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(54) MICRO-COGENERATOR

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EP 4 359 654 B1

Description

Field of the invention

[0001] The present invention relates to a micro-cogenerator for producing electrical energy and heat starting from a renewable and sustainable energy source, e.g., woody biomass. In particular, the present invention relates to a micro-cogenerator for household or small consumer use, comprising a pyrolytic gasifier, a burner, and a Stirling engine.

Background art

[0002] The need to search for solutions suited to new values and lifestyles is increasingly felt at a point in history in which the transition from a linear economy logic (in which every process creates new waste) to a circular economy logic has become vitally important, and in which fossil fuels are becoming increasingly scarce and expensive. Self-generation is the most suitable answer in terms of sustainability, autonomy, and safety in electrical energy production.

[0003] Biomass-fueled cogeneration systems consisting of three basic parts, i.e. a pyrolytic gasifier, a burner, and a Stirling engine, are well known. The fuel syngas is produced starting from the biomass in the pyrolytic gasifier; the syngas produced is burned with a controlled supply of air in the burner; the Stirling engine, by virtue of the heat generated by the combustion of the syngas, sets the electric generator in oscillation, thus producing electrical energy.

[0004] Pyrolytic gasification is a thermal-chemical process by virtue of which a combustible gas (syngas), comprising a mixture of hydrogen, carbon monoxide, methane and, to a lesser extent, other compounds, can be extracted from organic material, such as biomass. Pyrolytic gasification occurs by maintaining the biomass at a particularly high temperature in a low-oxygen environment. The by-product of pyrolytic gasification is a solid residue, named char, which contains almost exclusively carbon.

[0005] The use of pyrolytic gasification, compared with direct combustion of the biomass, reduces carbon emissions into the atmosphere because, once the fuel syngas is extracted, only the char remains which contains the portion of carbon that will not be emitted into the atmosphere in the form of CO_2, but is evacuated in solid form and collected. Furthermore, the use of pyrolytic gasification provides a fuel gas which is much more effective in the combustion in terms of maximum achievable temperature, emissions of particulate matter and heating of the heat exchangers.

[0006] Examples of cogenerators based on the application of the pyrolytic gasification and the Stirling engine are described in US 2009/0078176 and US 2006/0089516. WO 2015/018742 discloses an apparatus for generating energy by gasification. CN 109 424 964 discloses a horizontal double-layer tube rotary superconducting waste pyrolysis gasifier.

[0007] However, to date, the need is increasingly felt to maximize the efficiency and the chemical and mechanical resistance of the pyrolytic gasifier, which is a particularly delicate element of the micro-cogenerator, inside which an environment that is difficult to manage and control is created.

[0008] The pyrolytic gasifier contains a reaction chamber inside which the biomass is gasified in the presence of a given amount of air, generating syngas. By its nature, the atmosphere inside said reaction chamber during its operation is strongly reducing, because, since it is rich in hydrogen, carbon monoxide and methane, it has a strong tendency to react with oxygen. In such an environment, the refractory materials do not show the same heat resistance they would have in a neutral or oxidizing environment, but rather their classification temperature undergoes a significant reduction. As a consequence, said materials rapidly tend to degrade chemically.

[0009] For these reasons, the need is strongly felt to increase the chemical resistance of the pyrolytic gasifier under such process conditions and at very high temperatures of approximately 1200-1400°C, ensuring at the same time good mechanical strength, excellent resistance to thermal shock due to the thermal gradient generated longitudinally to the reactor itself, and maximizing gasification efficiency.

[0010] Therefore, the technical problem underlying the present invention is to provide a micro-cogenerator for domestic or small consumer use, in which the pyrolytic gasifier can ensure high performance characteristics and meet the requirements presented above.

Summary of the invention

[0011] The problem described above is solved by a micro-cogenerator as outlined in the accompanying claims, the definitions of which form an integral part of the present description.

[0012] The object of the present invention is a micro-cogenerator comprising:

- a pyrolytic gasifier adapted to produce syngas and biochar starting from a renewable and sustainable energy source, preferably woody biomass,
- a burner adapted to receive the syngas produced by said pyrolytic gasifier and to generate hot combustion gases,
- a Stirling engine comprising a heat exchanger (the so-called "hot exchanger") fed with said hot combustion gases, said Stirling engine being adapted to generate electrical energy,
- wherein said pyrolytic gasifier comprises a reaction chamber inside which said energy source is gasified in the presence of air, thus generating syngas and biochar,
- wherein said reaction chamber has truncated-cone

shape and is made of a polycrystalline alumina fiber-based material comprising at least 70% by weight of polycrystalline alumina, and optionally, at least 5% by weight of silica, said material having a density preferably between 350 and 500 kg/m^3,

said micro-cogenerator comprising an exhaust system (33) adapted to receive exhaust fumes (34) leaving the hot exchanger (38) of the Stirling engine (4),

wherein said exhaust system (33) comprises an exchanger (56) for the recovery of heat from said exhaust fumes (34), a lambda probe (57) which provides a signal based on which the ratio of air (31) to syngas (8) at the burner (3) inlet is adjusted, and a thermocouple (58) which measures the temperature of said exhaust fumes (34),

said micro-cogenerator further comprising an extraction fan (59) connected to said exchanger (56) for the recovery of heat from the exhaust fumes (34), said extraction fan (59) is configured to extract the exhaust fumes (34) thus creating a vacuum inside the burner (3) and the pyrolytic gasifier (2) and, in turn, to adjust the inflow of the syngas (8) from the pyrolytic gasifier (2) to the burner (3) and the inflows of air into both the pyrolytic gasifier (2) and the burner (3).

[0013] For ease of reference, the terms energy source and biomass will be used indiscriminately in the description below. Therefore, the term biomass should by no means be understood as limiting.

[0014] Advantageously, said energy source is gasified in the presence of a sub-stoichiometric amount of air.

[0015] According to an embodiment of the present invention, said polycrystalline alumina fiber-based material comprises at least 75% by weight of polycrystalline alumina, preferably at least 80% by weight, such as about 90% by weight. Preferably, said polycrystalline alumina fiber-based material further comprises an amount of silica of at least 5% by weight, preferably between 10% and 30% by weight, more preferably between 10% and 25% by weight, even more preferably between 10% and 20% by weight.

[0016] For example, said polycrystalline alumina fiber-based material is produced by the company Unifrax under the trade name High Temperature Saffil® Rigiform™. Preferably, said material is produced by the company Unifrax under the trade name Saffil® 160 HD.

[0017] According to an embodiment of the present invention, said pyrolytic gasifier comprises an outer coating with respect to said reaction chamber, said outer coating having an annular shape.

[0018] Preferably, said outer coating is made of microporous insulating material, preferably comprising silica. Preferably, said microporous insulating material comprises powder or reinforcing filaments of pyrogenic silica, to which opacifiers and/or inorganic oxides may be added. For example, said microporous insulating material is produced by the company Promat under the trade name Promalight®, or by the company Bifire under the trade name Microbifire®, or by the company Unifrax under the trade name Excelfrax®.

[0019] According to a preferred embodiment, the aforesaid outer coating having an annular shape consists of a plurality of superimposed rings made of said microporous insulating material.

[0020] According to an embodiment of the present invention, the pyrolytic gasifier comprises a layer of said polycrystalline alumina fiber-based material having varying thickness interposed between said reaction chamber and said outer coating. Preferably, said reaction chamber and said layer of polycrystalline alumina fiber-based material form a monolithic structure.

[0021] According to a preferred embodiment, said truncated-cone reaction chamber has an upper surface and a lower surface, wherein the diameter of the upper surface is smaller than the diameter of the lower surface, said diameters being such as to give the inner surface of the truncated-cone reaction chamber a draft angle comprised between 2° and 15°, preferably comprised between 2° and 10°, preferably of about 4°.

[0022] In an embodiment of the present invention, the pyrolytic gasifier comprises:

an unloading auger for the evacuation of the biochar,

a hopper connecting the reaction chamber and the unloading auger, said hopper forming a collection volume of the syngas produced in the reaction chamber, and

a connection duct between said hopper and the burner, from which the syngas is sucked and fed to said burner.

[0023] Preferably, said hopper comprises an upper frame (or edge) adapted to support the aforesaid outer coating, preferably through an appropriate support plate.

[0024] Preferably, said hopper comprises a lip, which projects below said frame and defines a support base for the reaction chamber through which the hopper receives the syngas produced.

[0025] Preferably, the reaction chamber comprises an electric heater adapted to heat the reaction chamber to the gasification temperature, and a thermocouple adapted to monitor the temperature in the upper part of the reaction chamber. Preferably, the reaction front is comprised between said heater and said thermocouple. The aforesaid heater integrates a special sensor inside it, e.g., a thermocouple.

[0026] In a preferred embodiment, the energy source under reaction is supported by the biochar produced during the gasification of said energy source, and the micro-cogenerator does not comprise any support grid for said energy source.

[0027] The micro-cogenerator object of the present invention comprises an exhaust system adapted to receive exhaust fumes exiting the hot exchanger of the

Stirling engine. Said exhaust system comprises an exchanger for the recovery of heat from said exhaust fumes, a lambda probe and a thermocouple which measures the temperature of said exhaust fumes. Said lambda probe regulates the air-to-syngas ratio at the burner inlet; more in particular, it provides a signal based on which said air-to-syngas ratio is adjusted.

[0028] According to this embodiment, the micro-cogenerator object of the present invention further comprises an extraction fan connected to said exchanger for the recovery of heat from the exhaust fumes, such as to extract the exhaust fumes thus creating a vacuum inside the burner and the pyrolytic gasifier and, in turn, to adjust the inflow of the syngas from the pyrolytic gasifier to the burner and the inflows of air into both the pyrolytic gasifier and the burner.

