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(11) **EP 0 955 350 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
10.11.1999 Bulletin 1999/45

(51) Int. Cl.⁶: **C10J 3/00**, C10J 3/26

(21) Application number: **98830256.8**

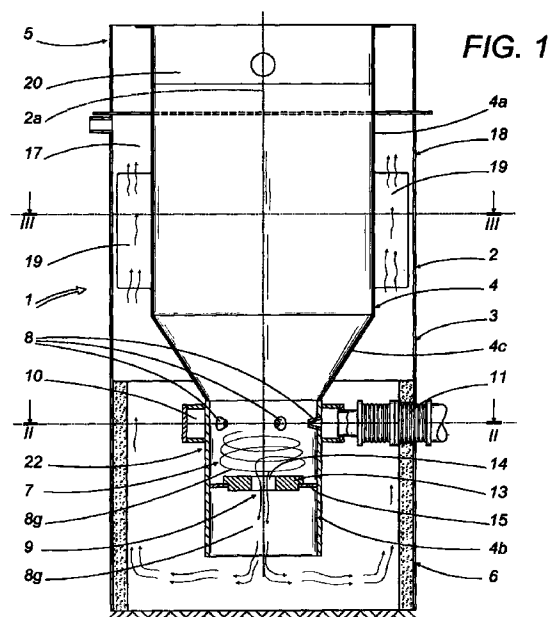
(22) Date of filing: **28.04.1998**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE**
Designated Extension States:
AL LT LV RO SI
(71) Applicant:
Mase Generators S.p.A.
47020 Pievesestina di Cesena (Forlì) (IT)

(72) Inventor: **Spegni, Marco**
00189 Roma (IT)
(74) Representative: **Lanzoni, Luciano**
c/o BUGNION S.p.A.
Via Goito, 18
40126 Bologna (IT)

(54) **A device and method for the gasification of wood**

(57) A device and method for the gasification of wood, according to which, inside a reactor (22) housed within an inner casing (4) with vertical axis (2a) and equipped with an oxidation zone (7) located near the base (6) of an outer container (2) containing said inner casing (4), at which a plurality of fluid conveyor elements (8, 8'), supplied with air from an external source (21) and positioned above a zone (9) for the discharge of the gas produced by the reactor (22), are oriented in such a way as to create, in the oxidation zone (7), a gaseous flow (8g) containing the gas, rotating about the longitudinal axis (2a) and moving forwards towards the discharge zone (9), which comprises a diaphragm (13) across the longitudinal axis (2a) and having a discharge hole (14); the diaphragm (13), together with the vertical walls of a lower section (4b) of the inner casing (4), constitutes a transit duct in which the gaseous flow (8g) is intercepted and suddenly diverted towards the discharge hole (14), causing the release of solid particles, which accumulate on the diaphragm (13) and on the inner walls of the lower section (4b), providing them with heat insulation and protecting them from any direct contact with the following gaseous flow (8g).



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Description

[0001] The present invention relates to a device for the gasification of wood and, in general, is part of the technology of apparatuses by means of which a solid fuel, in this case a biomass consisting of wood, is only partially oxidised in order to obtain a combustible gas.

[0002] Research on renewable energy sources proposes the gasification of wood as one of the most interesting, considering the quantity of discarded wood available in industrial societies and the fact that at least 50% of this discarded wood is simply dispersed by burning it or even distributing it over the ground, causing permanent damage to the environment.

[0003] As indicated above, the gasification of a wooden biomass is a thermochemical process based on the partial oxidation of vegetable carbon and the breakdown of the products deriving from the thermal decomposition of the biomasses, including the decomposition of the water absorbed by the original biomass and that of formation. This reaction is followed by reduction of the carbon dioxide on a bed of incandescent pure carbon automatically generated by the previous reaction.

[0004] The above-mentioned reactions occur under conditions of thermal equilibrium, with a production of heat sufficient to allow the thermochemical process to supply its own energy, without the aid of external energy sources. The set of reactions which break down the biomass into simple elements of the pyroligneous derivatives is that characteristic of wood chemistry, although the quantity varies according to the type and characteristics of the biomass gasified.

[0005] The device forming the subject-matter of the present invention comprises, in particular, a reactor in which the above-mentioned gasification process which, to summarise, envisages the drying, pyrolysis, carbonisation and gasification of the solid wooden biomass, is effected according to a procedure generally known as the "Imbert process".

