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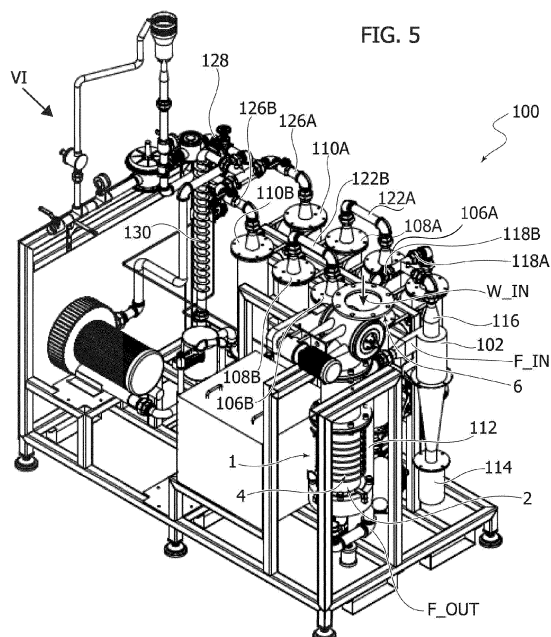
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(54) **A DEVICE AND A PLANT FOR TREATMENT OF WASTE**

(57) There is described a device (1) for the pyrolysis treatment of non recyclable waste, which is configured for producing a synthesis gas as a gaseous pyrolysis product. Moreover, there is described a plant for the treat-

ment of synthesis gas having a modular structure and being adapted to operate continuously, even during maintenance work.



Description

Field of the Invention

[0001] The present invention refers to the treatment of waste. Specifically, the invention was developed with reference to the thermal conversion treatment of non recyclable waste.

Prior Art

[0002] The growing importance of issues being presently debated (not only from a scientific point of view) concerning the environment and the improvement of energy efficiency inevitably raises various unsolved technical problems in the cycle of waste disposal. Although the range of partially or totally recyclable waste is very wide nowadays, there are still some waste typologies which, for their intrinsic characteristics, cannot be recycled. This is the case e.g. of sea waste, of some plastic materials, of medical waste and of the waste in the agricultural sector having a moisture content up to 40%, only to name a few examples. The disposal of such waste is seriously critical, because they are rich in contaminants which are not easily convertible or separable by means of the known methods, e.g., pyrolysis treatments. In this regard, the devices for pyrolysis treatment of non recyclable waste often have a poor efficiency because of a less than optimal use of the reaction volume, due to the massive formation of deposits and of a synthesis gas - syngas - which is released as a pyrolysis product and which is highly contaminated and extremely difficult to process. The aftertreatment plants for synthesis gas are therefore very costly, and they need frequent maintenance due to the aggressiveness of the treated chemicals (with the consequent need of plant downtimes). Ultimately, all these technical difficulties make the recycling of synthesis gas unprofitable.

Object of the Invention

[0003] The object of the present invention consists in solving the technical problems outlined in the foregoing. Specifically, the object of the invention is providing a device for the pyrolysis treatment of waste, particularly of non recyclable waste, having a high conversion efficiency and yielding a pyrolysis product substantially devoid of deposits.

[0004] A further object of the invention is providing a plant for the aftertreatment of gaseous pyrolysis products (synthesis gas or syngas) which may lead to a complete and efficient refinement of synthesis gas and which may be adapted to different operational loads, and/or which may enable the continuation of the refinement cycle even during maintenance work.

Summary of the Invention

[0005] The object of the invention is achieved by means of a device for pyrolysis treatment of waste, and by means of a plant for the treatment of gaseous pyrolysis products having the features set forth in the claims which follow, and which constitute an integral part of the technical disclosure provided herein in relation to the invention.

Brief Description of the Figures

[0006] The invention will now be described with reference to the annexed Figures, provided by way of non-limiting example only, wherein:

- Figure 1 is a side view of a device for treatment according to the invention,
- Figure 2 is a partially cross-sectional and perspective view of the device of Figure 1,
- Figure 3 is a detail perspective view being partially sectioned along arrow III of Figure 1,
- Figure 4 is a block diagram representing a plant according to the invention,
- Figure 5 is a perspective view of a preferred embodiment of the plant according to the invention, and
- Figure 6 is a perspective view along arrow VI of Figure 5.

[0007] Some of the Figures include a Cartesian reference system X-Y-Z (Z = vertical) which enables defining the reference characters of the axes shown in the Figures (the reference prefix denotes the direction in the system X-Y-Z to which the axis is parallel; if such condition is not given, the axis is denoted by a Greek letter).

Detailed Description

[0008] Referring to Figures 1 to 3, reference 1 generally denotes a device for the pyrolysis treatment of waste according to the invention.

[0009] The device 1 comprises:

- a treatment shell 2 extending along a shell axis Z2 and defining a waste treatment volume V2 inside shell 2,
- a heating unit 4 configured for operating in a heat exchange relationship with one or more walls of shell 2,
- a waste loading unit 6 configured for inputting waste into the treatment volume 2,
- a manifold unit 8 configured for receiving treatment products from treatment volume V2,
- a waste displacement unit configured for displacing, along shell axis Z2, the waste which in use undergoes pyrolysis in treatment volume V2.

[0010] In a preferred embodiment, as shown in the Figures, the waste displacement unit comprises a first rotor unit 10, arranged inside the treatment volume V2 and comprising a screw rotor 12 rotatable about a rotor axis Z12, preferably coaxially to axis Z2, and configured for displacing, along rotor axis Z12, the waste which in use undergoes pyrolysis in the treatment volume V2. Preferably, the rotor axis is coaxial to (and thus coincides with) the shell axis Z2.

