

(19)



(11)

EP 4 359 653 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:

19.03.2025 Bulletin 2025/12

(21) Application number: **22741848.0**

(22) Date of filing: **24.06.2022**

(51) International Patent Classification (IPC):

F01N 5/02 ^(2006.01) **F23G 5/027** ^(2006.01)
F23B 50/06 ^(2006.01) **F23B 90/06** ^(2011.01)
F23G 5/46 ^(2006.01) **F23G 7/10** ^(2006.01)

(52) Cooperative Patent Classification (CPC):

F01N 5/02; F23B 50/06; F23B 90/06; F23G 5/027;
F23G 5/46; F23G 7/10; F02G 2243/00;
F23G 2206/20; F23G 2900/50204; F23N 2223/12;
F23N 2227/02

(86) International application number:

PCT/IB2022/055875

(87) International publication number:

WO 2022/269554 (29.12.2022 Gazette 2022/52)

(54) **COGENERATION PROCESS AND RELATED APPARATUS**

KOGENERATIONSVERFAHREN UND ZUGEHÖRIGE VORRICHTUNG

PROCÉDÉ DE COGÉNÉRATION ET APPAREIL ASSOCIÉ

(84) Designated Contracting States:

AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR

(30) Priority: **25.06.2021 IT 202100016703**

(43) Date of publication of application:

01.05.2024 Bulletin 2024/18

(73) Proprietor: **Kira Technology S.R.L.**

I-47039 Savignano sul Rubicone, Forlì-Cesena
(IT)

(72) Inventor: **PELLEGRINI, Fabio**

47039 Savignano sul Rubicone, Forlì-Cesena (IT)

(74) Representative: **Meroni, Francesca et al**

Jacobacci & Partners S.p.A.
Via Senato, 8
20121 Milano (IT)

(56) References cited:

EP-A2- 2 522 708 JP-A- 2005 274 123
US-A1- 2006 089 516 US-A1- 2009 078 176

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

Field of the invention

[0001] The present invention relates to a process of cogeneration of electrical energy and heat and the related apparatus. In particular, the present invention relates to a process of cogeneration of electrical energy and heat and the related apparatus for household or small consumer use, starting from a renewable and sustainable energy source, e.g., woody biomass.

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 CO₂, 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. JP 2005/274123 discloses a power generation system and a control method thereof. EP 2 522

708 discloses an apparatus and a method for gasifying biomass.

[0007] However, to date, the need is increasingly felt to maximize syngas combustion efficiency and heat exchange with the Stirling engine, and to minimize the production of pollutant gases, making combustion safe under all circumstances and simplifying construction and periodic maintenance. Other requirements that are currently very much in demand, especially in CHP systems for domestic use, concern the quietness of the system and the ability to start and stop the gasification process according to the energy demands of the consumer.

[0008] Until today, there is no cogeneration system for domestic, or small consumers, use that can meet all of the above benefits.

[0009] Therefore, the problem underlying the present invention is to make available a cogeneration process for domestic use and related apparatus capable of high-performance characteristics under all circumstances and of meeting all the requirements explained above.

Summary of the invention

[0010] The problem presented above is solved by a process of cogeneration of electrical energy and heat and the related apparatus as outlined in the accompanying claims, the definitions of which form an integral part of the present description.

[0011] A first object of the invention is a process of cogeneration of electrical energy and heat starting from a renewable and sustainable energy source, preferably woody biomass, in a micro-cogenerator comprising a pyrolytic gasifier, a burner, and a Stirling engine, said process comprising the following steps:

- i) feeding said energy source to the pyrolytic gasifier which comprises a reaction chamber inside which said energy source reacts thus generating syngas and biochar;
- ii) feeding the syngas generated during step i) to said burner which comprises a combustion chamber inside which the syngas is burned in the presence of combustion air thus generating hot combustion gases;
- iii) subjecting said hot combustion gases to heat exchange in a heat exchanger, so-called "hot exchanger", of the Stirling engine adapted to generate electrical energy, obtaining exhaust fumes deriving from said heat exchange,

during said step ii), the ratio of combustion air to syngas being adjusted based on a signal provided by a lambda probe crossed by a flow of said exhaust fumes, by virtue of a valve located on an inlet duct of the combustion air, said process comprising a start-up phase of the micro-cogenerator and a full operation phase (regime phase) following said start-up phase,

and being **characterized in that** said start-up phase comprises a first step a) of detecting the presence of syngas inside the burner and a subsequent step b) of ignition of the burner, wherein:

said first step a) comprises calculating the integral over time of the temperature of the reaction chamber of the pyrolytic gasifier and calculating the integral over time of the value read by said lambda probe, during said step a) the calculated value of the integral over time of the temperature of the reaction chamber is compared with a preset threshold value of said integral, so-called first threshold value, and, when said first threshold value is exceeded, the calculated value of the integral over time of the value read by the lambda probe is compared with a preset threshold value of said integral, so-called second threshold value, until it is exceeded, the exceeding of said second threshold value being an indication of the presence of syngas and of the substantial absence of air inside the burner, said second step b) is started when said second threshold value is exceeded and comprises an increasing supply of combustion air into the combustion chamber of said burner until the ignition of a flame.