[0006] This type of process envisages the use of a vertical gasification device in which the wood, fed in continuously from the top of the device, gradually moves towards the base, undergoing said gasification with concurrent flow; that is to say, in which the gaseous flow of the products of the reaction, of the water vapour, of the fuel, and finally of the comburent atmospheric air, all follow the direction from top to bottom.

[0007] The device is of the type comprising vertical outer walls, a head and a base which together form a long tank with a vertical longitudinal axis; a heating zone inside the tank, near the base, this zone being surrounded by lower portions of the walls of said tank; a plurality of comburent air conveyor elements, located in the oxidation zone and in fluid communication with an external air source, so that the air can be transferred from the air source to the oxidation zone; a discharge zone for the gas produced by the reactor, normally

called the neck, located below the conveyor elements and having a hole that allows the discharge of the gas to the outside of the tank.

[0008] Gasifier devices of the above-mentioned type are already described in documents US 5 226 927 and EP 0693545 A1.

[0009] The main disadvantage of such types of wood gasification devices is the high content of dust and tar transported by the gas, which, downstream of the reactor, require expensive and not completely effective filtration plants, envisaged to make the gas suitable for use in internal combustion engines. The tar content produced in the gasifier device reactor is in inverse proportion to the local oxidation-reduction reaction temperatures.

[0010] In conventional Imbert reactors, in particular, the comburent air conveyor elements are distributed over the walls of the reactor in such a way that they lie on a horizontal plane and are all oriented so as to direct the air conveyed by each of them exactly to a central point of the heating zone.

[0011] The discharge zone, called the neck, has a twin truncated cone structure, in which the smaller bases of the two truncated cones are opposite one another and are joined at a narrow central zone, in which the discharge hole or neck is located.

[0012] Due to the high temperatures of the gas (1000 - 1400 °C); the high chemical reactivity of the gas; its strong abrasive action caused by the speed and the large amount of dust transported, the nozzles are made of special, high-alloy steels, which are stainless and resistant to high temperatures.

[0013] For these main reasons, the reactor operating temperature is limited, in use, to the maximum temperature sustainable by the nozzle and the materials of which the reactor core is made. The reactor core, therefore, constitutes a critical element for further raising the reactor general operating temperatures and requires complex construction solutions that are expensive to maintain, since despite the careful selection of construction materials, the reactor is subject to rapid deterioration of its mechanical characteristics, thus requiring necessary and frequent stopping of the gasifier plant in which the reactor is installed and complex reactor part substitutions.

[0014] In addition to the need to contain the operating temperatures, as indicated above, an equally critical question is the local non-uniformity in the thermal and dynamic conditions of the transit of the effluents in the reaction zone: cold veins and overheated zones subject the metal walls of the zone in question to thermal stress, causing rapid mechanical deterioration.

[0015] The aim of the present invention is to overcome the above-mentioned disadvantages, allowing the creation of gasifier devices in which the relative reactors are able to operate without disadvantages at operating temperatures that are higher than those that can currently be reached and substantially uniform in a manner that

was impossible using conventional plant.

[0016] In accordance with the present invention, this aim is achieved by a gasifier device comprising a reactor in which the fluid conveyor elements or comburent conveyor nozzles are oriented in such a way that a flow of air is sent to the oxidation zone, said flow of air imparting to the gaseous mixtures and reagents produced in the reactor a rotary motion about the longitudinal axis of the gasifier, in addition to the conventional forward motion, towards the discharge zone or neck, directed parallel with said longitudinal axis. The reactor reaction zone also comprises a diaphragm held crossways by the reactor walls, said diaphragm having a discharge hole.

[0017] Together with the adjacent reactor walls, the diaphragm delimits a duct with a through-section whose shape varies suddenly, creating a situation in which the dynamics of the gases in transit are similar to those of the cyclone effect. The gas drawn by the flow of air sent by the conveyor elements moves forwards, turning about the longitudinal axis and, at the moment in which it is intercepted by the diaphragm and forced to pass through the discharge hole or neck with smaller diameter, is subjected to a violent acceleration that separates the solid particles which it transports, causing them to be deposited on the vertical walls of the reactor and on the surface of the diaphragm. The solid particles settle in a funnel shape and coat the walls of the diaphragm and the connecting zone between the diaphragm and the inner walls of the reactor with refractory material as far as the nozzles.

[0018] The coating, consisting of ash, of which the surface is in a melted paste state, is deposited, drips and is continuously regenerated during the turbulent gasification process, thus protecting the metal walls of the reactor from heat and, lacking cohesion, from mechanical stress.