[0011] In other embodiments, the waste displacement unit comprises a gas supply unit configured for supplying - into volume V2 - a gas flow having a direction parallel to shell axis Z2, so that the gas flow drags and displaces the mass of waste in the treatment volume V2 along the shell axis Z2. In an embodiment, the gas flow may comprise a recirculated flow of gaseous pyrolysis products of device 1. In other embodiments, the gas flow comes from a generator (or, generally speaking, from an external supply unit), and may include an oxygen percentage promoting pyrolysis within volume V2. In some embodiments, the gas flow may comprise an air flow.

[0012] In a preferred embodiment, such as shown in the Figures, shell 2 is a cylindrical tubular element comprising a first flange (lower flange) 14 for the connection to the manifold unit 8, and a second flange (upper flange) 16 for the connection to the loading unit 6. The connection of the shell 2 to the loading unit 6 is preferably provided by means of a further cylindrical tubular element 18, provided with a lower flange 20 coupled to flange 16 of shell 2, and with an upper flange 22 coupled to the corresponding flange 24 of the loading unit 6.

[0013] In a preferred embodiment, such as depicted in the Figures, the heating unit 4 comprises an induction heater arranged externally to shell 2 and enclosing shell 2 around shell axis Z2. The induction heater comprises (Figure 3) an inductor 26 shaped as a tubular element, preferably made of copper, developing in a plurality of turns around axis Z12 and wrapping the outer shell 2. The tubular element has an inner lumen 28 configured for the transit of a flow of refrigerant fluid (liquid), e.g., refrigerant water. The lumen 28 of inductor 26 is part of a cooling hydraulic circuit, including a pump configured for delivering a refrigerant fluid into lumen 28, a heat exchanger which is in fluid communication with the lumen 28 and which is configured for reducing the temperature of the refrigerant liquid at the exit of lumen 28. The heat exchanger is in fluid communication with the pump intake for the recirculation of refrigerant fluid, and may optionally branch to a heat sink (in order to tackle with thermal loads in conditions of emergency) or to a secondary circuit in order to recover thermal energy.

[0014] The inductor 26 is electrically connected to a generator of alternating current, comprising an IGBT (Insulated-Gate Bipolar Transistor), which is substantially a hybrid electronic device between a bipolar transistor and a MOSFET.

[0015] The IGBT is configured for providing an automatic monitoring of the operating frequency, oscillating

between 30 and 100 kHz. The penetration depth of the electric current is strictly connected to the operating frequency, to the properties of the material and to the temperature reached by the component. The high operating frequency (30-100 kHz) enhances the skin effect and leads to an optimal surface heating for thin-walled elements (such as shell 2 in the preferred embodiments of the invention). The inductor 26 operates by providing energy to the shell 2, by heating the latter and volume V2 by means of a high alternating electromagnetic field. The electrical current flows in the inductor 26, thus creating around it a magnetic field with mirror image.

[0016] A 100% duty cycle enables a continuous use of the system throughout the day, with downtimes being only required for the ordinary maintenance work.

[0017] The tubular element 26 encloses shell 2 (which is preferably made of steel AISI 410), and it is configured for heating the walls thereof inductively, and for keeping a preset temperature within volume V2 by convection and irradiation of volume V2 itself.

[0018] Due to the combination with induction heater 4, the shell 2 preferably has walls with reduced thickness (2 mm). The reduced thickness of the reactor (2 mm) facilitates the manufacturing of shell 2, while imparting to it a low thermal inertia, and thus enabling it to react more quickly to the temperature variation control within volume V2. This enables, e.g., reaching the predetermined temperature within volume V2 in a time shorter than 30 minutes, starting from inactivity conditions.

[0019] The control of the generator of alternating current may preferably be performed by means of a PLC controller, configured for the electrical supply of inductor 26, so as to vary the temperature within volume V2 with a closed loop control.

[0020] Preferably, there are present a first and a second insulating layers, in order to minimize heat losses: a first layer is provided between shell 2 and inductor 26, and a second layer is provided as a sheath around inductor 16, in order to limit or avoid heat losses to the outside, by concentrating the heat flow towards volume V2 wherein, in use, waste undergoes the pyrolysis treatment.

[0021] Referring to Figures 1 and 2, the waste loading unit 6 includes a waste input port 30 and a rotary valve 32, which in turn includes an impeller 34 being rotatably driven around an axis Y34 by means of an electric motor M34 through a transmission (e.g., a belt or chain transmission). The rotation of impeller 34 brings about the displacement of a flow of waste W_IN from the port 30 through the valve body 32 and towards flange 24, which functionally serves as a delivery port of flow W_IN towards volume V2.

[0022] In other embodiments, the heating unit 4 comprises - instead of inductor 26 - a resistive heating element, while keeping the arrangement of insulators described in the foregoing (in other words, the resistive element takes the place of inductor 26, taking into account possible geometry variations of the resistive element with

respect to the helical geometry of inductor 26). In still further embodiments, the heating unit 4 comprises a combustion gas supply unit, for instance in order to provide energy integration with another plant or device wherein a combustion takes place which releases combustion products having a usable enthalpy.