[0012] According to an embodiment, said step b) further comprises the generation of an ignition spark; more in particular, said ignition spark is advantageously generated before the supply of said combustion air. Alternatively, said ignition spark is generated at the beginning of the start-up phase. Said ignition spark of the flame is generated by a high-voltage electronic transformer. Advantageously, the onset (ignition) of the combustion inside the burner is performed by means of an electric arc generated by a high-voltage electronic transformer and related electrodes appropriately positioned, such as to be lapped by the gas flow.

[0013] The expression "first threshold value" means the preset threshold value of the integral over time of the temperature of the reaction chamber of the pyrolytic gasifier. The expression "second threshold value" means the preset threshold value of the integral over time of the value read by the lambda probe.

[0014] Advantageously, the process according to the present invention allows detecting the time when the pyrolytic gasifier begins to produce fuel syngas and, consequently, the time when the latter is available for combustion in the burner. Detecting the presence of fuel syngas in the burner is critical to identify the exact moment in which the burner can be ignited, the latter being a crucial stage for the following reasons.

[0015] An excessively long wait before ignition of the

burner would result in the emission of unburned syngas, rich in pollutants such as carbon monoxide and methane, into the atmosphere.

[0016] Conversely, an excessively short wait before ignition of the burner could cause a burst inside the combustion chamber that could risk damaging some components of the micro-cogenerator. Furthermore, given the application in the domestic scope, it is desirable for the micro-cogenerator to be silent; therefore, generating a burst whenever the burner is ignited is highly undesirable.

[0017] According to a preferred embodiment, said start-up phase further comprises a step c) of detecting the presence of the flame in the combustion chamber of the burner. During said step c), the derivative of the temperature, i.e., the temperature gradient, of the combustion chamber with respect to time is compared with a preset threshold value of said derivative; the exceeding of said threshold value is an indication of the presence of the flame. In a preferred embodiment of the invention, two thermocouples are placed in the hot exchanger of the Stirling engine and, during the aforesaid step c), the value of the gradient of the average temperature of the two thermocouples is compared with said threshold value.

[0018] 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).

[0019] In this description, the "value read by the lambda probe" means the electrical signal provided by the lambda probe, while the "lambda value (λ)" means the theoretical value properly so called as defined above.

[0020] Generally, a lambda value (λ) equal to 0 indicates the presence of syngas only and the absence of air, a lambda value (λ) of 1 indicates the presence of air in stoichiometric amount, and a lambda value (λ) greater than 1 indicates the presence of air in excess of the amount strictly necessary for syngas combustion. During the aforesaid step a), the lambda value (λ) is 0 or close to 0, e.g., it is comprised between 0 and 0.2. During the aforesaid steps b) and c), the lambda value (λ) is higher, preferably it is about 1, e.g., it is comprised between 0.9 and 1.1. During the regime phase, the value read by the lambda probe is lower than during the start-up phase, hence the lambda value (λ) is higher; preferably the lambda value (λ) is higher than 1, e.g., is comprised between 1.1 and 1.5.

[0021] The mV values of the electrical signal provided by the lambda probe, indicated in the present patent application, were detected experimentally with the lambda probe NGK - OZA685-WW1.

[0022] According to a preferred embodiment, said step c) further comprises a control of the value read by the lambda probe. Advantageously, a value comprised between 0 and 1000 mV, e.g., comprised between 5 and 960 mV, or between 10 and 900 mV, or between 50 and 800 mV, is an indication of the presence of the flame.

[0023] The expression "threshold value" means a calibratable threshold value, i.e., subject to calibration by means of experimental tests.

[0024] During the aforesaid step a) of the start-up phase, the threshold value of the integral over time of the temperature of the reaction chamber of the gasifier (first threshold value) is preferably comprised between 5000 and 25000 °C·s, more preferably between 10000 and 20000 °C·s, even more preferably between 13000 and 18000 °C·s, e.g., it is 15000 °C·s.

[0025] During the aforesaid step a) of the start-up phase, the threshold value of the integral over time of the value read by the lambda probe (second threshold value) is preferably comprised between 500 and 5000 mV·s, more preferably between 800 and 3000 mV·s, even more preferably between 1000 and 2000 mV·s, e.g., it is 2000 mV·s.