[0019] The gasifier device is also equipped with heat exchangers with fins which, applied to the outer wall of the inner container or tank, allow partial recovery of the heat energy carried by the exiting gas and containment of its temperature, improving the energy equilibrium of the gasification reaction by raising the general tank temperatures, raising the oxidation-reduction temperatures and drying the wood which, therefore, does not have to be pre-treated outside the gasifier device.

[0020] The top of the gasifier device is fitted with a head vapour condenser, which allows any excess humidity in the raw wooden biomass to be condensed and extracted.

[0021] Raising of the reactor operating temperatures and the reduction of the risk of cold veins in the reagent gases allows maximised breaking of the heavy chains deriving from the tar and pyroigneous oils into light, volatile chains, comprising gaseous hydrocarbon fractions and into simple carbon and hydrogen elements.

[0022] The resulting cleanness and stability of the gas produced by this reactor is directly relevant in the plant

construction economics, allowing the complexity and costs of complicated and inefficient purification apparatus conventionally upstream of the engines that use the wood gas to be reduced to a minimum.

[0023] In accordance with the above-mentioned aims, the present invention also provides a gasification method implemented by the device equipped with the reactor made according to the present invention.

[0024] The technical characteristics of the invention according to the above-mentioned aims are described in the claims below and its advantages are apparent from the detailed description which follows, with reference to the accompanying drawings which illustrate preferred embodiments of the invention and in which:

- Figure 1 is an assembly view of a gasifier device made in accordance with the present invention;
- Figure 2 is a cross-section of the reactor illustrated in Figure 1, according to a plane II - II;
- Figure 3 is a cross-section of the reactor illustrated in Figure 1, according to a plane III - III;
- Figure 4 is a scaled-up cross-section of a first detail of the reactor illustrated in Figure 1;
- Figures 5 and 6 are respectively a scaled-up elevation view and a scaled-up top plan view of a second detail of the reactor illustrated in Figure 1;
- Figures 7 and 8 are respectively two cross-sections of a third detail of the reactor, illustrated according to planes VII - VII and VIII - VIII;
- Figure 9 is a partial view of the reactor, schematically illustrating a characteristic reactor operating condition.

[0025] With reference to the accompanying drawings, Figure 1 illustrates a gasifier device, labelled as a whole with the numeral 1, envisaged for the production of combustible gas from a wooden biomass, by means of a thermochemical process based on the partial oxidation of vegetable carbon and the thermal decomposition of the pyroigneous compounds deriving from the thermal decomposition of the biomasses, and also relative to the decomposition of the water absorbed by the original biomass and that of formation.

[0026] The above-mentioned thermochemical treatment is carried out by the device 1, in accordance with the "IMBERT" process with concurrent flow, therefore, the device 1 comprises a long, cylindrical outer container 2, substantially vertical, with a vertical outer side wall 3, a head 5 and base 6, connected to one another.

[0027] The outer container 2 houses a tubular inner casing 4. The inner casing 4 is mounted within the outer container 2 at a distance designed to delimit a gap 17 between them, and they are positioned axial to one another on a shared vertical, longitudinal axis 2a.

[0028] The outer container 2 is basically cylindrical. The inner casing 4 is made of stainless steel, resistant to high temperatures and the chemical action of the process gases and has two cylindrical end sections 4a

and 4b, with different diameters, joined to one another by an intermediate truncated cone portion or hopper 4c, which connects the upper cylindrical section 4a with larger diameter, to the lower cylindrical section 4b with smaller diameter.

[0029] Near the base 6, the inner casing 4 houses a biomass oxidation zone 7, at the lower cylindrical section 4b of the casing 4 and equipped with a plurality of fluid conveyor elements or nozzles 8 and a zone 9 for discharge of the gas towards the outside of the casing 4.

[0030] The conveyor elements 8 (Figure 2) comprise a set of nozzles which: are distributed over the wall of the lower cylindrical section 4b; are coplanar with one another and located on a basically horizontal plane; and are connected with a ring-shaped chamber 10 that encompasses the lower cylindrical section 4b of the inner casing 4. The ring-shaped chamber 10 is connected to an external air source 21 (schematically illustrated in the figures) by a connector 11, so that the air is transferred from the source 21 into the oxidation zone 7 by the nozzles 8.

[0031] The unit comprising the lower cylinder 4b, ring-shaped chamber 10 and nozzles 8, constitutes the so-called reactor 22.