[0023] With reference to Figure 3, the manifold unit 8 comprises a manifold shell 36 including a first manifold 38 having a toroidal internal volume coaxial to the shell axis Z12, and configured for receiving fluid treatment products from treatment volume V2, the first manifold 38 comprising one or more pervious walls configured for enabling a fluid communication between the treatment volume and one or more first discharge ports F_OUT provided on the manifold shell 36. In the embodiment shown in the Figures, the first manifold 38 comprises:

- a cylindrical inner wall 40 which is perforated, and therefore pervious to fluids,
- a cylindrical outer wall 41 which is perforated, and therefore pervious to fluids,
- an annular bottom wall 42 which is perforated, and therefore pervious to fluids, and
- an annular top wall 44, which is perforated and therefore pervious to fluids. Preferably, the top wall is configured as an annular wall (which may be integral with, or forming a part of, shell 36), wherein the perforations are provided only at the ports F_OUT (or at the port F_OUT, if only one is present); in other words, it practically corresponds to an annular wall which is perforated at the positions of ports F_OUT. In some embodiments, the top wall may include an assembly of a first perforated wall, similar to wall 42 and arranged below ports F_OUT, and an annular wall (which may be integral with, or forming a part of, shell 36) which is perforated only at the positions of ports or port F_OUT.

[0024] This structure defines a toroidal internal volume having a quadrangular section, which preferably accommodates hollow metal spheres acting as a filtration element, or else spheres coated with a catalyst agent for pre-treating the gaseous products from volume V2.

[0025] A further perforated circular wall 46 is arranged substantially flush with wall 44, but it is located within wall 40 spanning the whole inner lumen of the shell 2, i.e. the whole section of volume V2.

[0026] The manifold shell 36 moreover comprises a second manifold 48, which is essentially configured as a collection vessel to receive solid treatment products from the treatment volume V2. The second manifold 48 comprises a second rotor unit including a rotor 50 with curved blades, having a rotation axis coinciding with axis Z12 of the first rotor unit 12 (and with axis Z2), which is rotatably driven by means of an electric motor having an output shaft meshing with a pinion P52 which is fitted onto a hollow shaft 52, the latter being rotatably connected to a hub of rotor 50.

[0027] The second rotor unit, and specifically rotor 50, is configured for displacing the solid treatment products falling into the second manifold to one or more second discharge ports, which are provided or managed directly on the wall of the manifold shell 36. In the embodiment shown in the Figures, only one discharge port is present, which is coupled to a screw conveyor 54 inside which there is rotatably mounted (around axis γ 56) an auger, which is rotatably driven by means of an electric motor M56 (Figures 1, 2).

[0028] It will moreover be observed, always referring to Figure 3, that the second manifold 48 has a volume which is at least partially delimited by one or more pervious walls 40, 41, 42, 44 (in this case primarily by walls 40, 42) of the first manifold 38, and which is external to the inner (toroidal) volume of the first manifold 38.

[0029] Referring to Figures 2, 3, the screw rotor 12 comprises a hollow shaft 58 whereon a helical profile (principle) develops having an external diameter substantially equal, apart from operational clearances, to the inner diameter of shell 2. In other words, the screw rotor is essentially shaped as an auger, having an outer diameter (corresponding to the ridges of the helical profile of rotor 12) substantially corresponding to the inner diameter of shell 2.

[0030] Preferably, the helical profile of screw rotor 12 has a constant pitch, but embodiments may be envisaged wherein the pitch is variable. The variable pitch structure enables tackling with situations of variable permanence time and/or variable flow of the material entering the reaction chamber.

[0031] The hollow shaft 58 comprises a cavity 60 which extends along the rotor axis Z12 (coaxial to axis Z2) and which leads out at one or more outlet orifices 62, so that it is configured for delivering a fluid, specifically an oxidising fluid, to treatment volume V2. At least one and preferably all outlet orifices 62 have a radial orientation with respect to the rotor axis Z12.

[0032] As can be seen in Figure 3, the hollow shaft 58 is arranged inside hollow shaft 52 and exits it only at a lower end, which features a gear wheel P52 meshing with a driving wheel C52, which is fitted onto an output shaft of an electric motor M12 which rotatably drives rotor 12.

[0033] With reference to Figures 4 to 6, reference number 100 generally denotes a plant for the treatment of gaseous pyrolysis products according to the invention.

[0034] Generally speaking, and referring to the schematic diagram of Figure 4, the plant 100 comprises the device for treatment 1 and an aftertreatment line configured for processing the gaseous treatment products exiting the device for treatment 1.

[0035] According to the invention, the aftertreatment line comprises two treatment paths A, B (although, generally speaking, a plurality of parallel treatment paths may be provided), each comprising a sequence of treatment stages associated with reference numbers 104, 106, 108, 110 (the reference numbers are integrated with the letter

"A" or "B" according to the treatment path which they belong to). Preferably, a common cyclonic separator 102 is installed upstream the treatment paths A, B, but according to needs two cyclonic separators may be provided, so that the treatment paths A, B each include a respective cyclonic separator 102.

[0036] Each sequence of treatment stages 104, 106, 108, 110 (and 102, if it is present on both paths A, B) of each treatment path A, B is configured for operating in parallel with the treatment sequence of the other treatment path B, A, respectively, and moreover for operating when the other treatment path is in an inactive condition, e.g. for the purpose of maintenance work.

[0037] In the preferred embodiment shown herein, each sequence of treatment stages comprises the same treatment stages, specifically:

- a first dechlorination stage 104A, 104B
- a second desulfurization stage 106A, 106B
- a third catalytic reforming stage 108A, 108B
- a fourth gas/liquid separation stage 110A, 110B.

[0038] More specifically, each reaction stage 104, 106, 108 preferably comprises a cartridge filtration element, coated with one or more catalyst agents adapted to perform said functions.

[0039] Referring to Figures 5 and 6, the fluid connections between the various elements of plant 100 will now be detailed.