[0029] The combustion air inflow to the burner is advantageously adjusted by means of an electronically-driven motorized valve. Advantageously, such a valve is driven based on the signal provided by the lambda probe, i.e., based on the information provided by the lambda probe about the amount of air present in the exhaust fumes. The need to carefully control the amount of air is related to the fact that performance and emissions (CO, NO_x) are strongly affected by the fuel/combustion air ratio; an optimal ratio of combustion air to syngas can be maintained by virtue of the signal provided by the lambda probe. The position of the valve which regulates the combustion air supply is preferably calculated by a PID (Proportional Integrative Derivative) control, which takes as input the value read by the lambda probe and outputs the position of the air adjustment valve.

[0030] The lambda probe provides an electrical signal (in mV) through which it is possible to have a measurement of the "lambda value (λ)" properly so called, i.e., the ratio between the actual AFR (*air-fuel-ratio*) and the stoichiometric AFR (*air-fuel-ratio*); in other words, the "lambda value (λ)" properly so called is to be understood as the ratio of air to fuel relative to the stoichiometric ratio of the fuel used. The electrical signal provided by the lambda probe is an indirect measurement of said lambda value (λ); the higher the value of the electrical signal, the lower the lambda value (λ).

[0031] Preferably, the pyrolytic gasifier comprises a first butterfly valve at the input interface of the energy source into the reaction chamber such as to allow the inflow of the energy source into the chamber and the hermetic closure thereof during the shutdown phase.

[0032] Preferably, the pyrolytic gasifier further comprises a second butterfly valve at the output interface of the biochar from the unloading auger such as to allow the evacuation of the biochar from the reaction chamber, if necessary.

[0033] Preferably, said first and second butterfly valves comprise a cylindrical valve body, a plate-like shutter, and an insert having the shape of an arc of circumference. When the butterfly valve is in the fully open position, the shutter takes a position parallel to the longitudinal axis X-X of the cylindrical valve body, and the insert adheres to a portion of the edge of the shutter, thus filling the gap between the valve body and the shutter along the longitudinal axis X-X of the cylindrical valve body. This prevents the deposition of the energy source or, respectively, of the biochar on the edge of the shutter. Therefore, said insert fulfills the function of protecting the seal of the plate-like shutter when the valve is in the fully open position.

[0034] The pyrolytic gasifier according to the present invention, thanks to the peculiar characteristics mentioned above, both with regard to its structure and the materials with which it is made, can ensure high performance characteristics and remarkable durability, by virtue of a surprising chemical and mechanical resistance in a strongly reducing environment which reaches temperatures of approximately 1200-1400°C. Furthermore, the pyrolytic gasifier according to the present invention has compact dimensions, provides high thermal insulation and high resistance to thermal shock, and allows a good flow of the biomass inside it.

[0035] Further features and advantages of the invention will be apparent from the description of some embodiments, given here by way of a non-limiting example.

Brief description of the drawings

[0036]

Figure 1 shows a section of the micro-cogenerator according to an embodiment of the present invention.

Figure 2 shows a section of the pyrolytic gasifier of the micro-cogenerator according to an embodiment of the present invention.

Figure 3 shows a section of the assembly comprising the reactor and the hopper of the pyrolytic gasifier according to an embodiment of the present invention.

Figure 4 shows a perspective view of a butterfly valve according to an embodiment of the present invention adapted to allow the inflow of the biomass into the reactor of the gasifier shown in Figure 3 and to allow the evacuation of the biochar from said reactor, if necessary.

Figure 5 shows a detail of the butterfly valve of Figure 4 when said valve is in the fully open position.

Figure 6 shows a first view of the assembly consisting of the burner and the Stirling engine according to an embodiment of the present invention.

Figure 7 shows the section, along the axis A-A shown in Figure 6, of the assembly consisting of the burner and the Stirling engine according to an embodiment of the present invention.

Figure 8 shows a detail of the burner shown in Figure 7.

Figure 9 shows a second view of the assembly consisting of the burner and the Stirling engine ac-

cording to an embodiment of the present invention.
Figure 10 shows the section, along the axis C-C shown in Figure 9, of the assembly consisting of the burner and the Stirling engine according to an embodiment of the present invention.

Detailed description of the figures

[0037] With reference to Figure 1, a micro-cogenerator according to an embodiment of the present invention is globally indicated with reference numeral 1.

[0038] Said micro-cogenerator 1 comprises a pyrolytic gasifier 2, a burner 3 and a Stirling engine 4.

[0039] The pyrolytic gasifier 2 is shown in more detail in Figure 2, while the burner 3 and the Stirling engine 4 are more visible in Figures 6-10.

[0040] The gasifier 2 in Figure 2 comprises:

a storage container 5 of the biomass 6;
a reactor 7 inside which the biomass 6 is gasified generating combustible syngas 8 and biochar 9;
a loading auger 10 of the biomass 6 which connects the container 5 to the inlet 11 of the reactor 7;
an unloading auger 12 through which the biochar 9 is evacuated;
an outlet duct 13 for the combustible syngas 8, through which the latter is fed to the burner 3;
a hopper 14, which connects the outlet 15 of the reactor 7 to the unloading auger 12 of the biochar 9, and through which the combustible syngas 8 is sucked into the duct 13;
a collection container 16 of the biochar 9 extracted from the reactor 7.

[0041] The reactor 7 defines a reaction chamber 17 and comprises an electric heater 18 and a thermocouple 19. The electric heater 18 brings the biomass contained in the reaction chamber 17 to the gasification temperature of, e.g., 900°C, while the thermocouple 19 monitors the temperature in the upper part of the reaction chamber 17 during the gasification process. The heater 18 and the thermocouple 19, respectively, represent the lower limit and the upper limit of the zone within which the biomass reaction front 6 must be maintained.

[0042] A connecting element 20, named "buffer", is interposed between the loading auger 10 of the biomass 6 and the inlet 11 of the reactor 7. A sensor 21 detects the filling level of the buffer 20, and the loading auger 10 of the biomass 6 is started whenever said sensor 21 detects that the filling level of the buffer 20 is below a predetermined threshold value.

[0043] The biomass 6 under reaction is supported by the biochar 9 generated during the pyrolytic gasification process seamlessly inside the reaction chamber 17. Advantageously, the pyrolytic gasifier 2 according to the present invention has no support grid for the biomass under reaction which separates it from the spent biochar 9. Preferably, the unloading auger 12 and the hopper 14 are constantly kept full of biochar 9.

[0044] The reactor 7 of the pyrolytic gasifier 2 is shown in greater detail in Figure 3.

[0045] As mentioned above, the reactor 7 comprises a reaction chamber 17 in which the biomass 6 is gasified in the presence of a given amount of air (sub-stoichiometric). The reactor 7 further comprises an outer coating 71 to said reaction chamber 17. Said reaction chamber 17 is truncated-cone in shape and is advantageously made of a polycrystalline alumina fiber-based material, preferably formed under vacuum, comprising at least 70% by weight of polycrystalline alumina and having a density preferably between 350 and 500 kg/m^3. For example, said polycrystalline alumina fiber-based material is produced by the company Unifrax under the trade name High Temperature Saffil® Rigiform™, e.g. Saffil® 160 HD.

[0046] The reaction chamber 17 has an upper surface 72 and a lower surface 73, wherein the diameter of the upper surface 72 is slightly smaller than the diameter of the lower surface 73 in order to give an adequate draft angle, e.g., about 4°, to the inner surface of the reaction chamber 17. For example, the diameter of the upper surface 72 is comprised between 70 and 90 mm and the diameter of the lower surface 73 is comprised between 100 and 120 mm. Said geometry of the reaction chamber 17 facilitates the downward flow of the biomass 6.

[0047] Said outer coating 71 has an annular shape and is advantageously made of a microporous insulating material comprising silica. For example, said microporous insulating material is produced by the company Promat under the trade name Promalight®, or by the company Bifire under the trade name Microbifire®, or by the company Unifrax under the trade name Excelfrax®.

[0048] Said outer coating 71 consists of a plurality of overlapping rings 74 made of said microporous insulating material, which guarantee the thermal insulation of the reactor 7.

[0049] In the example in Figure 3, the reactor 7 further comprises a layer 75 of said polycrystalline alumina fiber-based material having varying thickness interposed between the reaction chamber 17 and the outer coating 71. Preferably, the reaction chamber 17 and the layer 75 of the polycrystalline alumina fiber-based material form a monolithic structure. According to a specific example, said monolithic structure is sealed on top with the structure by means of a rubber gasket 76; on the bottom, instead, given the high working temperature, it is sealed by means of a polycrystalline alumina fiber-based gasket 77.

[0050] The hopper 14 shown in Figures 2 and 3 comprises an upper frame (or edge) 78 adapted to support the outer coating 71 through an appropriate support plate 79, preferably annular. In the example of Figure 3, an insulating plate 80, which is also preferably annular, made, e.g., with biosoluble refractory fibers, is placed above said support plate 79; said plate 80 ensures the thermal break with the support plate 79 and thus with the hopper 14, as well as an airtight seal. Both the hopper 14 and the support plate 79 are advantageously made of stainless steel.

[0051] Said hopper 14 further comprises a lip 81, which projects below said frame 78 and defines a support base for the reaction chamber 17 through which the hopper 14 itself receives the produced syngas 8. Said geometry allows creating an annular volume in the upper part of the hopper 14 through which the syngas 8 is sucked into the duct 13.

[0052] The syngas feeding duct 13 has a gasket at the interface with the support plate 79 consisting of polycrystalline alumina fiber-based rings 82.

[0053] The hopper 14 is advantageously insulated from the unloading auger 12 by means of an element 83 made of said microporous insulating material.

[0054] A first valve 22 separating the biomass 6 (shown in Figures 2 and 3) is placed at the inlet interface of the biomass 6 in the reactor 7, in particular above the buffer 20. A second valve 23 separating the biochar 9 (shown in Figure 2) is positioned at the outlet interface of the biochar 9 from the unloading auger 12.