[0032] The conveyor elements 8 are oriented on the wall of the lower cylindrical section 4b in such a way that they respectively direct the flow of air 8f conveyed by each of them tangentially to a horizontal circle 12 centred on the longitudinal axis 2a (see also Figure 7).

[0033] The discharge zone 9, located below the conveyor elements 8, comprises a flat, ring-shaped diaphragm 13, through the centre of which there is a cylindrical discharge hole 14 (Figure 4). The diaphragm 13 is supported crossways by the lower cylindrical section 4b of the inner casing 4 and, approximately half way down the casing, by means of a ring-shaped washer 15 (Figures 5 and 6), which connects the diaphragm 13 to the wall of the lower cylindrical section 4b.

[0034] Due to the orientation of the conveyor elements 8, the flow of fuel air 8f fed into the oxidation zone 7 imparts to the gaseous flow 8g in which the gases and solid particles generated in the gasification process flow together, a rotation about the longitudinal axis 2a.

[0035] Since the reactor 22 is of the type with concurrent flow, as it rotates, the gaseous flow 8g simultaneously moves along the longitudinal axis 2a of the lower cylinder 4b, towards the discharge zone 9 below. As a result of the cylindrical shape of the lower section 4b of the inner casing 4, and of the shape and position of the diaphragm 13 inside said section, the above-mentioned elements (diaphragm 13, washer 15 and walls of the lower cylindrical section 4b) together form a transit duct, whose through-section is suddenly reduced at the discharge hole 14.

[0036] As it advances along the longitudinal axis 2a, the flow of gases 8g is intercepted by the diaphragm 13 and washer 15, undergoing a modification in its fluid

dynamics, which creates a fluid stagnation in the zones of the transit duct closest to the connecting zone between the diaphragm 13 and the inner wall of the casing 4.

5 [0037] The solid particles transported by the gaseous flow 8g are, therefore, deposited on the diaphragm 13, on the washer 15 and on the vertical inner wall of the lower cylindrical section 4b of the reactor 22, gradually coating them with a mass 16 of particles (Figure 9) which are deposited and accumulate in controlled, regular shapes, which in the case illustrated in the figure are represented by truncated cones set opposite one another.

10 [0038] The masses 16 of particles deposited on the vertical inner wall of the lower cylindrical section 4b constitute, as indicated above, a mass 16 with the shape of a funnel of particles, in a melted paste state on the surface, and basically comprise ash and coal dust.

15 [0039] These provide heat insulation for the diaphragm 13, washer 15 and the portions of the inner wall of the lower cylindrical section 4b adjacent to them and reduce the dispersion of heat to the outside of the casing 4 at its hottest zone, comprising the oxidation zone 7 of the reactor 22. Moreover, they cause a reduction in the actual wall temperature reached by the metal surfaces at the oxidation zone 7 and prevent the hot gases from cooling by touching the metal surfaces of the washer 15 and diaphragm 13 wall, with the obvious exception of the portion of the surface relative to the discharge hole 14.

20 [0040] The diaphragm 13, washer 15 and hole 9 assembly is followed by a further portion of the lower cylindrical section 4b, which forces the gases to make contact for longer periods with the reducing carbon masses which fill the gap 17.

25 [0041] It should also be noticed that, with the reactor 22 operating, the masses 16 of ash also form downstream of the diaphragm 13, following the sudden widening of the cross-section encountered by the gaseous flow that exits the discharge hole 14 below the diaphragm 13.

30 [0042] The masses 16 of ash located below the diaphragm 13 also remain stably in position during continuous operation of the reactor 22.

35 [0043] If said masses 16 were to precipitate towards the base 6 of the outer container 2 due to the effects of gravity, for example, if operation of the reactor 22 were interrupted, following restarting of the reactor 22, the masses 16 would reform automatically and, after a brief period of time, would continue to carry out their coating and insulating function.

40 [0044] The technical characteristics of the above-described reactor 22 allow the obtainment of all of the advantages that can be linked to an increase in and a more uniform distribution of the operating temperatures of the reactor 22.

45 [0045] The increase in and homogeneous distribution of the temperatures is allowed, on one hand, by an

increased heat resistant capacity of the walls of the lower cylinder 4b and diaphragm 13, and on the other hand, by reduced heat dispersion from the oxidation zone 7 to the outside of the container 2.

[0046] As regards the actual shape of the flow conveyor elements 8, the above description refers to tubular nozzles; however, many alternative embodiments are possible, with equivalent functions. One possible alternative embodiment, shown by way of example only in Figures 7 and 8, shows that the conveyor elements 8 may comprise simple holes 8', which in the example illustrated are round, made in the wall of the lower cylindrical section 4b of the inner casing 4 and oriented in such a way that they are offset according to angles α designed to direct the flow of air 8f eccentrically relative to the longitudinal axis 2a of the container 2.