[0040] The functional inlet of plant 100 corresponds to the connection with the discharge port (or ports) F_OUT on the manifold unit 8. A duct 122 starts from here and establishes a fluid communication between the port(s) F_OUT and the cyclonic separator 102, with respect to which the flow F_OUT is an input flow and therefore is associated to reference F_IN. Flow F_IN essentially comprises gaseous pyrolysis products, having variable amounts of liquid and solid particles suspended therein. The cyclonic separator 102 comprises a collection vessel 114 adapted to receive the solid particles which have been separated by means of a centrifugal action from the gaseous flow corresponding to flow F_IN, and an outlet duct 116, configured for carrying the syngas processed in separator 102 towards a fork branching into two ducts 118A, 118B, respectively leading to the inlets of the dechlorination stages 104A and 104B. The inlet is located at the top, but of course it may be located at the bottom.

[0041] At the exit from the dichlorination stages 104A and 104B, the syngas thus further processed is sent to the desulfurization stages 106A, 106B through a further pair of ducts 120A, 120B which lead to the inlet of the desulfurization stages 106A and 106B, respectively. The inlet is located at the bottom, but it may obviously be located at the top (stages 104-110 have a predominantly axial flow, and therefore they are supplied in series along the paths A, B, alternating top and bottom inlets).

[0042] At the exit from the desulfurization stages 106A

and 106B, the syngas thus further processed is sent to the catalytic reforming stages 108A, 108B through a further pair of ducts 122A, 122B which lead to the inlet of the catalytic reforming stages 108A and 108B, respectively. The inlet is located at the top, but it may obviously be located at the bottom according to the previously mentioned alternating pattern.

[0043] At the exit from the catalytic reforming stages 108A and 108B, the syngas thus further processed is sent to the gas/liquid separation stages 110A, 110B through a still further pair of ducts 124A, 124B, which lead to the inlet of the gas/liquid separation stages 110A, 110B, respectively. The inlet is located at the bottom, but the inlet may also be located at the top according to the previously mentioned alternating pattern.

[0044] At the exit of the gas/liquid separation stages 110A, 110B, the syngas thus further processed is sent to a still further pair of ducts 126A, 126B, which converge into a single node 128 to be led to a last filtration stage, which removes possible residues of suspended particles in the syngas.

[0045] The operation of device 1 and of plant 100 is as follows. Device 1 functionally operates as a pyrolysis reactor for non recyclable waste (for example sea waste, plastics, medical waste, agricultural waste with a maximum moisture content of 40%), and performs a conversion of the waste into syngas, which is refined by means of aftertreatment in plant 100.

[0046] Before entering the loading device 6, the waste flow W_IN is subjected to a sorting process, in order to remove metal and glass parts, and to shredding so as to obtain a mass with a maximum grain size lower than 35 mm. The shredded material is then poured into the loading unit 6, and it is introduced into the rotary valve 32. Motor M34 is then set in motion, so that the impeller 34 starts rotating and displaces the flow W_IN towards treatment volume V2. The rotary valve 32, thanks to the small play between the impeller 34 and the valve body, limits or completely prevents the inflow of air from the outside and the mixing thereof with flow W_IN.

[0047] The treatment volume V2 is a pyrolysis volume for the flow W_IN thanks to the heating action of unit 4, and specifically of inductor 26. This enables establishing, within volume V2, a temperature which varies as a function of the conditions of the material constituting flow W_IN (moisture, composition, grain size), but which anyway exceeds 600°C (up to 1000°C). Pyrolysis moreover takes place thanks to the addition of an oxidising flow, specifically oxygen, by means of rotor 12 and through cavity 60 and holes 62. The amount of the oxygen flow is adjusted according to the composition of the gaseous pyrolysis products exiting volume V2.

[0048] When the waste flow W_IN has been introduced into volume V2, the generator is activated in order to supply inductor 26; according to needs, the circulation of refrigerant fluid in lumen 28 is started and the screw rotor 12 starts rotating thanks to the activation of motor M12 (which is provided with an inverter). According to the in-

vention, the rotor 12 ensures the adjustment of the period during which the material of flow W_IN remains within volume V2. Such an adjustment prevents the material from depositing on the bottom of volume V2, and enables varying the flow of input material (5-50 kg) without modifying the treatment volume V2.

[0049] Rotor 12, as can be seen in Figure 3, has an axial extension along axis Z12 which is substantially equal to the axial extension of inductor 26 along the same axis. This means that the displacement of the waste flow W_IN, which undergoes pyrolysis by means of the inductive heating of the walls of shell 2, globally takes place along a direction parallel to axis Z2, and within an axial band corresponding to the region of influence of inductor 26. Therefore, the screw rotor 12 maximizes the filling of treatment volume V2, while always keeping the waste undergoing treatment within an axial band which is directly subjected to the inductive heating. As the screw rotor 12 has an outer diameter substantially corresponding to the inner diameter of the shell, it is possible to manage the mass of the waste undergoing pyrolysis essentially by means of the screw rotor 12 only, because the movements of the pyrolysis mass which do not involve the interaction of the rotor are minimized or excluded.

[0050] In the embodiments envisaging the use of a gas flow for displacing the waste in volume V2, through the control of the gas flow (pressure and speed) it is also possible to always keep the waste being treated within an axial band which is directly subjected to inductive heating, as in the case of rotor 12, so that the mass of waste is always kept within the area subjected to inductive heating.

[0051] Of course, the same considerations apply if heating takes place by means of a resistive element or resistive elements, or by means of a flow of combustion products: in all such cases, there is always an axial band of influence - on shell 2 - which is subjected to the action of the heating element or medium being used, and the waste displacement unit keeps the mass of waste within the area of influence.

