondence of a terminal portion of an outlet conduit that is positioned on the top of the hopper.

[0044] According to an aspect of the present invention, said first chamber comprises an exhaust of fumes, and wherein said exhaust comprises furthermore thermal exchanger.

[0045] In detail, said thermal exchanger preheat and/or dry said combustible material upstream of the inlet within said pyrolysis reactor.

[0046] According to an aspect of the present invention, said gas of combustion within said first chamber have a content of oxygen always higher than zero and typically comprised between the 3% and the 15%.

[0047] In detail, in said flow generation chamber are found:

- a first zone wherein there is a burner for said pyrolysis gases; and
- a second zone wherein there are said nozzles;

and wherein in said first zone are in use present gases of combustion comprising oxygen and directed toward said first chamber and wherein in said second zone are in use present gas of combustion without oxygen and directed toward said anoxic decarburization unit.

[0048] In detail, said first zone is a zone interposed between said nozzles and said burner.

[0049] According to the present invention it is furthermore realized a proceeding for transforming the combustible material into clean tar-free gases, said proceeding being characterized in that it comprises:

- a step of introduction of said combustible material within a pyrolysis reactor of a plant for transforming the combustible material into clean gases;
- a step of heating of a rotating drum of said pyrolysis reactor, said rotating drum being at least partially introduced within a first thermally insulated chamber, and wherein said step of heating of said rotating drum takes place burning pyrolysis gases produced from said pyrolysis reactor;
- a step of transfer of a char produced in said pyrolysis reactor within a chamber of anoxic decarburization by means of first inlet means to said chamber of anoxic decarburization interposed between said pyrolysis reactor and said chamber of anoxic decarburization;
- wherein in said chamber of anoxic decarburization takes place a step of anoxic decarburization of said char, wherein said step of anoxic decarburization takes place by means of chemical reactions that take place for contact with the warm flow of combustion gas received from the adjacent flow generation chamber.

[0050] According to an aspect of the present invention, takes place a step of burning of said pyrolysis gases into

a flow generation chamber underlying said first chamber and separated from it by means of septa through which the gas of combustion of said pyrolysis gases heat at least partially said rotating drum.

[0051] According to an aspect of the present invention, said method comprises a step of positioning of second inlet means in said chamber of anoxic decarburization to a height lower than said first inlet means.

[0052] According to an aspect of the present invention, said method comprises a step of filtering of pyrolysis gases produced from said pyrolysis reactor upstream of their said burning within said flow generation chamber.

[0053] In detail, burning said pyrolysis gases, within said first chamber are produced combustion gases within said first chamber, and said combustion gases have a content of oxygen always higher than zero and typically comprised between 3% and 15%.

[0054] In detail, in said flow generation chamber said pyrolysis gases are burnt generating two separate flows of combustion, wherein a first flow of combustion contains oxygen and is directed towards said first chamber and a second flow of combustion, that is absolutely oxygen-free and is directed toward said second inlet means to the anoxic decarburization unit.

[0055] Therefore, said second flow is obtained from a mixing step of said gas of combustion produced in said first chamber with a fraction or part of said pyrolysis gases.

[0056] In detail, said pyrolysis gases are introduced in said chamber for a quantity at least sufficient for consuming, through its combustion, the oxygen contained in said gases of combustion used in the mixing.

Description of the figures

[0057] The invention will be herein described referring to the annexed figures wherein:

- figure 1 shows a plant for transforming combustible materials of a known type;
- figure 2 shows a plant for transforming combustible materials into tar free clean gas according to the present invention.

Detailed description of the invention

[0058] With reference to figure 2, with the reference number 10 is indicated as a whole a plant for transforming combustible materials into tar-free clean gas.

[0059] The pyrolysis unit receives the combustible material that is subjected to the proceeding of pyrolysis. As it is known in background art, in the proceeding of pyrolysis the material to be treated is heated, in absence of oxygen, up to temperatures comprised about between 400 and 800°C, maintaining it in those conditions for a time enough to cause the complete transformation into gas, vapors of condensable substances (called tars) and char.

[0060] The char is composed by a combustible and energetic fraction, essentially carbon, and by a non-combustible part the composition thereof depends by the material supplied to the plant. As an example, dealing with biomasses, the incombustible part of the char is composed by minerals and other material while treating unsorted waste into the composition of the incombustible part there are also metal and glass.