[0047] With reference to Figure 1, it can be seen that within the gap 17 between the outer container 2 and the inner casing 4, at the upper cylindrical section 4a, the outer container 2 is fitted with a heat exchanger 18 to recover at least part of the heat carried by the gases that flow out of the inner casing 4. The heat exchanger 18 (see also Figure 3) comprises a plurality of flat, rectangular fins 19, attached vertically to the innermost casing 4 of the device 1. The fins 19 are distributed evenly along the outer edge of the inner casing 4 and project into the gap 17, protruding radially towards the outermost casing 3.

[0048] The gases that flow out of the inner casing 4 through the discharge hole 14 are caused to rise up through the gap 17 from the base 6 to the head 5.

[0049] As they pass through the heat exchanger 18, the gases touch the fins 19 and, cooling, give up part of their heat which, through the wall of the upper cylindrical section 4a of the inner casing 4, is transferred to the biomass still to be treated, that in the meantime is moving downwards inside the inner casing 4 and proceeds from the head 5 to the base 6, gradually being dried and subjected to a carbonisation pre-treatment.

[0050] The heat exchanger 18 allows not only the advantage of recovering heat useful to the thermal equilibrium of the process, but also heats the biomass stored in the upper cylindrical section 4a of the inner casing 4, promoting its drying, the formation of water vapour that enters the general concurrent flow of treated compounds and, finally, allowing an advantageous reduction in the temperature of the gases exiting the reactor 22.

[0051] The head 5 of the device 1 is fitted with a vapour condenser 20, which allows the adjustable separation and elimination of any excess humidity in the biomass.

[0052] In operation, the device 1 envisages the insertion of the wooden biomass to be treated in the upper cylindrical section 4a, through the head 5. The biomass, therefore, constitutes a column of layered material, which gradually descends along the axis 2a of the inner casing 4 and, during this movement, is dried at the top

of the upper cylindrical section 4a, carbonised at the bottom of the cylindrical section 4a and of the truncated cone connector or hopper 4c and, finally gasified at the lower cylindrical section 4b of the inner casing 4.

[0053] As the column of material descends inside the casing 4, the size of the biomass is gradually reduced, so that the product exiting the lower cylindrical section 4b is represented only by the gases and the ash generated in the partial combustion and by the fragments of pure carbon with a smaller cross-section than the discharge zone 9 of the diaphragm 13. Part of the ash is deposited on the base 6 of the outer container 2, from which it is extracted using conventional extraction means, not illustrated.

[0054] The ash which remains suspended in the gas is eliminated by means of a battery of filters, again not illustrated, as they do not form part of the present invention, located downstream of the device. Finally, the gases exiting the battery of filters are sent on for use, for example, to fuel internal combustion engines that drive generators.

[0055] The invention thus designed allows full achievement of the aim of economically obtaining, with reduced running costs, a gas from which the dust and tar have been removed to a degree suited to the construction specifications of conventional engines for the generation of electrical or mechanical energy.

[0056] Moreover, the device with the relative reactor operating in accordance with the method described, is more adaptable to the chemical-physical characteristics of wood, with increased operating flexibility of the gasification device.