[0052] During the treatment of flow W_IN, the tubular element 18 is essentially configured as an extension of the shell 2, which is not necessarily configured for the treatment of the mass of waste W_IN, but which acts as an intermediate chamber between the loading unit 6 and the volume V2, more precisely the band subjected to inductive heating from inductor 26, and which performs three functions:

- i) thermal interruption between the volume V2 (and the shell 2) and the loading unit 6, with the purpose of reducing the thermal load on loading unit 6
- ii) housing sensor equipment, which preferably includes a pressure sensor and a temperature sensor,
- iii) routing the waste from loading unit 6 directly into volume V2.

[0053] The treatment of flow W_IN causes the formation of pyrolysis products which are both solid and fluid (liquids and gases, the latter constituting the main part). The gaseous fraction of the pyrolysis products, which is still raw because it contains suspended solid and liquid particles, is raw synthesis gas (syngas), which can go through the walls, the disk 46 on the bottom of volume V2, and therefrom the pervious walls of the first manifold 38, thereby entering the toroidal volume thereof, which constitutes a pre-treatment chamber for syngas. Here, the metal spheres within the volume of manifold 38 perform a first filtration of the syngas, and at the same time they start reducing the amount of tar which is present in the syngas. Traversing the pervious walls of manifold 38 also leads to the collection of the syngas at the top of the manifold shell 36, wherefrom it can head towards the ports F_OUT.

[0054] The solid pyrolysis products, which are much heavier than syngas, reach by gravity the second manifold 48, and by means of the second rotor 50 they are sent to the auger 56, in order to be expelled through port S_OUT. The expulsion is achieved by rotatably driving the auger 56, and the flow of solid pyrolysis product S_OUT which has been disposed of in this manner is sent to a collection vessel, preferably through a hermetically sealed rotary valve, so as to prevent air from entering from the outside.

[0055] The syngas exiting through ports F_OUT is then treated in plant 100 with the purpose of reducing the amount of contaminants contained therein (HCl, H₂S, tar, particulate matter, etc.) so that the gas may be used in engines or fuel cells for combined heat and power production.

[0056] The hot syngas (flow F_OUT) which exits device 1 flows through the duct 112 and enters the cyclonic separator 102. The latter is preferably made of thermally insulated steel, and is kept at a temperature higher than 450°C. The cyclonic separator 102 is configured for the centrifugal mechanical separation of the bigger particles suspended in the syngas. Once they have been separated mechanically, the particles are collected in vessel 114, while the syngas is sent into duct 116 and, through ducts 118A, 118B, enters the dechlorination stages 104A, 104B. The latter preferably comprise a cartridge filter containing pellets (3 - 8 mm) of CaO-based reagents, which are able to convert the hydrochloric acid HCl which is suspended in the syngas, and generally speaking the chloric compounds. The pellets of reagents are kept at temperatures higher than 450°C by means of electrical resistors. The cartridge may be removed in order to replace the reagent material.

[0057] Once the dechlorination treatment is completed, the syngas is sent to ducts 120A and 120B, and from there to the desulfurization stages 106A, 106B. As a matter of fact, the syngas contains hydrogen sulfide (or hydrogen sulphide) H₂S and other sulfuric products, especially carbonyl sulphide COS. The removal of such pollutants is of paramount importance, because H₂S is a

strongly corrosive agent (which may therefore cause damages to plant 100); moreover, sulfuric compounds are responsible for the deactivation of the most widely used Ni-based catalyst agents for catalytic tar reforming, and so they may contaminate stages 108A, 108B.

[0058] The desulfurization stages 106A, 106B comprise a removable cartridge filter containing a zinc-oxide-based reagent, which is kept at temperatures higher than 450°C by means of electrical resistors. It will be noticed that the removal of hydrogen sulphide may also take place at low temperatures, but the removal of other sulfuric products requires higher temperatures. For this reason, it is preferable to operate at temperatures around 450°C.

[0059] As previously stated, one of the main problems of the syngas obtained from plastics which cannot be sorted is the high tar content. This pollutant is therefore reduced by sending the syngas which exits the desulfurization stages 106A, 106B to ducts 122A, 122B, and therethrough to the catalytic reforming stages 108A, 108B. The latter comprise a cartridge filter having catalyst agents which promote tar reforming, i.e., the conversion of most undesirable tar compounds into gaseous hydrogen H₂. The catalyst agents which are employed are Ni-based (specifically NiO-based) catalysts. The cartridge filter enables employing different kinds of catalyst agents, depending on the material to be treated which enters stages 110A, 110B. The catalyst agents contained in the filter are kept at temperatures higher than 650°C by means of electrical resistors. Within the catalytic reforming stages there is moreover preferably provided a filtration cartridge having a shredded biomass bed, which performs the function of a biological filter in order to eliminate possible residual particles from the syngas. Moreover, the filtering material of the cartridge bed may in turn be introduced into the rotary valve 32 and equally converted into syngas.

[0060] The syngas which exits stages 108A, 108B is sent to ducts 124A, 124B, it is cooled by means of a tube bundle heat exchanger 130 and brought to a temperature $T < 150^{\circ}\text{C}$ in order to enter the gas/liquid separation stages 110A, 110B, wherein the liquid fraction which is still present in the syngas is separated and condensed. The gas/liquid separation stages 110A, 110B comprise a labyrinth of metal sheets having a corrugated surface, thus enabling the coalescence and the separation of oils and generally of condensate from the syngas. The collected liquid material is again input into the waste treatment cycle in the device for treatment 1, together with the material being input into the rotary valve 32. This recycling process leads to increasing the calorific value of the syngas and to reducing the amount of residual pollutants. The completely purified syngas is sent to the ducts to the gas/liquid separation stages 126A, 126B, and from there to node 128 and to further utilization stages (e.g. a combined heat and power production plant).