[0061] Obtaining a clean gas, therefore free from condensable substances (called by experts in the art "tars") and dusts, is an extremely important condition for the use of the gas as combustible in engines or turbines, therefore for the generation of electricity, or as basic substance for the production of liquid combustibles, of synthetic natural gas or other synthesis products. While the dust of the gas can be completely removed through easy filtering, the removal of tars necessitates much more complex systems and usually generates under-products of difficult and expensive disposal.

[0062] Always proceeding with a schematic description, the char generated in the unit of pyrolysis is then transferred to an anoxic decarburization unit to the end of energetically enhancing the carbon contained in said char and at the same time obtaining a residual of lower mass possible and totally non combustible.

[0063] The proceeding put into place in this last unit has the scope of completely removing the carbon contained in the char; the removal takes place absolutely without the contribution of oxygen and in conditions of controlled temperature.

[0064] For the purposes of the present invention, for anoxic decarburization is intended therefore a process of removal of the carbon in absence of oxygen.

[0065] This to the end of differentiate this particular proceeding from the most known ones and used by the experts in the art such as the combustion and the air gasification (or other gas mixture containing oxygen) where instead there is, in a more or less important way, contact between the char and the oxygen.

[0066] In the proceeding of anoxic decarburization that takes place in the plant 10 object of the present invention, the fusion of the ashes is avoided thanks to the absence of oxygen and thanks of the fact that this is an endothermic process (that absorbs heat). The maximum temperature reached in the process is the one of the decarburizing flow, better explained hereinafter, generated and controlled with precision into the flow generation chamber. For this reason in the unit of decarburization cannot be formed, not even locally, zones with excessive temperatures and such to cause the fusion of the ashes.

[0067] Between the char and the decarburizing flow inserted in the unit of decarburization take place chemical reactions that generate a combustible gas wherein there is entirely the chemical energy of the char generated and then consumed by the proceeding. This combustible gas is the main product of the proceeding and has, as better further described, the particularity of being absolutely free from condensable substances (tars) making it suit-

able for being used, after filtration and cooling, in motors or gas turbines or basic substance for chemical syntheses.

[0068] The flow generation chamber is an essential composant of the system, making the proceeding possible in its entirety as well as giving innovative character to the system considered as a whole.

[0069] In the plant 10 object of the present invention there are mainly three elements, physically united between them and inseparable: the unit of pyrolysis, the flow generation chamber and the anoxic decarburization unit.

[0070] The combustible material to be treated is directed toward the plant 10 (arrow A) through an inlet 40 provided with means (rotary feeders, double guillotines, double clapper, etc.) suitable for ensuring water tightness respective to the surrounding environment.

[0071] Downstream to said inlet 40 the plant comprises a supplying equipment 50 or power supply, that conveys the material (arrow B), by means of an auger, pusher pistons or equivalent technical means system, toward the inner of a pyrolysis reactor.

[0072] The pyrolysis reactor comprises a rotating drum 20 sheathed and partially lying in a chamber 30 thermally insulated (first chamber); the wall of the rotating drum 20 is touched by fumes of combustion that go through the space comprised between said rotating drum 20 and a first chamber 30 thermally insulated that contains it, exiting (arrow C) through an exhaust conduit 130.

[0073] For the purposes of the present invention the rotating drum is defined partially lying within the first chamber 30 thermally insulated, even if some ending portions of said drum are on the outside.

[0074] These fumes release mostly of the part of their heat to the pyrolysis reactor 20, within which there is the combustible material to be treated, heating itself at temperatures higher or equal to about 400°C and anyway not less than 300°C, undergoes a process of pyrolysis. In other terms in the plant object of the present invention there is a direct contact between fumes and the combustible material to be treated; the plant is therefore definable as direct pyrolysis plant.

[0075] During the process of pyrolysis, are generated gases, condensable substances at vapor state (tars) and char. The remaining residual heat in fumes when they reached the exhaust 130 can be retrieved through thermal exchanger 230 for then being consequently directed (arrow P) to other uses such as the drying upstream of the plant 10 of the combustible material to be treated or the pre-heating of the air of combustion used in a burner 210 better described hereinafter.

[0076] The plant 10 object of the present invention comprises also an outlet conduit 60 for the exiting (arrow E) of pyrolysis gases or pyrogas.