[0055] The separation valve 22 of the biomass 6 is opened at the process start-up and allows the inflow of biomass 6 and air into the reactor 7. The air supply, although limited, is necessary to support the gasification process by providing heat through the combustion of a small portion of the biomass 6 and the produced syngas 8.

[0056] The separation valve 23 of the biochar 9 is opened whenever it is necessary to expel the biochar 9, thus operating discontinuously.

[0057] Said separation valves 22, 23 are butterfly valves and are shown in more detail in Figures 4 and 5. The valve 22, 23 shown in Figure 4 is in the fully closed position, while the valve 22, 23 shown in Figure 5 is in the fully open position.

[0058] The valve 22, 23 according to the embodiment of Figure 4 comprises an actuator 24, a cylindrical valve body 25, a plate-like shutter 26 and an insert 27 shaped as an arc of circumference.

[0059] When said valve 22, 23 is in the fully open position (Figure 5), the plate-like shutter 26 assumes a position parallel to the longitudinal axis X-X of the cylindrical valve body 25 and the insert 27 adheres to a portion 28 of the edge of the shutter 26 which would otherwise come into contact with the biomass 6 or with the biochar 9. In this manner, the gap between the valve body 25 and the shutter 26 is filled along the longitudinal axis X-X of the valve body 25, preventing the biomass 6 and the biochar 9 from settling on the edge of the shutter 26, clogging the valve 22, 23 and preventing the proper closing of the valve itself.

[0060] In light of the aforesaid description, it is apparent that the gasifier 2 is of the "downdraft" (i.e., the biomass 6 flows downward and the syngas 8 produced transits in the same direction) "open core" (i.e., with air supply from above along with the biomass) type.

[0061] As mentioned above, Figures 6-10 illustrate the assembly consisting of the burner 3 and the Stirling engine 4.

[0062] The burner 3 comprises:

- a combustion chamber 30 in which the fuel syngas 8 coming from the gasifier 2 is burned in the presence of combustion air 31 generating hot combustion gases 32;
- an exhaust system 33, fixed on top of the combustion chamber 30, which receives the exhaust fumes 34 exiting the Stirling engine 4, as further described below;
- pre-mixing flanges 35 for the fuel syngas 8 and the combustion air 31;
- a nozzle or duct 36, preferably ceramic, downstream of the pre-mixing flanges 35, which conveys the fuel syngas 8 and the combustion air 31 into the combustion chamber 30. The mixture of fuel syngas 8 and combustion air 31 exiting the nozzle or duct 36 is indicated with the reference numeral 37 in Figure 8.

[0063] Furthermore, the pre-mixing flanges 35 allow partial cooling of the fuel syngas 8 by means of the combustion air 31.

[0064] The Stirling engine 4 comprises a high-temperature heat exchanger 38 (so-called "hot exchanger") shown in Figures 7, 8, 10, a low-temperature heat exchanger (so-called "cold exchanger"), a regenerator and an electric generator 39. The cold exchanger and the regenerator are not visible in the figures. The hot exchanger 38 of the Stirling engine is inserted inside the combustion chamber 30.

[0065] Downstream of the hot exchanger 38 of the Stirling engine, a tubular element 40 is placed, also indicated as a cooling ring, inside which a cooling fluid flows, so that heat transfer downstream of said hot exchanger 38 is prevented. In other words, the cooling ring 40 performs the thermal break function between the burner 3 and the Stirling engine 4, preventing unwanted heat from entering the part of the Stirling engine 4 under the hot exchanger 38 and safeguarding the underlying components from excessive heating.

[0066] The combustion chamber 30 of the burner 3 consists of a cylinder which integrates connections for the feeding duct 13 of the fuel syngas 8 coming from the gasifier 2 and for the feeding duct 41 of the combustion air 31. Furthermore, the combustion chamber 30 integrates the attachment flange 42 to the Stirling engine 4 and the attachment flange 43 to the exhaust system 33.

[0067] A bell 44 and an element 45 made of porous ceramic material (porous ceramic means 45) are placed inside the combustion chamber 30 of the burner 3.

[0068] Said bell 44 is open at the bottom and houses the hot exchanger 38 of the Stirling engine inside. In particular, said hot exchanger 38 is inserted from the open bottom of the bell 44. Said bell 44 is such to convey the hot combustion gases 32 into the hot exchanger 38, where they undergo heat exchange providing heat and generating exhaust fumes 34 (or combustion fumes 34). In other words, said bell 44 constrains the hot combustion gases 32 to flow through the entire hot exchanger 38 with minimal heat dissipation to the outside, thus optimizing the heat exchange with the Stirling engine 4.

[0069] Said bell 44 comprises steel walls internally lined with a refractory insulating material, preferably a material based on polycrystalline alumina fiber. For example, said material comprises at least 70% by weight of polycrystalline alumina, preferably at least 75% by weight, more preferably at least 80% by weight, such as about 90% by weight. Preferably, said material further comprises at least 5% by weight of silica, preferably between 10% and 30% by weight of silica, more preferably between 10% and 25% by weight of silica, even more preferably between 10% and 20% by weight of silica. For example, said polycrystalline alumina fiber-based material is produced by the company Schupp under the trade name ITM-Fibermax®, preferably Blanket 1600-130.

[0070] The aforementioned nozzle or duct 36 may be replaced by a hole made in said refractory insulating material, such as to convey the fuel syngas 8 and the combustion air 31 inside the combustion chamber 30.

[0071] There is a gap 46 between said bell 44 and said combustion chamber 30 which is traveled upward by the exhaust fumes 34 exiting the hot exchanger 38, as evident from Figure 8.

[0072] The porous ceramic means 45 is housed in the upper part of the bell 44 above the hot exchanger 38 and is supported at least partially by the refractory insulating material of the bell 44. Said porous ceramic means 45 is an optimized combustion volume in which the syngas 8 is combusted in the presence of combustion air 31 generating hot combustion gases 32 (Figure 8). Furthermore, the porous means 45 allows a homogeneous temperature distribution, ensuring optimal heat exchange with the Stirling engine 4 and low polluting emissions.

[0073] According to an embodiment, the porous material with which said means 45 is made comprises silicon carbide, alumina and silica and is, for example, produced by the company Lanik under the trade name Vukopor® S.

[0074] According to another embodiment, said porous ceramic material comprises alumina, silica, zirconia and magnesium oxide. Preferably, said porous ceramic material is produced by the company Lanik under the trade name Vukopor® HT.

[0075] In the example of Figures 7 and 8, the bell 44 comprises an additional element 47 made of refractory insulating material, e.g., based on polycrystalline alumina fiber, immediately below the porous ceramic means 45, such as to prevent unwanted entry of heat through the top of the Stirling engine below. Said element 47 mimics the shape of the upper dome of the hot exchanger 38 of the Stirling engine, visible in Figures 7, 8, 10.

[0076] The exhaust system 33 mentioned above receives the combustion fumes 34 exiting the hot exchanger 38 of the Stirling engine 4, once the latter have traveled upward through the gap 46 present between the combustion chamber 30 and the bell 44.

[0077] Said exhaust system 33 comprises an exhaust 55 from which combustion fumes 34 escape, a heat exchanger 56 connected to said exhaust 55 for recovering heat from the exhaust fumes 34 (Figure 10), a lambda probe 57 which provides a signal based on which the air-syngas ratio at the inlet of burner 3 is adjusted (Figures 6, 10), and a thermocouple 58 which measures the temperature of the combustion fumes 34 (Figures 6, 10).

[0078] An extraction fan 59 (shown in Figures 6 and 10) of the combustion fumes 34 is connected to said heat exchanger 56, by virtue of which the combustible syngas 8 from the gasifier 2 and the combustion air 31 are sucked inside the combustion chamber 30. Said extraction fan 59 has variable speed.

[0079] To obviate the fact that the pyrolytic gasifier and the Stirling engine, by their nature, have rather slow start-up and control reaction times, the micro-cogenerator 1 can advantageously be coupled to electrical energy storage systems (batteries) and thermal energy accumulation systems (puffers). The remaining capacity is measured for both accumulations so that micro-cogenerator 1 will only turn on if a minimum operating time necessary for heat regulation of all syngas ducts is guaranteed. In particular, a temperature probe is used for the puffer, and a voltage probe is used for the batteries. For the batteries, there is the possibility of both voltage reading and SoC ("state of charge") reading from the Bus and input of a digital request signal.

[0080] The micro-generator 1 is equipped with an electronic control, which manages the operation of the machine through the installed sensors and actuators and is independently powered by on-board batteries so that it can be safely shut down even in case the external electrical connection is interrupted. To be able to start up, the micro-generator 1 checks for the presence of the external power grid (both "on-grid" and "off-grid" via inverter).

[0081] The process of cogeneration of electrical energy and heat within the micro-cogenerator 1 starting from the biomass 6 is described below with reference to the figures.

[0082] The pyrolytic gasification process is started by means of the electric heater 18, which brings the biomass 6 to the gasification temperature, e.g., about 900°C. During the start-up phase of the process, the separation valve 22 of the biomass 6 is opened. During the start-up phase of the process, the extraction fan 59 is activated with a speed proportional to the temperature of the electric heater 18.

[0083] The biomass 6 is fed into the reactor 7 of the pyrolytic gasifier 2, through the inlet 11, by means of the loading auger 10. When the filling level of the buffer 20 is under a given threshold, the biomass loading auger 10 is started; when the filling level of the buffer 20 is above said threshold, the biomass loading auger 10 is stopped and the feeding of the biomass 6 to the reactor is interrupted.

[0084] Once the gasification has been started and the biochar 9 has accumulated in the reactor 7, the reaction front advances from the bottom to the top where biomass 6 not yet gasified is located.