[0061] According to the invention, the two flow paths A, B are completely independent from each other. They

are supplied in parallel starting from the fork branching downstream duct 116, and each stage thereof processes a respective percentage of the flow F_{IN}. This operating principle offers a double advantage:

- a) if either treatment path, A or B, is in an inactive condition, e.g., for the replacement of the filtration cartridge of one or several among the stages 104-110, the plant 1000 may continue operating with no interruptions by simply sending the whole flow F_{IN} along the treatment path (A or B) which is still operating;
- b) when both paths A and B are in operation, it is possible to treat a widely variable flow of syngas, the redundancy offering the possibility to treat even very large flows without the need of an upgrading of the plant 100.

[0062] These two advantages, together with the very high efficiency of the device for treatment 1, make the plant 100 an integrated and efficient solution for producing and refining synthesis gas from waste which cannot be sorted. Last but not least, this solution may be configured in a completely modular fashion. As a matter of fact, it is sufficient to vary the number of treatment paths A, B and/or of the devices for treatment 1 in order to build plants with different capacity ranges. In this regard, both the device 1 and the components of the plant 100 may generally be mutually integrated according to a "plug and play" logic.

[0063] In this regard, it should be borne in mind that plant 100 may operate also in conjunction with a device for the pyrolysis treatment of waste other than the device 1 described herein. Therefore, device 1 may operate in conjunction with a plant for the treatment of conventional gaseous pyrolysis products, and in any case with a plant other than according to the invention, and the plant 100 may be employed for the treatment of gaseous pyrolysis products deriving from a device (or reactor) for pyrolysis treatment other than device 1.

[0064] Of course, the implementation details and the embodiment may amply vary with respect to what has been described and illustrated herein, without departing from the scope of the present invention, as defined in the annexed claims.

Claims

1. A device (1) for pyrolytic treatment of waste, comprising:
 - a treatment shell (2) extending along a shell axis (Z2) and defining a waste treatment volume (V2),
 - a heating unit (4) configured to operate in a heat exchange relationship with one or more walls of said shell (2),

- a waste loading unit (6) configured to input waste (W_IN) into said treatment volume (V2),
 - a manifold unit (8) configured for receiving treatment products from said treatment volume (V2),
 - a waste displacement unit (10) configured for displacing along said shell axis (Z2) the waste which, in use, undergoes pyrolysis in said treatment volume (V2) .
2. The device (1) according to claim 1, wherein said waste displacement unit comprises a first rotor unit (10) arranged inside said treatment volume (V2), said rotor unit comprising a screw rotor (12) rotatable about a rotor axis (Z12) and configured for displacing along said rotor axis (Z12) the waste which, in use, undergoes pyrolysis in the treatment volume (V2).
3. The device (1) according to claim 2, wherein the screw rotor (12) comprises a hollow shaft (58), said hollow shaft (58) having a cavity (60) extending along said rotor axis (Z12) and leading out at one or more outlet orifices (62), said hollow shaft (58) being configured for delivering a fluid, particularly an oxidising fluid, to said treatment volume (V2).
4. The device (1) according to claim 2, wherein said rotor axis (Z12) is coaxial to said shell axis (Z2).
5. The device (1) according to claim 1, wherein said waste displacement unit comprises a gas supply unit configured to supply a gas flow having a direction parallel to said shell axis (Z2), said gas flow being configured to displace along said shell axis the waste which, in use, undergoes pyrolysis in said treatment volume (V2).
6. The device (1) according to any one of the preceding claims, wherein said heating unit (4) comprises an induction heater (26) arranged externally to said shell (2) and enclosing said shell (2) around said shell axis (Z2).
7. The device (1) according to claim 6, wherein said induction heater (26) comprises an inductor (26) having a tubular element developing in a plurality of turns around said rotor axis (Z12) and wrapping said outer shell (2), said tubular element having an inner lumen (28) configured for the transit of a flow of refrigerant fluid.
8. The device (1) according to any one of the preceding claims, wherein said manifold unit (8) comprises a manifold shell (36) including:
- a first manifold (28) having a toroidal internal volume coaxial to said axis of said shell (Z2), said first manifold (38) being configured to receive fluid treatment products from said treatment volume (V2) and comprising one or more pervious walls (40, 41, 42, 44) configured to enable a fluid communication between said treatment volume (V2) and one or more first discharge ports (F_OUT) of said manifold shell (36),
 - a second manifold (48) configured to receive solid treatment products from said treatment volume (V2), said second manifold (48) comprising a second rotor unit (50) configured to move said solid treatment products to one or more second discharge ports.
9. The device (1) according to claim 8, wherein said first manifold (38) comprises a filtration bed in said toroidal inner volume.
10. The device (1) according to claim 8 or claim 9, wherein:
- said second manifold (48) has a volume delimited at least in part by one or more pervious walls (40, 41, 42, 44) of said first manifold (38) and external to the inner volume of said first manifold,
 - said second rotor unit (50) is coaxially arranged with said first rotor unit (10).
11. A plant (100) for treating gaseous pyrolysis products comprising an aftertreatment line configured to process gaseous treatment products of a pyrolysis treatment device (1), the aftertreatment line comprising at least two treatment paths (A, B), each treatment path comprising a sequence of treatment stages (104, 106, 108, 110), the sequence of treatment stages (104, 106, 108, 110) of each treatment pathway (A, B) being configured to operate in parallel with the treatment sequence of the other treatment path (B, A), and to operate when the other treatment pathway (B, A) is in an inactive condition.
12. The plant (100) according to claim 11, wherein each sequence of treatment stages comprises the same treatment stages, in particular:
- a first dechlorination stage (104A, 104B)
 - a second desulfurization stage (106A, 106B)
 - a third catalytic reforming stage (108A, 108B)
 - a fourth gas/liquid separation stage (110A, 110B).
13. The plant (100) according to claim 11 or claim 12, further comprising a common cyclonic separator (102) upstream of said treatment paths (A, B).
14. The plant (100) according to any one of claims 11 to