[0077] The char, for effect of the rotation of the rotating drum 20 (that optionally but preferably can be combined with an opportune inclination of its longitudinal axis, even if in the present invention it is possible also a horizontal

configuration as schematically shown in figure 2), moves (arrow D) towards a hopper 90 wherein it lies (arrow F) and from which it is extracted through an extraction means 70 (rotary feeders, double guillotines, double clapper, etc.) suitable for ensuring a perfect division of the atmosphere existing upstream and downstream of itself and that in detail can bring to the decarburisation into the chamber that will be subsequently described also as vacuum. The extraction means 70 is followed (arrow G) by a transport auger 80 that supplies directly a chamber 100 of anoxic decarburization of fixed type.

[0078] The plant 10 object of the present invention comprises also a dust removal filter 180 installed in correspondence of a terminal portion of the outlet conduit 60 that is positioned on the top of the hopper 90; downstream of said dust removal filter, the plant 10 object of the present invention comprises also a fan 160.

[0079] The pyrolysis gases exiting from said outlet conduit 60 is dedusted in the dust removal filter 180 (for example of inertial type, with metallic or ceramic braid), aspirated by means of the fan 160 and, through conducts 170, directed (arrow J) to the flow generation chamber 140, that is fixed.

[0080] The dust retained by the dust removal filter 180, mainly composed by fine particles of char moved by the pyrolysis gases, is extracted with known means (not indicated in the annexed figures).

[0081] Into the flow generation chamber 140 are generated the gas flows necessary both for the heating of the rotating drum of the pyrolysis reactor 20, and for the chemical reactions that take place in a chamber 100 of anoxic decarburization, that is fixed.

[0082] The flow generation chamber 140 has the particularity of geometrically being an extension of the first chamber 30 sharing with it the external walls and being separated from it only by the divisor septum 190, this last provided with openings in number, size and position such as to subdivide the gas flow that moves here (arrow K) in a suitable way and ensure the sufficient heating of the pyrolysis reactor 20 and the correct distribution of the heat on its surface.

[0083] Another particular aspect is the fact that the flow generation chamber 140 itself is then directly connected also to the chamber of anoxic decarburization 100 fixed, thus creating, with the first chamber 30, a sole complete assembly, designed to reduce at the minimum the path of heated flows (at temperatures comprised between about 1200 and 1800°C and anyway preferably over 1000°C to the end of obtaining a correct heating of the pyrolysis reactor and an efficient anoxic decarburization) generated into the flow generation chamber 140 and sent to the other two chambers thus limiting the thermal losses and avoiding the use of conducts that, as it is known by the experts in the art are of complex realization. The size of the flow generation chamber 140 are anyway such that to ensure sufficient residing times for the material such that to have a completion of the chemical reactions that then take place.

[0084] The pyrolysis gas is distributed into the chamber of generation flows 140 in two different zones, controlling the subdivision of the flow through the adjustment valves 200. A part of the gas is burned in conditions of air excess in the burner 210 previously mentioned. Said burner 210 is in detail positioned at the top of the flow generation chamber 140, preferably laying on a side of itself in correspondence of a divisor septum 190 that separates said flow generation chamber 140 by the overlaying first chamber 30. A resting part of gas is directly injected in flow generation chamber 140 through the nozzles 220 located between the burner 210 and the connection to the chamber of anoxic decarburization 100. Part of fumes generated in the burner 210 heat the rotating drum 20 through the openings with which it is provided with the divisor septum 190 (arrow K).

[0085] THE fumes necessary to the heating of the pyrolysis reactor must have a well defined temperature to the end of ensuring the desired heat exchange and remaining at the same time under the limits of temperature of use of materials of the rotating drum 20.

[0086] The adjustment of the temperature of fumes takes place, as the technicians of the sector know, by acting on the air excess set to the burner 210. The fumes of combustion obtained will therefore have a tenor of oxygen always higher than zero (typically between the 3 and the 10%) and the function of the desired temperature.

[0087] The fraction of fumes not used for the heating of the rotating drum 20 passes through the flow generation chamber 140 (arrow M) reacting then with the gas flow injected through the nozzles 220 (arrow L).

[0088] Here, the oxygen contained in the flow of fumes deriving from the burner 210 is consumed due to the combustion of the pyrolysis gases injected through the nozzles 220 into the flow generation chamber 140 underlying the first chamber 30 thermally insulated. The resulting flow, free from oxygen and with a very high temperature (1200-1800°C) is then conveyed (arrow H) to the chamber of anoxic decarburization 100.