[0085] The reaction chamber 17 is maintained at a suitable gasification temperature at which the biomass reacts generating syngas and biochar, preferably comprised between 1000°C and 1200°C in order to maximize the syngas production.

[0086] The thermocouple 19 keeps the temperature of the upper part of the reaction chamber 17 monitored; when the integral over time of the temperature measured by thermocouple 19 exceeds a given threshold value of said integral, the separation valve 23 of the biochar 9 is opened, the unloading auger 12 is started and part of the biochar 9 is extracted. In this manner, the reacting biomass 6 is made to flow downward and along with it the reaction front as well, which remains confined to the reaction zone delimited between the thermocouple 19 and the electric heater 18.

[0087] The gasifier 2, once fully operational, works with a slow and intermittent flow of biomass 6 such as to maintain the reaction front within the aforementioned reaction zone.

[0088] The produced fuel syngas 8, before flowing out of the gasifier 2 through the duct 13, crosses a layer of biochar 9, which is still warm and ensures a good abatement of dust and tar.

[0089] During the step of shutting down the process, a small amount of biochar 9 is extracted to ensure that the biomass 6 is in a sufficiently low and safe zone of the reaction chamber, and the biomass separation valve 22 is closed to prevent air from entering the reactor 7 and fumes from escaping.

[0090] By operating the extraction fan 59, the system consisting of the gasifier 2 and the burner 3 is depressurized and the inflows of fuel syngas 8 from the gasifier 2 to the burner 3 and of air to both the gasifier 2 and the burner 3 are adjusted.

[0091] By operating the extraction fan 59, the combustion fumes 34 are extracted which travel upward through the gap 46 between the combustion chamber 30 and the bell 44, creating a vacuum inside the burner 3. In turn, the fuel syngas 8 exiting the gasifier 2 and the combustion air 31 are sucked into the combustion chamber 30 of the burner, respectively, through the supply ducts 13 and 41. In turn, air is sucked into the gasifier 2.

[0092] Once the presence of fuel syngas 8 is detected inside the burner 3, the latter is ignited and an increasing amount of combustion air 31 is supplied by acting on the air valve 60 located on the duct 41.

[0093] The fuel syngas 8 and the combustion air 31 are sucked inside the combustion chamber 30 passing through the pre-mixing flanges 35, then the nozzle or duct 36, until they arrive inside the porous ceramic means 45, which defines the volume in which the combustion takes place with the generation of the hot combustion gases 32.

[0094] The hot combustion gases 32 are subjected to heat exchange within the hot exchanger 38 of the Stirling engine 4, from which heat is recovered that puts the electric generator 39 in oscillation, thus obtaining the aforementioned combustion fumes 34 resulting from said heat exchange.

[0095] The combustion fumes 34 are extracted through the extraction fan 59. Said combustion fumes 34 travel upward through the gap 46 present between the combustion chamber 30 and the bell 44, pass through the exhaust 55 on which the lambda probe 57 and the thermocouple 58 are placed, then they are fed to the heat exchanger 56 for recovery of the heat contained therein. The lambda probe 57 provides a signal based on which the air-syngas ratio is adjusted accurately by virtue of the valve 60 located on the inlet duct 41 of the combustion air 31, adjusting the pressure drop and thus the inflow.

[0096] It is apparent that only one particular embodiment of the present invention was described. Those skilled in the art will be able to make all the necessary modifications to the micro-cogenerator 1 for the adaptation thereof to particular conditions, without however departing from the scope of protection as defined in the appended claims.

Claims

1. A micro-cogenerator (1) comprising:

a pyrolytic gasifier (2) adapted to produce syngas (8) and biochar (9) from a renewable and sustainable energy source (6), preferably woody biomass,
a burner (3) adapted to receive the syngas (8) produced by said pyrolytic gasifier (2) and to generate hot combustion gases (32),
a Stirling engine (4) comprising a heat exchanger (38) fed with said hot combustion gases (32), said Stirling engine (4) being adapted to generate electric energy,
wherein said pyrolytic gasifier (2) comprises a reaction chamber (17) inside which said energy source (6) is gasified in the presence of air, thus generating syngas (8) and biochar (9),
characterized in that said reaction chamber (17) has truncated-cone shape and is made of a polycrystalline alumina fiber-based material comprising at least 70% by weight of polycrystalline alumina and, optionally, at least 5% by weight of silica, said material having a density preferably between 350 and 500 kg/m^3,
said micro-cogenerator comprising an exhaust system (33) adapted to receive exhaust fumes (34) leaving the heat exchanger (38) of the Stirling engine (4),

wherein said exhaust system (33) comprises an exchanger (56) for the recovery of heat from said exhaust fumes (34), a lambda probe (57) which provides a signal based on which the ratio of air (31) to syngas (8) at the burner (3) inlet is adjusted, and a thermocouple (58) which measures the temperature of said exhaust fumes (34),

said micro-cogenerator further comprising an extraction fan (59) connected to said exchanger (56) for the recovery of heat from the exhaust fumes (34), said extraction fan (59) is configured to extract the exhaust fumes (34) thus creating a vacuum inside the burner (3) and the pyrolytic gasifier (2) and, in turn, to adjust the inflow of the syngas (8) from the pyrolytic gasifier (2) to the burner (3) and the inflows of air into both the pyrolytic gasifier (2) and the burner (3).

2. A micro-cogenerator (1) according to claim 1, wherein said polycrystalline alumina fiber-based material comprises at least 75% by weight of polycrystalline alumina, preferably at least 80% by weight, more preferably about 90% by weight, and an amount of silica of at least 5% by weight, preferably between 10% and 30% by weight, more preferably between 10% and 25% by weight, even more preferably between 10% and 20% by weight.

3. A micro-cogenerator (1) according to claim 1 or 2, wherein said pyrolytic gasifier (2) comprises an outer coating (71) with respect to said reaction chamber (17), said outer coating (71) having an annular shape and being preferably made of a microporous insulating material comprising silica.

4. A micro-cogenerator (1) according to claim 3, wherein said pyrolytic gasifier (2) comprises a layer (75) of said polycrystalline alumina fiber-based material having variable thickness interposed between said reaction chamber (17) and said outer coating (71), preferably said reaction chamber (17) and said layer (75) of polycrystalline alumina fiber-based material forming a monolithic structure.

5. A micro-cogenerator (1) according to any one of the preceding claims, said truncated-cone reaction chamber (17) having an upper surface (72) and a lower surface (73), wherein the diameter of the upper surface (72) is smaller than the diameter of the lower surface (73), said diameters being such as to give the inner surface of the truncated-cone reaction chamber a draft angle comprised between 2° and 15°, preferably of about 4°.

6. A micro-cogenerator (1) according to any one of the preceding claims, wherein said pyrolytic gasifier (2) comprises:

an unloading auger (12) for the evacuation of the biochar (9),

a hopper (14) connecting the reaction chamber and the unloading auger (12), said hopper (14) forming a collection volume of the syngas (8) produced in the reaction chamber, and

a connection duct (13) between said hopper (14) and the burner (3), from which the syngas (8) is sucked and fed to said burner (3),

wherein said hopper (14) comprises an upper frame (78) adapted to support said outer coating (71), preferably through a suitable support plate (79), and a lip (81) projecting below said frame (78) and defining a support base for said reaction chamber (17) through which the hopper (14) receives the syngas (8) produced.

7. A micro-cogenerator (1) according to any one of the preceding claims, wherein said reaction chamber (17) comprises an electric heater (18) adapted to heat the reaction chamber (17) to the gasification temperature, and a thermocouple (19) adapted to monitor the temperature in the upper part of the reaction chamber (17),

wherein the reaction front is comprised between said heater (18) and said thermocouple (19).

8. A micro-cogenerator (1) according to any one of the preceding claims, wherein the energy source (6) under reaction is supported by the biochar (9) produced during the gasification of said energy source (6), said micro-cogenerator (1) not comprising any support grid for said energy source (6).

9. A micro-cogenerator (1) according to any one of the preceding claims, wherein said pyrolytic gasifier (2) comprises a first butterfly valve (22) at the input interface of the energy source (6) in the reaction chamber such as to allow the inflow of the energy source (6) into the reaction chamber (17), and/or a second butterfly valve (23) at the output interface of the biochar (9) from the unloading auger (12) such as to allow the evacuation of the biochar (9) from the reaction chamber (17) if required, said butterfly valves (22, 23) comprising a cylindrical valve body (25), a plate shutter (26), and an insert (27) having the shape of an arc of circumference,

when said valve (22, 23) is in the fully open position, the shutter (26) takes a position parallel to the longitudinal axis (X-X) of the cylindrical valve body (25),

said insert (27) adhering to a portion (28) of the edge of the shutter (26) when the valve (22, 23) is in the fully open position, thus filling the space between the valve body (25) and the shutter (26) along the longitudinal axis (X-X) of the cylindrical valve body (25) and preventing the energy source (6) or the biochar (9) from depositing on the edge of the shutter (26).