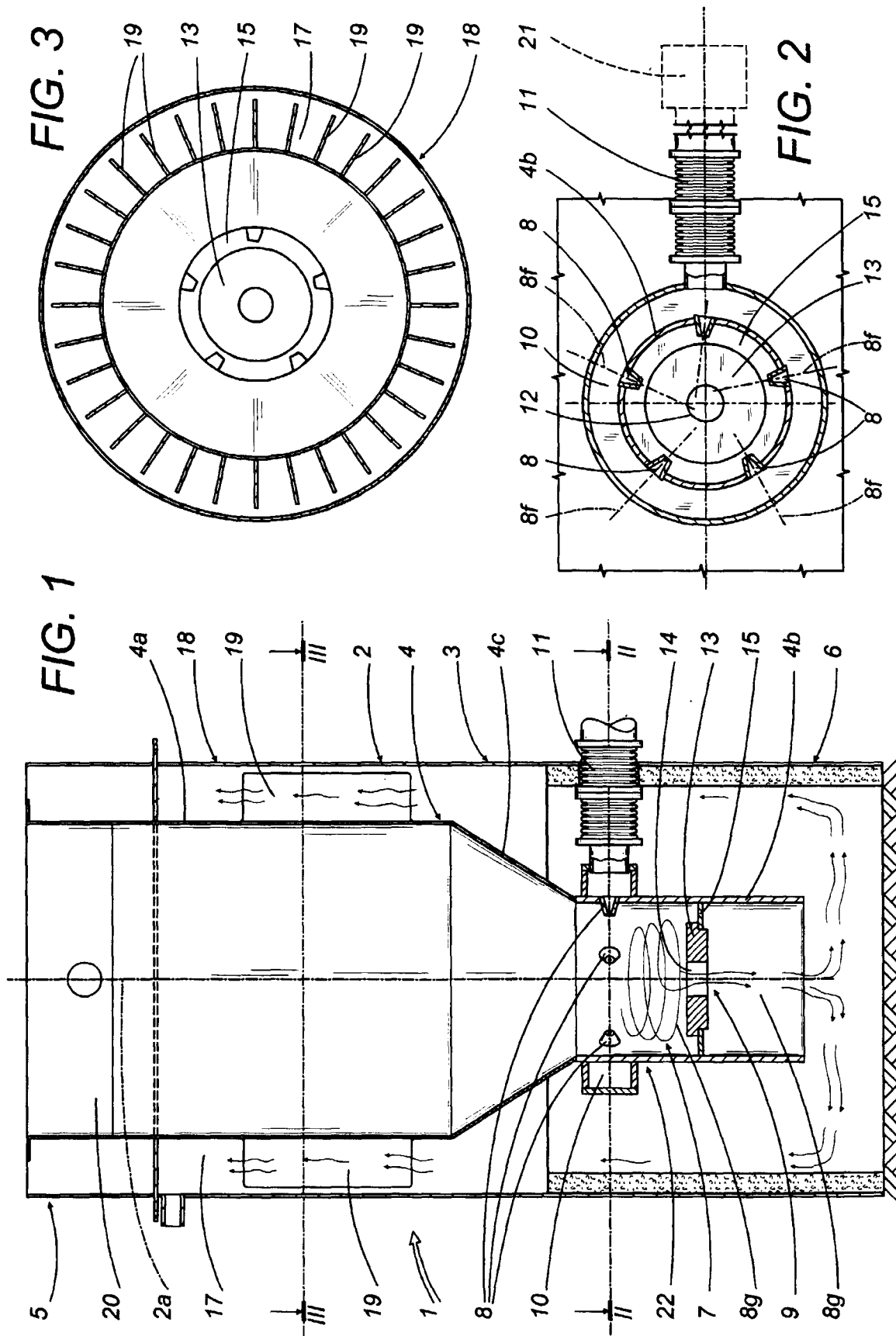
Claims

1. A device for the gasification of wood, comprising an outer container (2), an inner casing (4), both having a vertical longitudinal axis (2a), a head (5) and a base (6), said inner casing having an upper cylindrical section (4a), a hopper (4c) and a lower section (4b); an oxidation zone (7), being positioned inside the lower section (4b) of the inner casing (4) near the base (6); a plurality of fluid conveyor elements (8, 8'), being positioned at the oxidation zone (7) and in fluid communication with an external air source (21), so that the air can be transferred from the air source (21) to the oxidation zone (7), said lower zone (4b) and oxidation zone defining a reactor (22); a zone (9) for the discharge of the gas produced by the reactor (22), being located below the conveyor elements (8, 8') and having a hole (14) for the discharge of the gas to the outside of the inner casing (4), the device characterised in that the fluid conveyor elements (8, 8') are oriented in such a way that they send into the oxidation zone (7) a flow of air (8f) which generates a gaseous flow (8g) containing the gases generated, said flow rotating about the longitudinal axis (2a) and simultaneously

moving forwards towards the discharge zone (9) parallel with the longitudinal axis (2a), and the device characterised also in that the discharge zone (9) comprises a diaphragm (13), being attached to the lower section (4b) of the inner casing (4) across the longitudinal axis (2a) and having said discharge hole (14), the diaphragm (13) together with the inner walls of the lower section (4b) delimiting a transit duct for the gaseous flow (8g) with a cross-section that varies suddenly, in which the gaseous flow (8g) is intercepted by the diaphragm (13) and diverted to the discharge hole (14), said interception causing the gaseous flow (8g) to release solid particles that accumulate on the diaphragm (13) and the adjacent vertical inner walls of said section (4b), remaining there and at least partially insulating them against heat and protecting them from direct contact with the following gaseous flow (8g) that passes through the transit duct and the discharge hole (14).