[0089] The distribution of the gas between the burner 210 and the nozzles 220 is such as that the flow resulting from the interaction of two is absolutely free from oxygen. Practically, the flow of gas injected through the nozzles 220 must be, as defined by the experts in the art, stoichiometric (quantity of gas exact for consuming all the available oxygen) or slightly over-stoichiometric (quantity of gas excessive respective to the available oxygen). Therefore into the flow generation chamber 140 takes place the combustion stoichiometric or sovra stoichiometric of part of pyrolysis gases in the burner 210, wherein a part of pyrolysis gases that is provided again in inlet into the flow generation chamber 140 through the nozzles 220, is then mixed with the product of the combustion by obtaining heated flow gases totally free from oxygen of which the tars contained in said pyrolysis gases are totally burned.

[0090] In summary and easier terms, into the flow generation chamber 140 there is a flow of heated fumes free

from oxygen. Since into the first chamber 30 thermally insulated there are heated fumes, but with some oxygen, part of these fumes are captured and recirculated in retroaction being mixed with a predetermined quantity of pyrolysis gases. The little oxygen present in heated fumes of the first chamber 30 thermally insulated burns therefore a part of pyrolysis gases, where the oxygen is introduced in quantity equal or higher to the one that served for only consuming the present oxygen.

[0091] Practically the mixed quantity of said pyrolysis gases is always set to higher values in order to ensure with certainty the consumption of all the oxygen.

[0092] THE tars normally present in said pyrolysis gases are completely removed during the process of combustion.

[0093] In other terms, into the flow generation chamber 140 generate two flows of fumes of combustion, both composed by nitrogen, carbon dioxide and water (under the form of vapor), but with the particularity that one of them contains also oxygen while the second one is free from it. Into the flow generation chamber 140 there are therefore two zones with different atmospheres: a first zone located between burner 210 and the nozzles 220 where there are fumes containing oxygen and a second zone located between the nozzles 220 and chamber of decarburization 100 where the fumes are completely free from oxygen.

[0094] In the attached figure the zone of transition between the two zones into the chamber 140 is indicated with the dotted line 240.

[0095] Downstream of the extraction means 70 the char is collected and transported by an equipment of distribution 80 (arrow G), that in the preferred shape of embodiment described and here shown is an auger conveyor and represents the first inlet means for the chamber of anoxic decarburization.

[0096] The use of a chamber of anoxic decarburization fixed advantageously permits a better chemical reaction between the gas flows deriving from the flow generation chamber 140 and the material present into the chamber 100 of anoxic decarburization. This is in detail true even if the supply of said chamber 100 of anoxic decarburization takes place from bottom. The gas flows produced by the flow generation chamber 140 pass through therefore the material posed into the chamber 100 of anoxic decarburization from bottom up (arrows Z) in a substantial stasis condition of the material. More in particular, the char present into the chamber of anoxic decarburization and that already is undergoing the process of gasification with the flows deriving from the flow generation chamber 140, is progressively covered by new char transported by the transport auger 80 and gradually that the process of anoxic decarburization takes place, falls into the direction substantially detected by the force of gravity, toward the bottom of the chamber itself, from which it is progressively extracted.

[0097] In other words, said char deposits on the bottom of the chamber of anoxic decarburization 100, of thermo-

insulated type, where, reacting with the gas flow generated and deriving (arrow H) from the chamber of generation of gas 140 consumes losing the carbon contained transforming so itself in an incombustible residual then removed (arrow I) by the chamber of anoxic decarburization 100 by means of an equipment of extraction 120 of a known type, for example of the auger type as shown in figure 2, combined with a system of watertight exhaust 150 (rotary feeders, double guillotines, double clappers, etc.) that separates the inner atmosphere of the chamber 100 of anoxic decarburization from the external environment. Summarizing therefore, the chamber of anoxic decarburization 100 has first inlet means represented by the equipment of distribution 80 and second inlet means that are represented by the conduct present between the flow generation chamber 140 and the portion lower than of the chamber of anoxic decarburization itself. The chamber of anoxic decarburization operates therefore in a controlled atmosphere, along the chain of distribution of the char and extraction of the residual through the means 120, in a controlled atmosphere.

[0098] Preferably, but in a non-limiting extent, said chamber of anoxic decarburization 100 has said second inlet means to a height lower than respective to said first inlet means. This advantageously allows for optimizing the flow of the pyrolysis gases reburned, exiting from the flow generation chamber, respective to the char that falls into the chamber of decarburization deriving from the equipment of distribution 80, ensuring a more complete and efficient decarburization.

[0099] The equipment of extraction 120 is activated and adjusted to the end of keeping constant the level of the bed of char into the chamber 140; level controlled with known equipments (such as propeller or ultra-sonic level-switches, etc.) not indicated in the figures.