[0026] Preferably, the aforesaid integral over time of the temperature of the reaction chamber of the gasifier is calculated, then compared with the corresponding threshold value (first threshold value), for temperatures of the reaction chamber of the gasifier of at least 300°C, preferably of at least 400°C, or at least 500°C, or at least 600°C, or at least 700°C, or at least 800°C.

[0027] Preferably, the aforesaid integral over time of the value read by the lambda probe is calculated, then compared with the corresponding threshold value (second threshold value), for values read by the lambda probe of at least 400 mV, preferably of at least 500 mV, or at least 600 mV, or at least 700 mV, or at least 800, or at least 900, or at least 1000 mV. For example, the integral over time of the value read by the lambda probe is calculated, then compared with the corresponding threshold value, for values read by the lambda probe of at least 850 mV.

[0028] During the aforesaid step c) of the start-up phase, the threshold value of the derivative of the temperature of the combustion chamber with respect to time is preferably comprised between 0.1 and 5.0 °C/s, more preferably between 0.3 and 2.0 °C/s, even more preferably between 0.5 and 1.0 °C/s, e.g., it is 0.5°C/s.

[0029] Advantageously, the regime phase is started at the end of the start-up phase and is characterized by a lower value read by the lambda probe, i.e., a higher combustion air-syngas ratio, than the start-up phase. More advantageously, the regime phase is started at the end of said step c).

[0030] During the aforesaid step ii), the combustion air-syngas ratio is regulated by a lambda probe crossed by a flow of said exhaust fumes, meaning that said combustion air-syngas ratio is adjusted based on the signal provided by said lambda probe.

[0031] During said step ii), the combustion air inflow is

advantageously adjusted by means of an electronically-driven motorized valve. Advantageously, such a valve is driven based on a 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. As already mentioned above, during the regime phase, air in excess of the amount strictly necessary for syngas combustion will be present in the exhaust fumes. For example, the excess air is comprised between 1 and 15%, or between 3 and 10%.

[0032] The need to carefully control the amount of air is related to the fact that performance (in terms of burner power) 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. Said ratio of combustion air to syngas is kept substantially constant during the regime phase.

[0033] Advantageously, through experimental tests, the optimal value read by the lambda probe is identified as compromise between performance and emissions, which is used as an input to a PID controller. As already mentioned above, the optimal lambda value (λ) during the regime phase is greater than 1. More in particular, the position of the valve which regulates the combustion air supply is 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. During the start-up phase as well, the position of the valve which adjusts the supply of combustion air is calculated by a PID control.

[0034] According to a preferred embodiment, during step ii) the syngas exiting the pyrolytic gasifier is sucked into the combustion chamber of the burner by virtue of the presence of a vacuum generated by an appropriate extraction fan of said exhaust fumes. Preferably, said extraction fan is active with a speed proportional to the temperature of the reaction chamber of the pyrolytic gasifier during the start-up phase.

[0035] According to alternative embodiments of the present invention, during the regime phase the extraction fan is driven by taking into account a power error (or delta) or by taking into account a temperature error (or delta).

[0036] In other words, according to a first embodiment, during the regime phase the electrical power of the micro-cogenerator is compared with a target electrical power thus obtaining a power delta, and the speed of the extraction fan is adjusted, i.e., increased or decreased as needed, as a function of the power delta thus obtained. According to this embodiment, the speed of the extraction fan is increased until the temperature of the burner exceeds a predetermined limit value.

[0037] According to an alternative embodiment, during the regime phase the temperature of the burner is compared with a target temperature thus obtaining a temperature delta and the speed of the extraction fan is adjusted, i.e., increased or decreased as needed, as a function of the temperature delta.

[0038] 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.

[0039] According to a preferred embodiment, during both the start-up phase and the regime phase, the biomass is fed to the pyrolytic gasifier through an appropriate loading auger. The latter is advantageously started whenever the filling level of a connecting element (so-called "buffer") between the loading auger and the inlet of the reaction chamber of the pyrolytic gasifier is below a predetermined threshold value. The filling level of said connecting element is advantageously detected by a suitable sensor, preferably based on ultrasound technology.

[0040] According to a preferred embodiment, the reaction chamber of the pyrolytic gasifier is maintained at a suitable gasification temperature at which the biomass reacts generating syngas and biochar. Said gasification temperature is preferably comprised between 1000°C and 1200°C to maximize syngas production.

[0041] Preferably, the reaction front of the biomass inside the gasifier is comprised between an upper limit and a lower limit, and the biomass under reaction is supported by the biochar accumulated in the gasifier as long as the integral over time of the temperature of the upper limit of the reaction front does not exceed a preset threshold value of said integral; when said threshold value is exceeded, the biochar is at least partially discharged through an unloading auger causing the reaction front to lower so that it is maintained between said upper limit and said lower limit.

[0042] The expression "threshold value" means a calibratable threshold value, i.e., subject to calibration by means of experimental tests.