Patentansprüche

1. Mikro-Blockheizkraftwerk (1), umfassend:

einen pyrolytischen Vergaser (2), welcher dazu eingerichtet ist, aus einer erneuerbaren und nachhaltigen Energiequelle (6), vorzugsweise holzartiger Biomasse, Synthesegas (8) und Biokohle (9) zu erzeugen,
einen Brenner (3), welcher dazu eingerichtet ist, das durch den pyrolytischen Vergaser (2) erzeugte Synthesegas (8) aufzunehmen und heiße Verbrennungsgase (32) zu generieren,
einen Stirlingmotor (4), welcher einen mit den heißen Verbrennungsgasen (32) gespeisten Wärmetauscher (38) umfasst, wobei der Stirlingmotor (4) dazu eingerichtet ist, elektrische Energie zu generieren,
wobei der pyrolytische Vergaser (2) eine Reaktionskammer (17) umfasst, innerhalb welcher die Energiequelle (6) in der Gegenwart von Luft vergast wird, wodurch Synthesegas (8) und Biokohle (9) generiert wird,
dadurch gekennzeichnet, dass
die Reaktionskammer (17) eine Kegelstumpfform aufweist und aus einem polykristallinen Material auf Aluminiumoxidfaserbasis hergestellt ist, welches wenigstens 70 Gew.-% polykristallines Aluminiumoxid und, optional, wenigstens 5 Gew.-% Siliciumdioxid umfasst, wobei das Material eine Dichte von vorzugsweise zwischen 350 und 500 kg/m^3 aufweist
wobei das Mikro-Blockheizkraftwerk ein Abgassystem (33) umfasst, welches dazu eingerichtet ist, Abgase (34) aufzunehmen, welche den Wärmetauscher (38) des Stirlingmotors (4) verlassen,
wobei das Abgassystem (33) einen Tauscher (56) für die Rückgewinnung von Wärme aus den Abgasen (34), eine Lambdasonde (57), welche ein Signal bereitstellt, auf Grundlage dessen das Verhältnis von Luft (31) zu Synthesegas (8) an dem Brenner- (3) -Einlass eingestellt wird, und ein Thermoelement (58) umfasst, welches die Temperatur der Abgase (34) misst,
wobei das Mikro-Blockheizkraftwerk ferner einen mit dem Tauscher (56) verbundenen Absaugventilator (59) für die Rückgewinnung von Wärme aus den Abgasen (34) umfasst, wobei der Absaugventilator (59) dazu eingerichtet ist, die Abgase (34) zu extrahieren, wodurch ein Vakuum innerhalb des Brenners (3) und des pyrolytischen Vergasers (2) geschaffen wird, und wiederum den Zustrom des Synthesegases (8) von dem pyrolytischen Vergaser (2) zu dem Brenner (3) und die Zuströme von Luft in sowohl den pyrolytischen Vergaser (2) als auch den Brenner (3) einzustellen.

2. Mikro-Blockheizkraftwerk (1) nach Anspruch 1, wobei das polykristalline Material auf Aluminiumoxidfaserbasis wenigstens 75 Gew.-% polykristallines Aluminiumoxid, vorzugsweise wenigstens 80 Gew.-%, bevorzugter etwa 90 Gew.-%, und eine Menge an Siliciumdioxid von wenigstens 5 Gew.-%, vorzugsweise zwischen 10 Gew.-% und 30 Gew.-%, bevorzugter zwischen 10 Gew.-% und 25 Gew.-%, noch bevorzugter zwischen 10 Gew.-% und 20 Gew.-%, umfasst.

3. Mikro-Blockheizkraftwerk (1) nach Anspruch 1 oder 2, wobei der pyrolytische Vergaser (2) eine in Bezug auf die Reaktionskammer (17) äußere Ummantelung (71) umfasst, wobei die äußere Ummantelung (71) eine ringförmige Form aufweist und vorzugsweise aus einem mikroporösen isolierendem Material hergestellt ist, welches Siliciumdioxid umfasst.

4. Mikro-Blockheizkraftwerk (1) nach Anspruch 3, wobei der pyrolytische Vergaser (2) eine Schicht (75) aus dem polykristallinen Material auf Aluminiumoxidfaserbasis umfasst, welche eine variable Dicke aufweist und zwischen der Reaktionskammer (17) und der äußeren Ummantelung (71) eingefügt ist, vorzugsweise wobei die Reaktionskammer (17) und die Schicht (75) aus polykristallinem Material auf Aluminiumoxidfaserbasis eine monolithische Struktur bilden.

5. Mikro-Blockheizkraftwerk (1) nach einem der vorhergehenden Ansprüche, wobei die Kegelstumpf-Reaktionskammer (17) eine obere Fläche (72) und eine untere Fläche (73) aufweist, wobei der Durchmesser der oberen Fläche (72) kleiner ist als der Durchmesser der unteren Fläche (73), wobei die Durchmesser derart beschaffen sind, dass sie der inneren Fläche der Kegelstumpf-Reaktionskammer einen Verjüngungswinkel verleihen, welcher zwischen 2° und 15° umfasst ist, vorzugsweise etwa 4° beträgt.

6. Mikro-Blockheizkraftwerk (1) nach einem der vorhergehenden Ansprüche, wobei der pyrolytische Vergaser (2) umfasst:

einen Schneckenförderer (12) für die Abförderung der Biokohle (9),
einen Trichter (14), welcher die Reaktionskammer und den Schneckenförderer (12) verbindet, wobei der Trichter (14) ein Sammelvolumen für das in der Reaktionskammer erzeugte Synthesegas (8) bildet, und

ein Verbindungsrohr (13) zwischen dem Trichter (14) und dem Brenner (3), aus welchem das Synthesegas (8) gesaugt wird und dem Brenner (3) zugeführt wird,

wobei der Trichter (14) einen oberen Rahmen (78), welcher dazu eingerichtet ist, die äußere Ummantelung (71) zu tragen, vorzugsweise durch eine geeignete Trägerplatte (79), und eine Lippe (81) umfasst, welche unterhalb des Rahmens (78) vorsteht und eine Trägerbasis für die Reaktionskammer (17) definiert, durch welche der Trichter (14) das erzeugte Synthesegas (8) aufnimmt.

7. Mikro-Blockheizkraftwerk (1) nach einem der vorhergehenden Ansprüche, wobei die Reaktionskammer (17) einen elektrischen Heizer (18), welcher dazu eingerichtet ist, die Reaktionskammer (17) auf die Vergasungstemperatur zu erwärmen, und ein Thermoelement (19) umfasst, welches dazu eingerichtet ist, die Temperatur in dem oberen Teil der Reaktionskammer (17) zu überwachen,
wobei die Reaktionsfront zwischen dem Heizer (18) und dem Thermoelement (19) umfasst ist.

8. Mikro-Blockheizkraftwerk (1) nach einem der vorhergehenden Ansprüche, wobei die einer Reaktion unterliegende Energiequelle (6) durch die während der Vergasung der Energiequelle (6) erzeugte Biokohle (9) unterstützt wird, wobei das Mikro-Blockheizkraftwerk (1) kein Unterstützungsnetz für die Energiequelle (6) umfasst.

9. Mikro-Blockheizkraftwerk (1) nach einem der vorhergehenden Ansprüche, wobei der pyrolytische Vergaser (2) ein erstes Drosselventil (22) an der Eingangsschnittstelle der Energiequelle (6) in der Reaktionskammer, um den Zustrom der Energiequelle (6) in die Reaktionskammer (17) zu ermöglichen, und/oder ein zweites Drosselventil (23) an der Ausgangsschnittstelle der Biokohle (9) aus dem Schneckenförderer (12) umfasst, um die Abförderung der Biokohle (9) aus der Reaktionskammer (17) zu ermöglichen, falls erforderlich, wobei die Drosselventile (22, 23) einen zylindrischen Ventilkörper (25), einen Plattenverschluss (26) und einen Einsatz (27) umfassen, welcher die Form eines Umfangsbogens aufweist,

wobei, wenn sich das Ventil (22, 23) in der vollständig offenen Position befindet, der Verschluss (26) eine zu der longitudinalen Achse (X-X) des zylindrischen Ventilkörpers (25) parallele Position einnimmt,

wobei der Einsatz (27) an einem Abschnitt (28) des Rands des Verschlusses (26) anhaftet, wenn sich das Ventil (22, 23) in der vollständig offenen Position befindet, wodurch der Raum zwischen dem Ventilkörper (25) und dem Verschluss (26) entlang der longitudinalen Achse (X-X) des zylindrischen Ventilkörpers (25) gefüllt wird und verhindert wird, dass sich die Energiequelle (6) oder die Biokohle (9) an dem Rand des Verschlusses (26) absetzen.

Revendications

1. Micro-cogénérateur (1) comprenant :

un gazéifieur pyrolytique (2) adapté pour produire du gaz de synthèse (8) et du biocharbon (9) à partir d'une source d'énergie renouvelable et durable (6), de préférence une biomasse ligneuse,

un brûleur (3) adapté pour recevoir le gaz de synthèse (8) produit par ledit gazéifieur pyrolytique (2) et pour produire des gaz de combustion chauds (32),

un moteur Stirling (4) comprenant un échangeur de chaleur (38) alimenté en lesdits gaz de combustion chauds (32), ledit moteur Stirling (4) étant adapté pour produire de l'énergie électrique,

dans lequel ledit gazéifieur pyrolytique (2) comprend une chambre de réaction (17) à l'intérieur de laquelle ladite source d'énergie (6) est gazéifiée en présence d'air, produisant ainsi du gaz de synthèse (8) et du biocharbon (9),

caractérisé en ce que

ladite chambre de réaction (17) présente une forme de cône tronqué et est composée d'un matériau à base de fibres d'alumine polycristalline comprenant au moins 70 % en poids d'alumine polycristalline et, facultativement, au moins 5 % en poids de silice, ledit matériau présentant une densité de préférence entre 350 et 500 kg/m^3,

ledit micro-cogénérateur comprenant un système d'échappement (33) adapté pour recevoir des fumées d'échappement (34) sortant de l'échangeur de chaleur (38) du moteur Stirling (4), dans lequel ledit système d'échappement (33) comprend un échangeur (56) pour la récupération de chaleur provenant desdites fumées d'échappement (34), une sonde lambda (57) qui fournit un signal sur la base duquel le rapport d'air (31) sur le gaz de synthèse (8) au niveau de l'entrée du brûleur (3) est ajusté, et un thermocouple (58) qui mesure la température desdites fumées d'échappement (34),

ledit micro-cogénérateur comprenant en outre un ventilateur d'extraction (59) relié audit échangeur (56) pour la récupération de chaleur provenant des fumées d'échappement (34), ledit ventilateur d'échappement (59) est configuré pour extraire les fumées d'échappement (34) créant ainsi un vide à l'intérieur du brûleur (3) et du gazéifieur pyrolytique (2) et, ensuite, pour ajuster l'écoulement entrant du gaz de synthèse (8) depuis le gazéifieur pyrolytique (2) vers le brûleur (3) et les écoulements entrants d'air à la fois dans le gazéifieur pyrolytique (2) et le brûleur (3).