[0100] The combustible fraction of the char is essentially composed by carbon that is consumed into the chamber of anoxic decarburization 100 by the carbon dioxide and by the water (under the form of vapor) contained in the heated gas flow (arrow H) deriving from the flow generation chamber 140 transforming itself in combustible gases that comprise at least carbon monoxide and hydrogen thanks to endothermic chemical reactions.

[0101] These carbon monoxide and hydrogen gases then mix with the part of the heated gas flow deriving from the chamber of generation of gas 140 that has not reacted.

[0102] Therefore the final composition of the combustible gas produced by the plant will be a mix composed mainly by nitrogen, carbon dioxide, carbon monoxide, hydrogen and water (at the state of vapor) with concentrations of single compounds depending both by the composition of the beginning combustible solid material and by times and temperatures applied in the proceeding.

[0103] No reaction of oxidation with oxygen is possible for which the final residual solid has not oxidized due to the absence of oxygen and not fused since the chemical reactions implied are endothermic and therefore the max-

imum temperature of process is limited to the temperature of the gas flow in inlet (arrow H).

[0104] Furthermore the heated gas flow deriving from the chamber of generation of gas 140 is in quantity sufficient to complete the reactions of decarburisation; the residual is therefore free from unburned materials, since free from carbon.

[0105] The combustible gas obtained, free from condensable substances (tars) since they are absent both in the char and in the gas flow at the inlet of the chamber of anoxic decarburization 100, exits passing countercurrent through the bed of char (arrow N) and the upper free part of the chamber itself where, for effect of the reduction of speed, looses for decantation a good part of the displaced dusts. The gas is then extracted from the plant (arrow O) through a conduit 110, arranged in correspondence of the top of the said chamber of anoxic decarburization 100.

[0106] THE advantages of the plant object of the present invention are clear on the light of the description that precedes. In detail, said plant allows for producing residual solid free from combustible substances (called unburned materials) that, further than signifying an energetic loss, increase their mass and the cost of the eventual disposal. This, producing clean combustible gas, that can be used without further steps of treatment in applications such as motors or turbines, wherein it is burned for generating traction and/or mechanic couple or electricity. The plant object of the present invention can therefore advantageously be defined a direct pyrolysis plant, wherein there is a direct contact between the fumes and the char to be gasified.

[0107] Through the physical separation between the sections of pyrolysis and of gasification, this last comes already described taking place into the chamber 100, it is possible to obtain gas significantly clean and substantially without tar producing as exhaust residuals that are technically "ashes" even if totally without carbon residuals.

[0108] More in particular, said plant allows for having finally residuals without oxidized metals, since they are produced by anoxic proceedings; this allows for avoiding the plurality of residuals - such as for example the hexavalent chromium- that can be strongly toxic. Therefore, the plant object of the present invention is also characterized by an environmental friendliness greater respective to the past. The efficiency deriving from the absence of oxidized metals, derives in that the construction of the plant 10 permits to have a total absence of oxidative processes into the decarburing part of the process. Furthermore, this process allows for avoiding the creation of fused ashes.

[0109] Finally, the absence of electrical devices for heating the circuit of reaction permits the reduction of the total cost of the plant in combination with the removal of all the devices of electrical distribution of heating circuits, that especially in operating conditions wherein a plant of production of tar free gas operates, are significantly at

risk of malfunctioning.

[0110] In the plant here described the carbonization does not take place downstream of the gasification, and in detail does not take place in presence of overheated vapor and this permits a true and proper decarburization in absence of oxidants, and preferably, under vacuum.

[0111] It is finally clear that to the object of the present invention can be applied additions, modifications or variants obvious for an expert in the art without for this exiting from the scope of protection given by the attached claims.

Claims

1. Plant for transforming of combustible materials in clean gas free from tars, said plant comprising:

- a pyrolysis reactor (20) suitable for being provided with on an its inlet (40) by means of said combustible materials, said pyrolysis reactor (20) being at least partially installed in a first chamber (30) thermally insulated and being touched in use by gas of combustion of pyrolysis gases produced from said pyrolysis reactor (20), and wherein said pyrolysis reactor (20) produces exiting from the char;

- a flow generation chamber (140) underlying said first chamber (30) thermally insulated and communicating with it, wherein said flow generation chamber (140) has inlet nozzles (220) provided with pyrolysis gases produced from said pyrolysis reactor (20);

- a anoxic decarburization unit (100) fixed having first inlet means (80) provided with said char product exiting from said reactor of pyrolysis (20) and having second inlet means, directly connected with said flow generation chamber (140);

wherein

in said flow generation chamber (140) takes place a combustion stoichiometric or sovra stoichiometric of part of said pyrolysis gases takes place the mixing of the resting part of said pyrolysis gases supplied by said inlet nozzles (220) with the product of said combustion obtaining a hot flow totally free from oxygen with complete combustion of tars contained in said pyrolysis gases.