13, comprising a treatment device (1) according to any one of claims 1 to 10, said plant being configured to process gaseous treatment products said treatment device (1) by means of said aftertreatment line.

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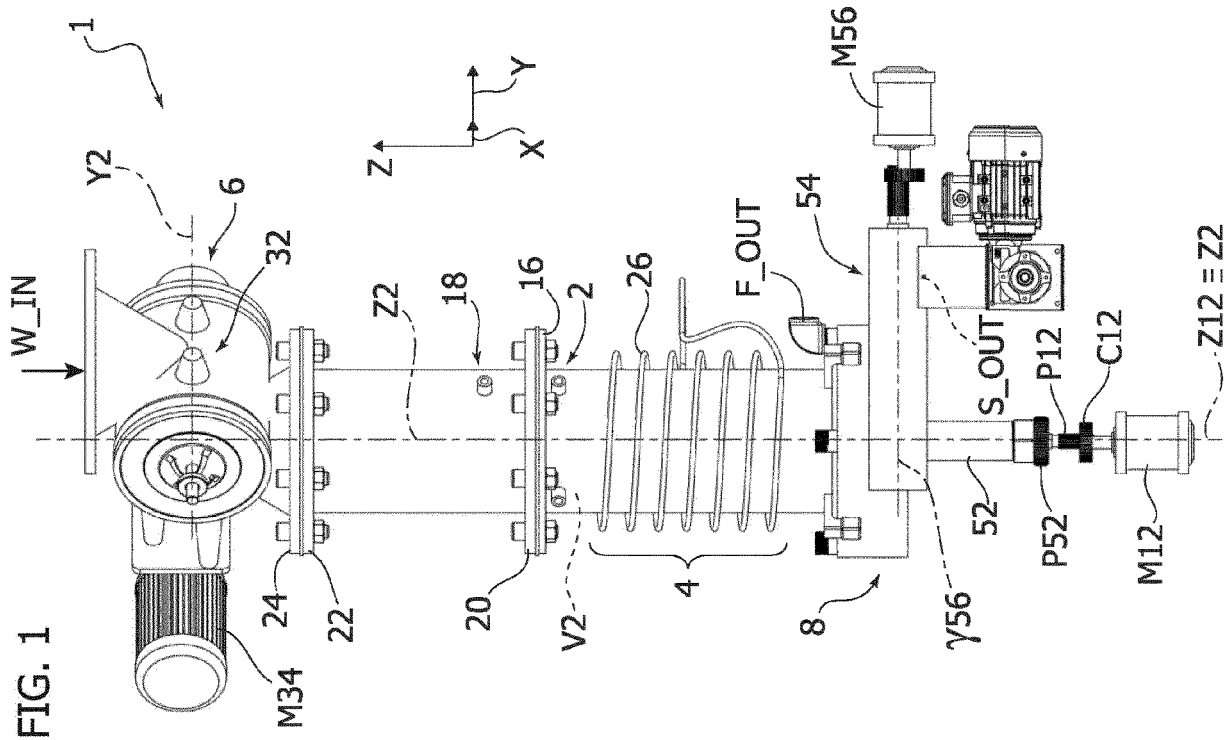
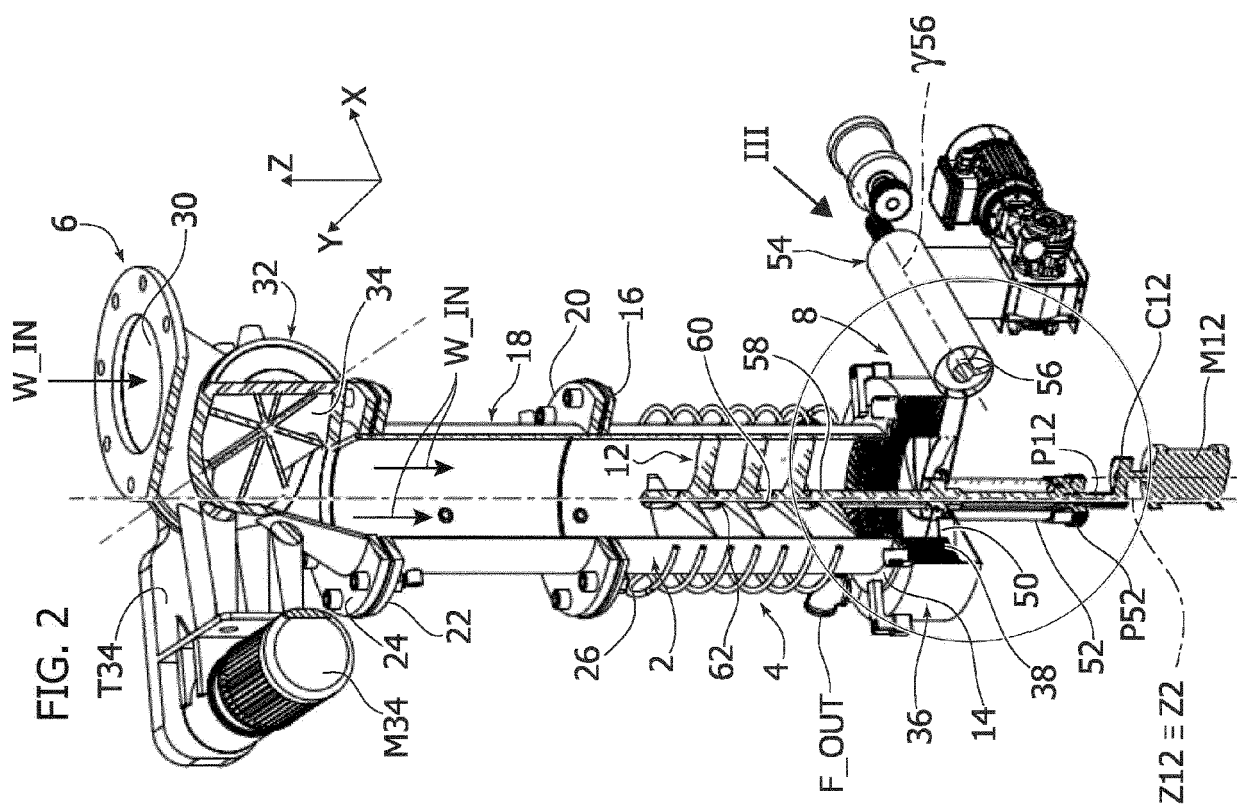
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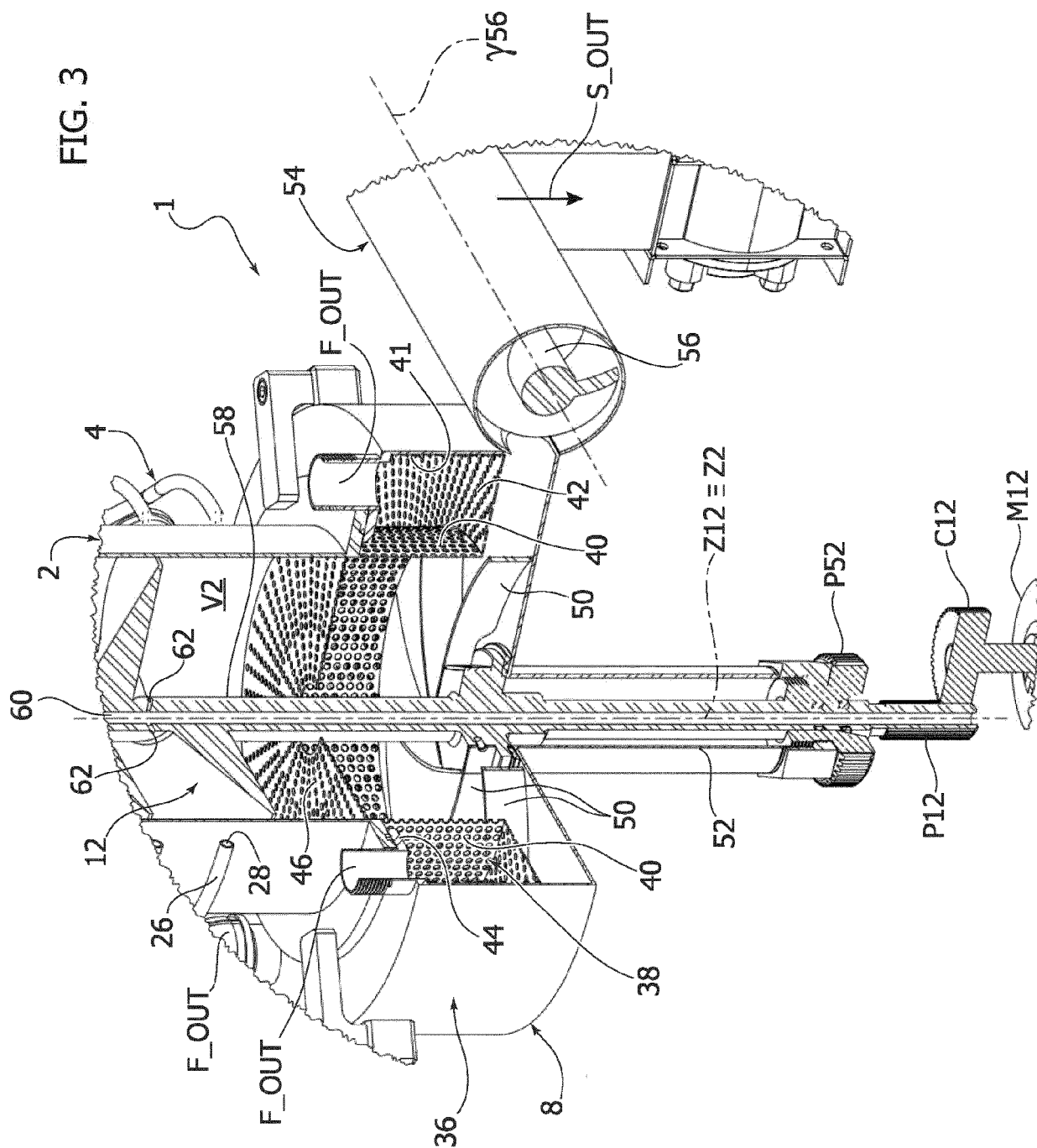


FIG. 4