2. Micro-cogénérateur (1) selon la revendication 1, dans lequel ledit matériau à base de fibres d'alumine polycristalline comprend au moins 75 % en poids d'alumine polycristalline, de préférence au moins 80 % en poids, plus préférablement environ 90 % en poids, et une quantité de silice d'au moins 5 % en poids, de préférence entre 10 % et 30 % en poids, plus préférablement entre 10 % et 25 % en poids, encore plus préférablement entre 10 % et 20 % en poids.

3. Micro-cogénérateur (1) selon la revendication 1 ou 2, dans lequel ledit gazéifieur pyrolytique (2) comprend un revêtement extérieur (71) par rapport à ladite chambre de réaction (17), ledit revêtement extérieur (71) présentant une forme annulaire et étant de préférence composé d'un matériau isolant microporeux comprenant de la silice.

4. Micro-cogénérateur (1) selon la revendication 3, dans lequel ledit gazéifieur pyrolytique (2) comprend une couche (75) dudit matériau à base de fibres d'alumine polycristalline présentant une épaisseur variable interposée entre ladite chambre de réaction (17) et ledit revêtement extérieur (71), de préférence ladite chambre de réaction (17) et ladite couche (75) de matériau à base de fibres d'alumine polycristalline formant une structure monolithique.

5. Micro-cogénérateur (1) selon l'une quelconque des revendications précédentes, ladite chambre de réaction en cône tronqué (17) présentant une surface supérieure (72) et une surface inférieure (73), dans lequel le diamètre de la surface supérieure (72) est plus petit que le diamètre de la surface inférieure (73), lesdits diamètres étant tels qu'ils donnent à la surface intérieure de la chambre de réaction en cône tronqué un angle de dégagement compris entre 2° et 15°, de préférence d'environ 4°.

6. Micro-cogénérateur (1) selon l'une quelconque des revendications précédentes, dans lequel ledit gazéifieur pyrolytique (2) comprend :

une tarière de déchargement (12) pour l'évacuation du biocharbon (9),
une trémie (14) reliant la chambre de réaction et la tarière de déchargement (12), ladite trémie (14) formant un volume de collecte du gaz de synthèse (8) produit dans la chambre de réaction, et
un conduit de liaison (13) entre ladite trémie (14) et le brûleur (3), duquel le gaz de synthèse (8) est aspiré et acheminé jusqu'audit brûleur (3),
dans lequel ladite trémie (14) comprend un cadre supérieur (78) adapté pour supporter ledit revêtement extérieur (71), de préférence par le biais d'une plaque de support appropriée (79), et un rebord (81) se projetant sous ledit cadre (78) et définissant une base de support pour ladite chambre de réaction (17) par le biais de laquelle la trémie (14) reçoit le gaz de synthèse (8) produit.

7. Micro-cogénérateur (1) selon l'une quelconque des revendications précédentes, dans lequel ladite chambre de réaction (17) comprend un élément chauffant électrique (18) adapté pour chauffer la chambre de réaction (17) à la température de gazéification, et un thermocouple (19) adapté pour contrôler la température dans la partie supérieure de la chambre de réaction (17),
dans lequel l'avant de réaction est compris entre ledit élément chauffant (18) et ledit thermocouple (19).

8. Micro-cogénérateur (1) selon l'une quelconque des revendications précédentes, dans lequel la source d'énergie (6) sous réaction est supportée par le biocharbon (9) produit durant la gazéification de ladite source d'énergie (6), ledit micro- cogénérateur (1) ne comprenant pas de grille de support pour ladite source d'énergie (6).

9. Micro-cogénérateur (1) selon l'une quelconque des revendications précédentes, dans lequel ledit gazéifieur pyrolytique (2) comprend une première vanne papillon (22) au niveau de l'interface d'entrée de la source d'énergie (6) dans la chambre de réaction de manière à permettre l'écoulement entrant de la source d'énergie (6) dans la chambre de réaction (17), et/ou une deuxième vanne papillon (23) au niveau de l'interface de sortie du biocharbon (9) de la tarière de déchargement (12) de manière à permettre l'évacuation du biocharbon (9) de la chambre de réaction (17) si nécessaire, lesdites vannes papillons (22, 23) comprenant un corps cylindrique (25) de vanne, un obturateur-plaque (26) et un insert (27) présentant la forme d'un arc de circonférence,

lorsque ladite vanne (22, 23) est dans la position totalement ouverte, l'obturateur (26) adopte une position parallèle à l'axe longitudinal (X-X) du corps cylindrique (25) de vanne,
ledit insert (27) adhérant à une partie (28) du bord de l'obturateur (26) lorsque la vanne (22, 23) est dans la position totalement ouverte, remplissant ainsi l'espace entre le corps (25)

de vanne et l'obturateur (26) le long de l'axe longitudinal (X-X) du corps cylindrique (25) de vanne et empêchant la source d'énergie (6) ou le biocharbon (9) de se déposer sur le bord de l'obturateur (26).