2. Plant according to claim 1, comprising furthermore a hopper (90) positioned exiting from said pyrolysis reactor (20) and wherein said first inlet means (80) comprise an auger of distribution of char, positioned to a height lower than respective to said hopper.

3. Plant according to claim 1, wherein said second inlet means of the said chamber of anoxic decarburization (100) are positioned to a height lower than respective to said first inlet means of the said chamber of anoxic

decarburization.

4. Plant according to any of the preceding claims, wherein said flow generation chamber (140) has the particularity of geometrically being an extension of the first chamber (30) sharing with it the external walls and being by it separated through a divisor septum (190). 5
5. Plant according to any of the preceding claims, comprising furthermore a dust removing filter (180) installed in correspondence of a terminal portion of an outlet conduit (60) that is positioned on the top of the hopper (90). 10
6. Plant according to any of the preceding claims, wherein said first chamber (30) comprises an exhaust (130) of fumes, and wherein said exhaust (130) comprises furthermore thermal exchanger (230). 15
7. Plant according to claim 6, wherein said thermal exchanger (230) preheat and/or dry said combustible material upstream to the injection within said pyrolysis reactor (20). 20
8. Plant according to any of the preceding claims, wherein said gas of combustion within said first chamber (30) have a tenor of oxygen always higher than zero and typically comprised between the 3% and the 15%. 25
9. Plant according to any of the preceding claims, wherein in said flow generation chamber (140) are detected: 30
 - a first zone wherein there is a burner (210) for said pyrolysis gases; and
 - a second zone wherein there are said nozzles (220),

and wherein in said first zone are in use present gas of combustion comprising oxygen and directed toward said first chamber (30) and wherein in said second zone are in use present gas of combustion without oxygen and directed toward said anoxic decarburization unit (100). 35
10. Plant according to claim 9, wherein said first zone is a zone interposed between said nozzles (220) and said burner (210). 40
11. Plant according to claim 3, wherein at least said first inlet means (80) are configured for insulating a inlet of the said chamber of anoxic decarburization. 45
12. Proceeding for transforming of combustible material in clean gases free from tars, said proceeding being

characterized in that it comprises:

- a step of introduction of said combustible material within a pyrolysis reactor (20) of a plant (10) for transforming of combustible material in clean gases;
 - a step of heating of a rotating drum of said pyrolysis reactor (20), said rotating drum being at least partially introduced within a first chamber (30) thermally insulated, and wherein said step of heating of said rotating drum takes place by burning pyrolysis gases produced from said pyrolysis reactor (20);
 - a step of transfer of a char product in said pyrolysis reactor (20) within a chamber of anoxic decarburization (100) by means of first inlet means (80) to said chamber of anoxic decarburization (100) interposed between said pyrolysis reactor (20) and said chamber of anoxic decarburization (100);
 - wherein in said chamber of anoxic decarburization (100) takes place a step of anoxic decarburization of said char by means of chemical reactions that take place for contact with the heated gas flow of combustion received from adjacent flow generation chamber (140).
13. Proceeding according to claim 12, comprising a step of burning of said pyrolysis gases in a flow generation chamber (140) underlying said first chamber (30) and by it separated by means of septa (190) through which the gas of combustion of said pyrolysis gases heat at least partially said rotating drum.
 14. Proceeding according to claim 12 or claim 13, comprising a step of positioning of second inlet means in said chamber of anoxic decarburization (100) to a quota lower than respective to said first inlet means.
 15. Proceeding according to any of the claims 12-14, **characterized in that** it comprises a step of filtering of pyrolysis gases produced from said pyrolysis reactor (20) upstream to said burning within said flow generation chamber (140).
 16. Proceeding according to any of the preceding claims 12-15, wherein burning said pyrolysis gases, within said first chamber (30) are produced gases of combustion within said first chamber (30), and said gas of combustion have a tenor of oxygen always higher than zero and typically comprised between the 3% and the 15%.
 17. Proceeding according to any of the claims 13-16, wherein in said flow generation chamber (140) said pyrolysis gases are burned generating two separated flows of combustion, wherein a first flow of com-

bustion contains oxygen and is directed toward said first chamber (30) and a second flow of combustion totally free from oxygen, is directed toward said second inlet means to said unit of anoxic decarburisation (100).