2. The device according to claim 1, characterised in that the conveyor elements comprise holes (8') made in the walls of the section (4b) of the inner casing (4).
3. The device according to claim 1, characterised in that the conveyor elements comprise tubes (8) oriented tangentially to a shared circle (12).
4. The device according to claim 3, characterised in that the conveyor elements (8, 8') and circle (12) are coplanar.
5. The device according to claim 1, characterised in that the lower section (4b) has the shape of a cylindrical tube and comprises a diaphragm (13), being supported by a flat ring (15), the latter being supported across the longitudinal axis (2a) by the inner walls of the lower section (4b) of the inner casing (4).
6. The device according to claim 1, characterised in that the inner casing (4) and outer container (2) are mounted coaxial to one another, being separated in such a way that, together, they delimit a gap (17), said gap (17) being transited by the gaseous flow (8g) that flows out of the discharge hole (14).
7. The device according to claim 6, characterised in that the gap (17) is fitted with heat exchange fins (19), being attached to the inner casing (4).
8. A method for the gasification of wood, in a device (1) comprising an outer container (2), an inner casing (4), both having a vertical longitudinal axis (2a), a head (5) and base (6), said inner casing having an upper cylindrical section (4a), a hopper (4c) and

a lower section (4b); an oxidation zone (7) being located within the lower section (4b) of the inner casing (4) near the base (6); a plurality of fluid conveyor elements (8, 8') being positioned at the oxidation zone (7) and in fluid communication with an external air source (21), so that the air can be transferred from the air source (21) to the oxidation zone (7), said lower section (4b) and oxidation zone defining a reactor (22); a zone (9) for the discharge of the gas produced by the reactor (22), being located below the conveyor elements (8, 8') and having a hole (14) for the discharge of the gas to the outside of the inner casing (4); the method characterised in that it comprises the stages of imparting to the gaseous flow (8g) containing the gases generated by the reactor (22) a rotary motion about the longitudinal axis (2a) and simultaneously a forward motion towards a discharge zone (9) to the outside of the inner casing (4); intercepting the flow (8g) with a diaphragm (13) oriented across the longitudinal axis (2a) and being shaped so that, together with the adjacent inner walls of the lower section (4b), it constitutes a transit duct, having a through-section that varies suddenly, in which the flow (8g) is intercepted by the diaphragm (13) and suddenly diverted towards a discharge hole (14), said intercepting stage causing the release of solid particles that accumulate on the diaphragm (13) and the vertical inner walls (4) of the lower section (4b), coating them at least partially so as to provide them with heat insulation and prevent the gaseous flow (8g) from making direct contact with the diaphragm (13) and the walls (4) of the lower section (4b).