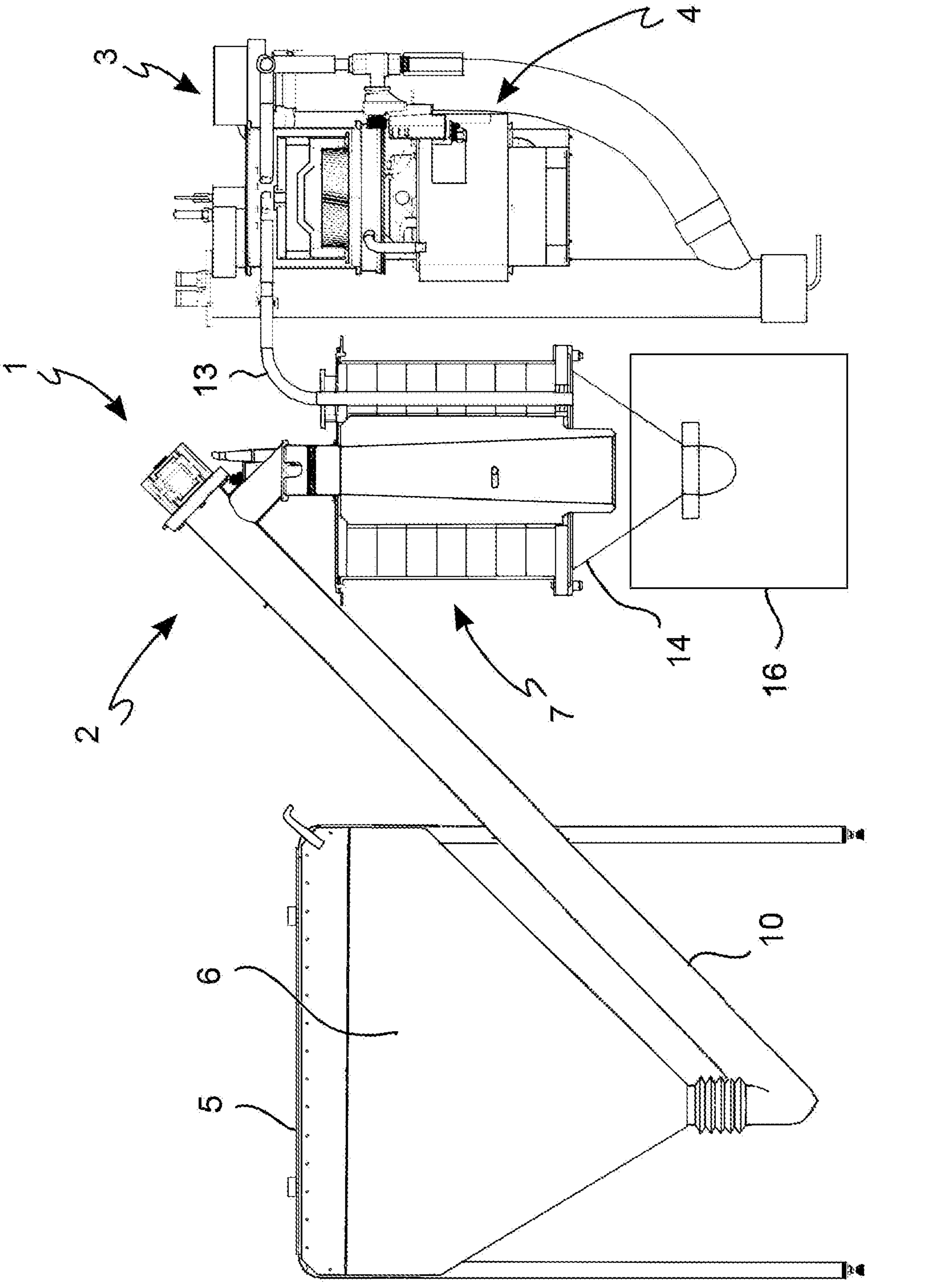

FIG. 1

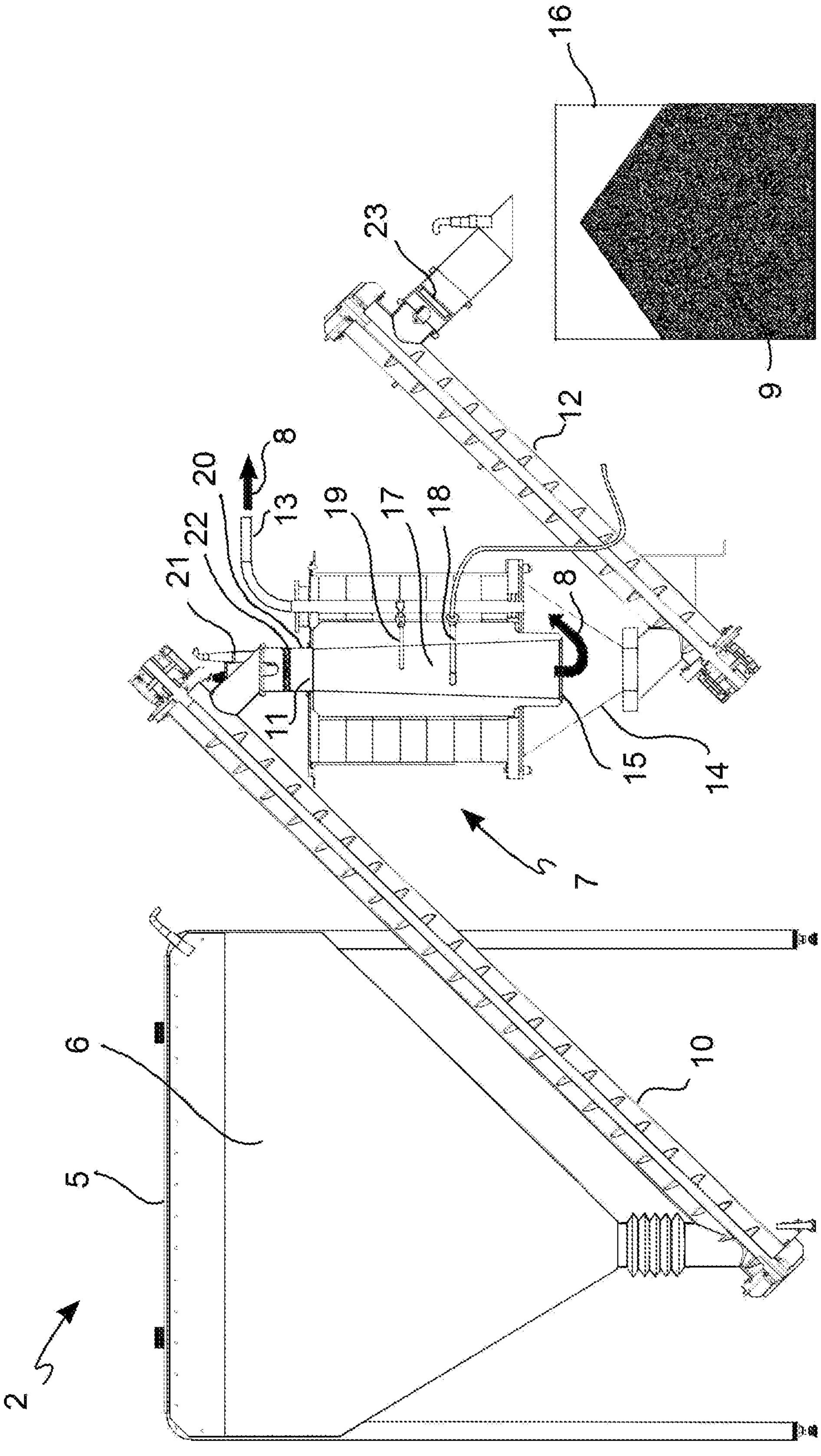

FIG. 2

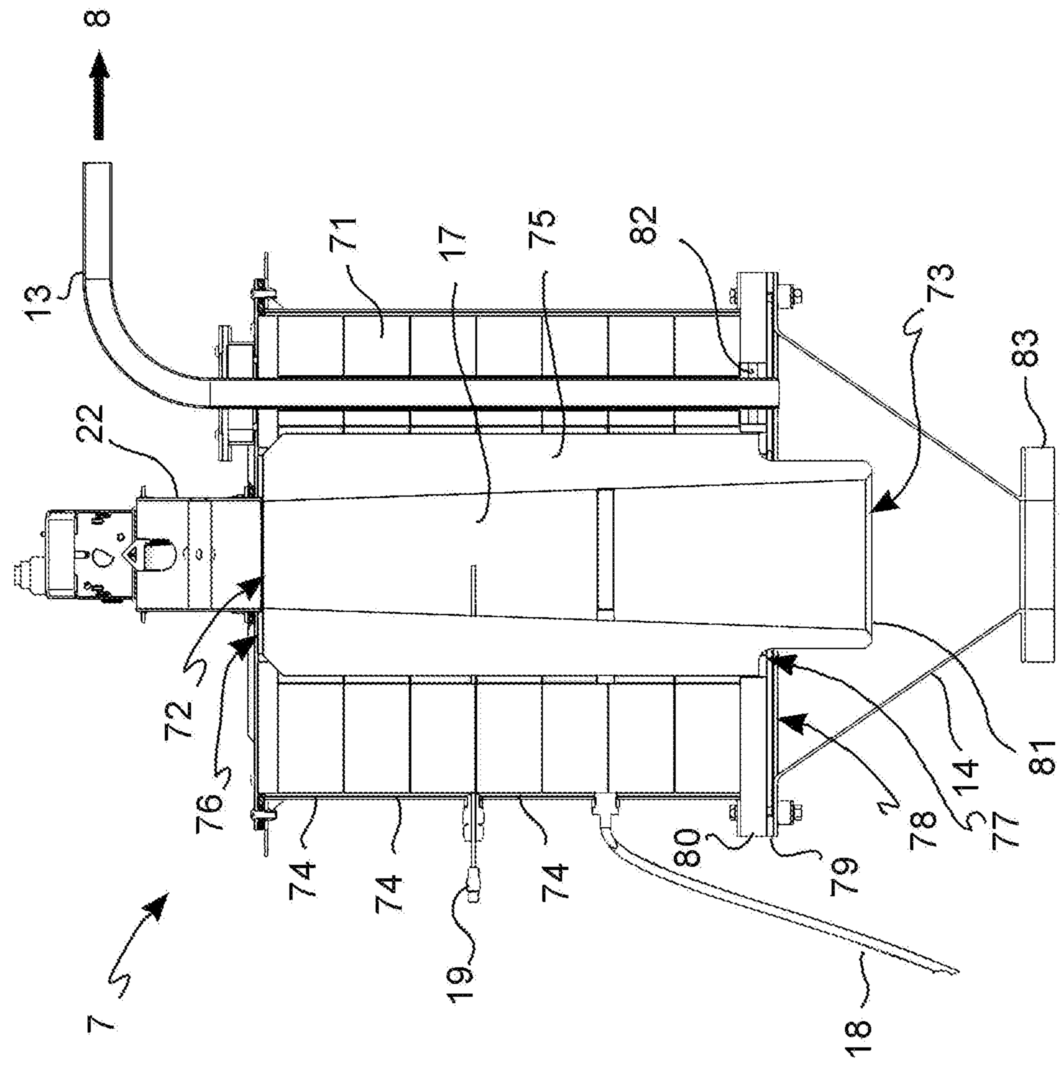

FIG. 3

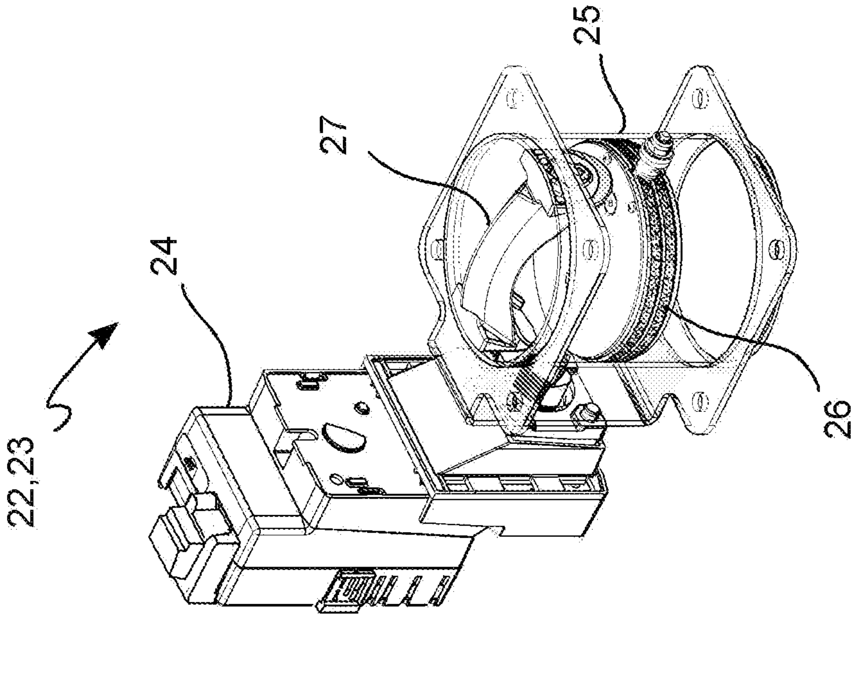

FIG. 4

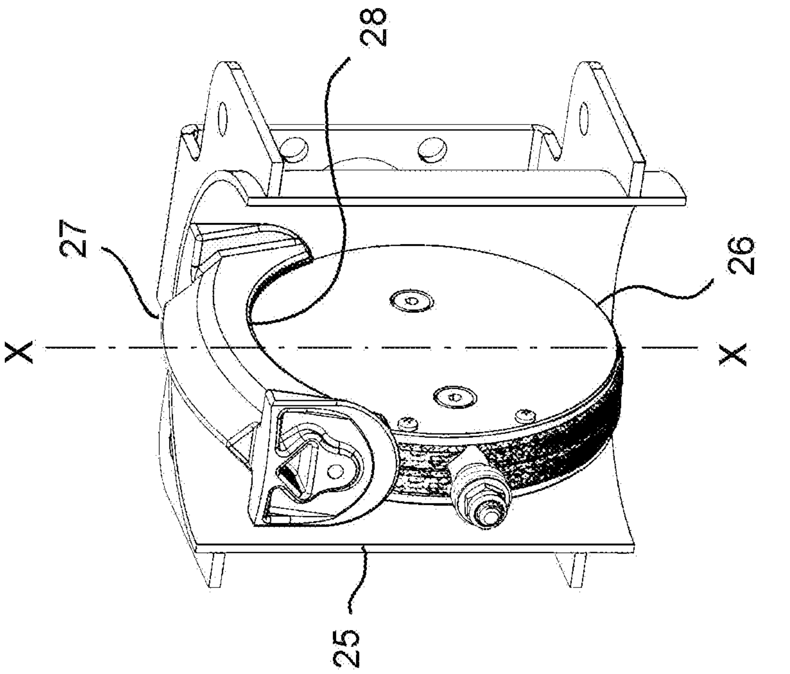

FIG. 5

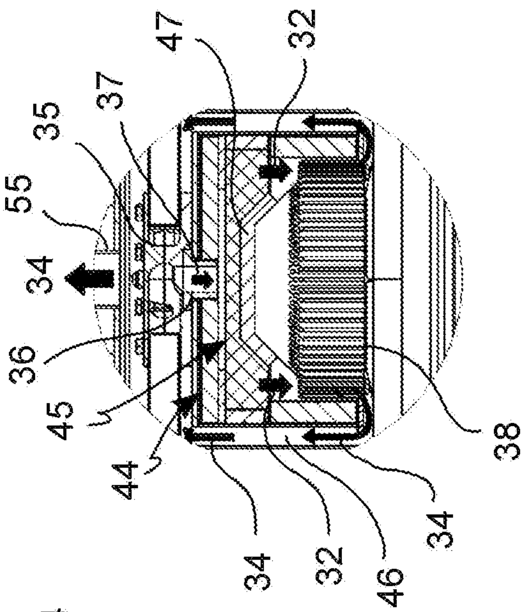