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18. Proceeding according to any of the previous claims, **characterized in that** said second flow is obtained from a step of mixing of said gas of combustion produced in said first chamber (30) with a fraction or part of said pyrolysis gases.

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19. Proceeding according to claim 18, **characterized in that** said pyrolysis gases are injected in said chamber for a quantity at least sufficient to consume, through its combustion, the oxygen contained into said gas of combustion used into the mixing.

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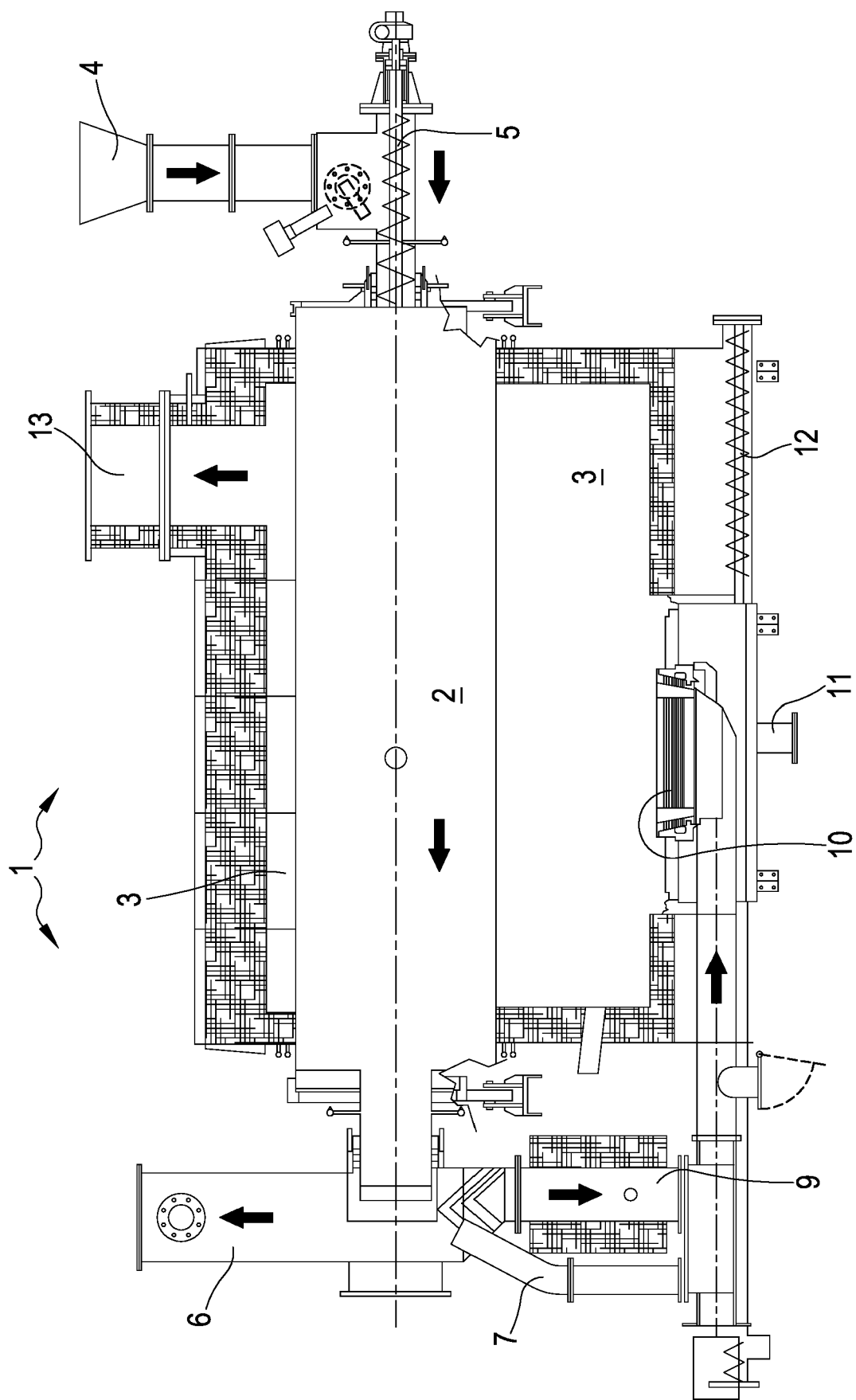