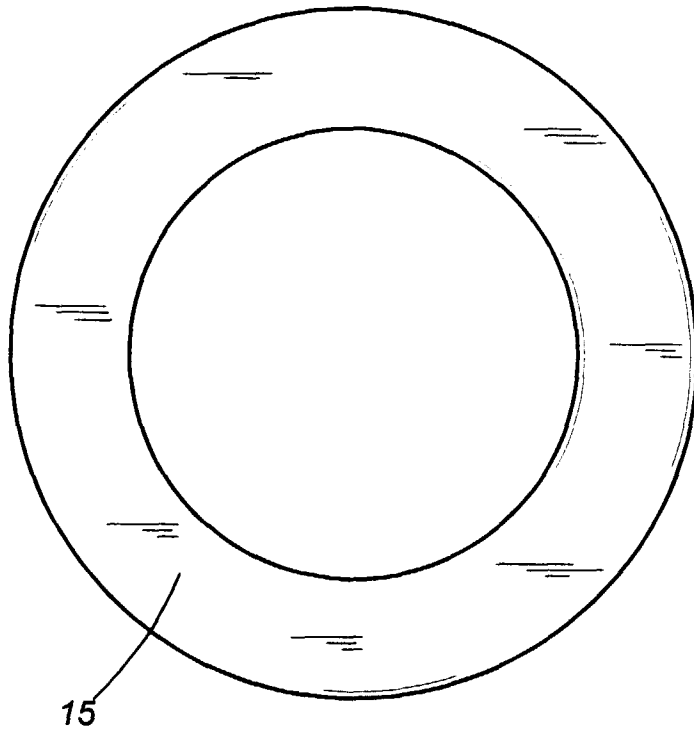


FIG. 6

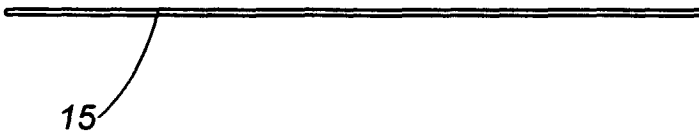


FIG. 5

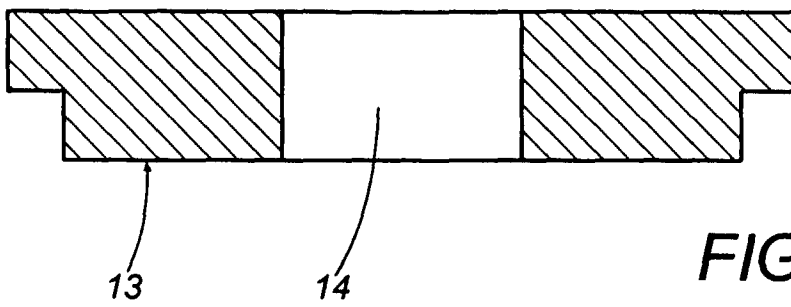


FIG. 4

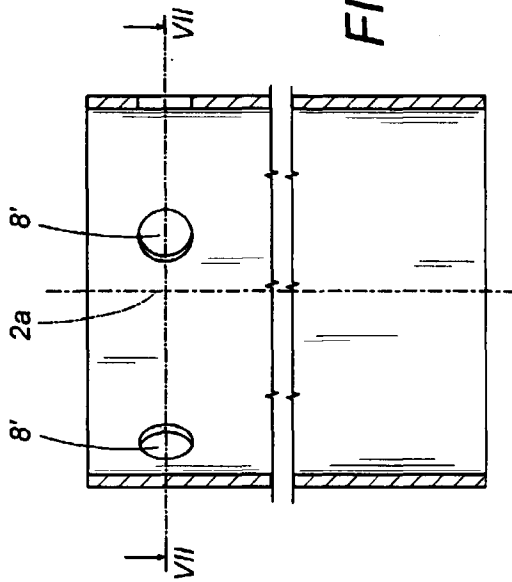


FIG. 8

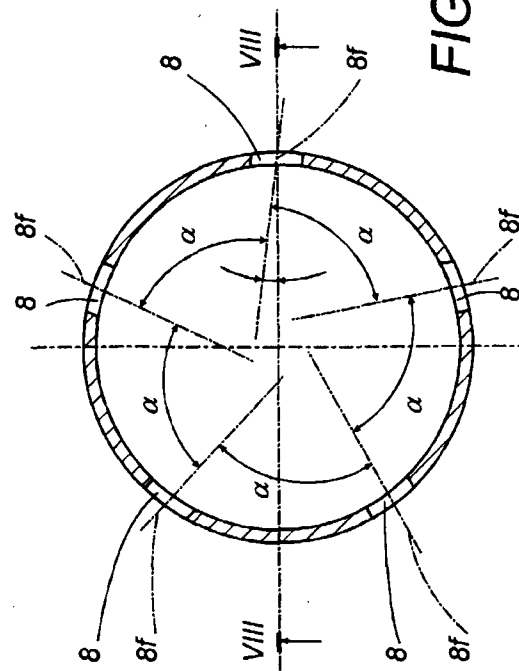
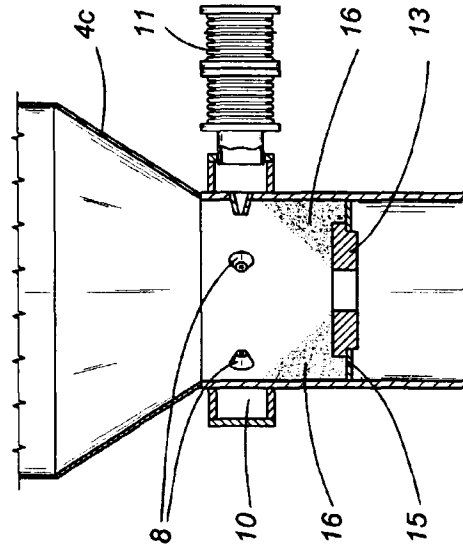


FIG. 7

FIG. 9





European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 98 83 0256

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	CH 237 348 A (PORSCHE) * the whole document * ---	1-4,8	C10J3/00 C10J3/26
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			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			C10J
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 24 September 1998	Examiner Wendling, J-P
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EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 98 83 0256

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