FIG. 8

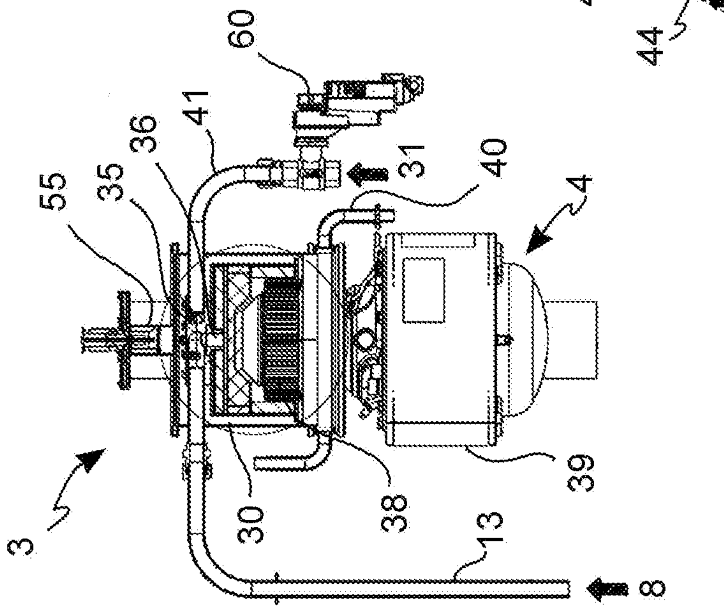

FIG. 7

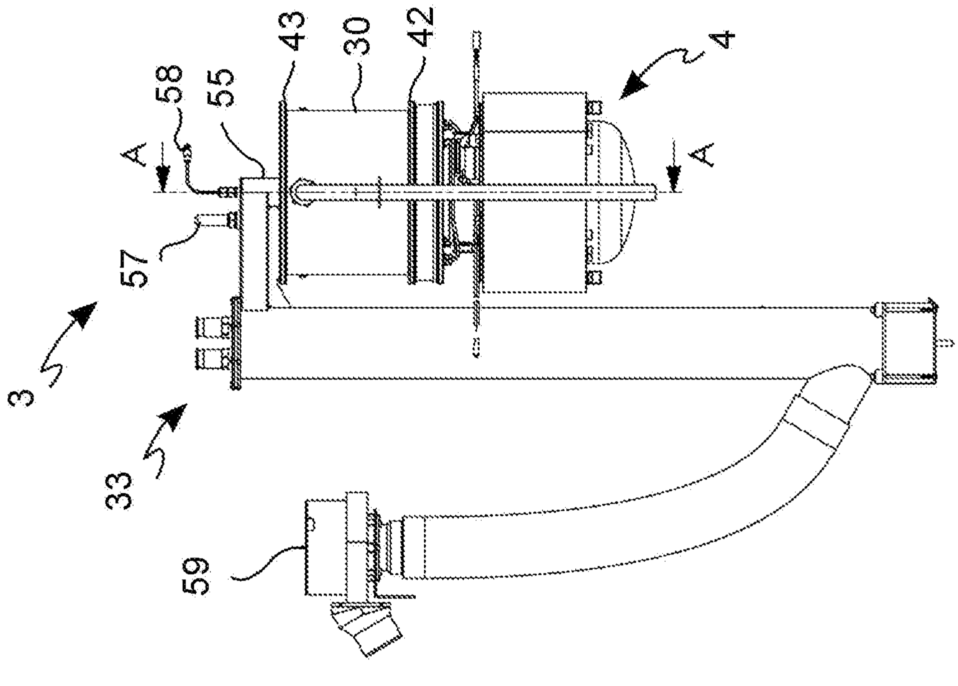

FIG. 6

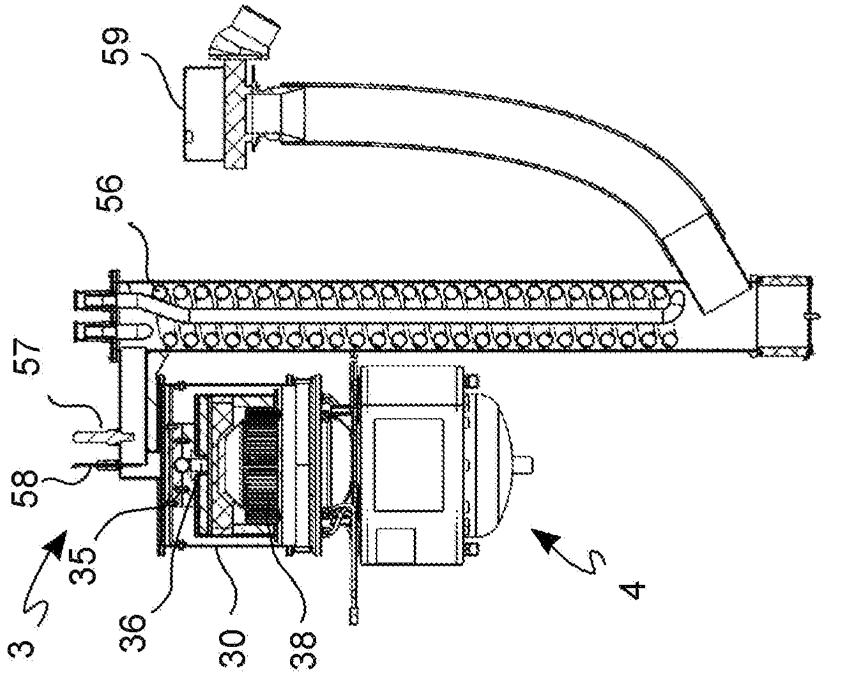

FIG. 10

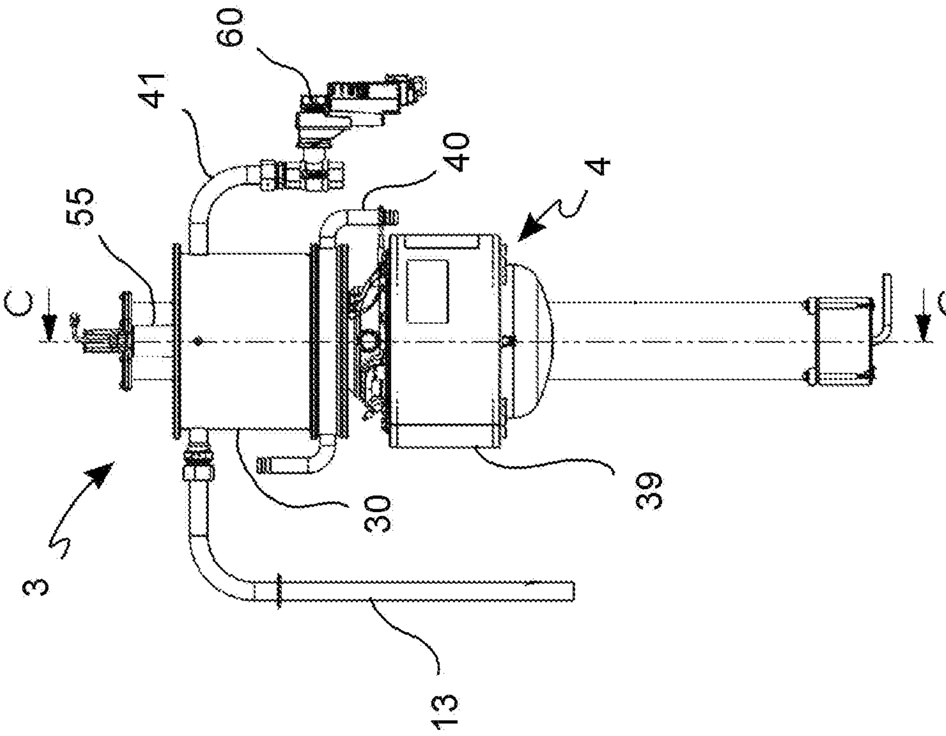

FIG. 9

REFERENCES CITED IN THE DESCRIPTION

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