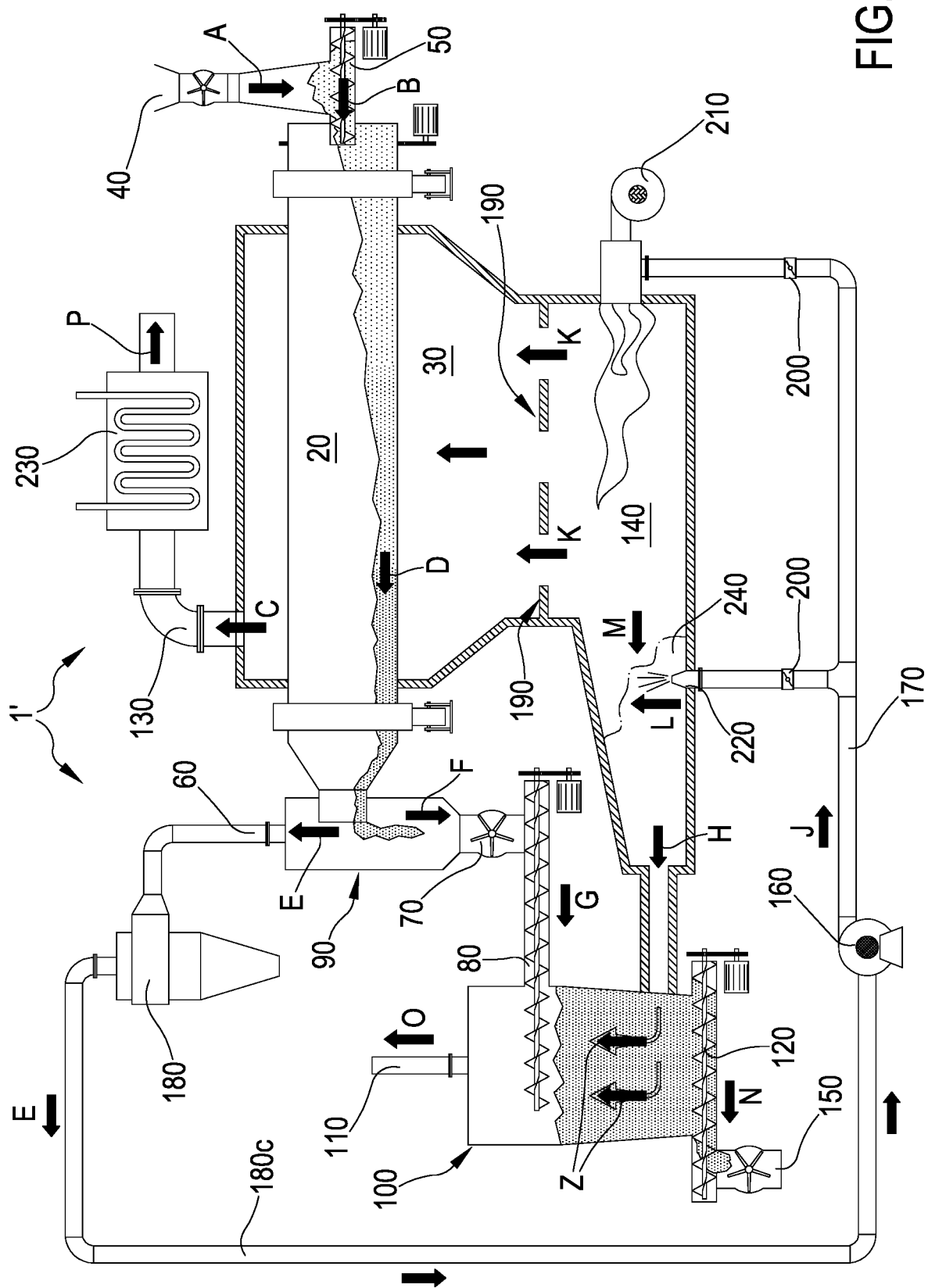


FIG.1





EUROPEAN SEARCH REPORT

 Application Number
 EP 16 20 2784

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2015/049659 A1 (ENI SPA [IT]) 9 April 2015 (2015-04-09) * page 17, line 24 - page 28, line 20; figure 1 *	1-19	INV. C10J3/30 C10J3/66 C10J3/00
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			TECHNICAL FIELDS SEARCHED (IPC)
			C10J
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 14 August 2017	Examiner Iyer-Baldew, A
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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14-08-2017

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