[0043] The aforesaid threshold value of the integral over time of the temperature of the upper limit of the biomass reaction front inside the gasifier is preferably comprised between 10000 and 90000 °C·s, more preferably between 15000 and 80000 °C·s, even more preferably between 20000 and 70000 °C·s, e.g., is 50000 °C·s.

[0044] Preferably, the aforesaid integral over time of the temperature of the upper limit of the biomass reaction front inside the gasifier is calculated, then compared with the corresponding threshold value, for temperatures of said upper limit of at least 300°C, preferably of at least 400°C, or at least 500°C, or at least 600°C, or at least 700°C, or at least 800°C.

[0045] According to a preferred embodiment, said lower limit is defined by an electric heater placed inside the reaction chamber by virtue of which the gasification reaction of the biomass is initiated, while said upper limit is defined by a thermocouple designed to monitor the temperature in the upper part of the reaction chamber. This means that the reaction front of the biomass is comprised between said electric heater and said thermocouple. The aforesaid heater integrates a special sensor

inside it, e.g., a thermocouple.

[0046] The expression "temperature of the reaction chamber of the gasifier" means the temperature of the electric heater when the process according to the present invention is in its start-up phase, and it means the temperature measured by the thermocouple when the process according to the present invention is in its regime phase.

[0047] A further 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, so-called "hot exchanger", fed with said hot combustion gases, said Stirling engine being adapted to generate electrical energy, 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 inlet of the burner (3) is adjusted, and a thermocouple (58) which measures the temperature of said exhaust fumes (34), wherein said burner comprises:

a combustion chamber inside which the syngas is burned in the presence of combustion air, pre-mixing flanges for the syngas and the combustion air upstream of the combustion chamber, a means downstream of said pre-mixing flanges adapted to convey the syngas and the air into the combustion chamber, said micro-cogenerator being **characterized in that** said combustion chamber comprises:

a bell open at the bottom inside which the hot exchanger of the Stirling engine is housed, said bell being adapted to convey the hot combustion gases into said hot exchanger and comprising steel surfaces internally coated, at least partially, with a refractory insulating material having low thermal inertia and high thermal reflectivity, an element made of a porous ceramic material housed in the upper part of the bell above the heat exchanger of the Stirling engine, said element made of porous ceramic material being at least partially supported by the refractory insulating material

and representing an optimized combustion volume inside which the syngas is burned in the presence of combustion air.

[0048] As will become apparent from the following description, the exhaust fumes resulting from the heat exchange of the hot combustion gases feeding said heat exchanger escape from the hot exchanger of the Stirling engine.

[0049] According to a first embodiment, said means adapted to convey syngas and air into the combustion chamber consists of a nozzle or a duct; preferably, said nozzle or duct is made of ceramic material.

[0050] According to a second embodiment, said means is a hole made in the insulating material that internally lines the bell. According to this embodiment, said insulating material has a hole at the outlet of the pre-mixing flanges.

[0051] In addition to constraining the hot combustion gases to flow through the entire hot exchanger of the Stirling engine, the aforesaid bell also has the advantage of optimizing heat exchange by radiation.

[0052] For the sake of brevity, in this description, the element made of porous ceramic material will be also referred to as a "porous ceramic means".

[0053] The porous ceramic means is thermally insulated from the bell by virtue of the presence of the refractory insulating material covering it. Advantageously, said porous ceramic means allows to stabilize the combustion, optimize the distribution thereof, and extend the flammability limit to higher air-fuel ratios, thus allowing to reduce polluting emissions at the exhaust.

[0054] According to a preferred embodiment, said combustion chamber comprises an additional element made of refractory insulating material interposed between said porous ceramic means and said hot exchanger of the Stirling engine. Said additional element has the advantage of preventing the unwanted entrance of heat into a part of the Stirling engine where it would reduce the thermodynamic efficiency of the engine itself.

[0055] According to a preferred embodiment, said refractory insulating material is a polycrystalline alumina fiber-based material, which ensures high reflection of radiations and reduced heat accumulation. Preferably, said material comprises at least 70% by weight of polycrystalline alumina, preferably at least 75% by weight, more preferably at least 80% by weight, for example 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 Blan-
ket 1600-130.

[0056] According to an embodiment, said porous ceramic material comprises silicon carbide, alumina and si-

lica. Preferably, said porous ceramic material is produced by the company Lanik under the trade name Vukopor® S.

[0057] 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.

[0058] According to a preferred embodiment, the micro-generator comprises a cooling ring downstream of the hot exchanger of the Stirling engine inside which a cooling fluid flows. Said cooling ring is such to prevent heat transfer downstream of said hot exchanger, preventing the entry of unwanted heat into the part of the Stirling engine below the hot exchanger, which comprises, for example, a regenerator, a low-temperature heat exchanger and an electric generator, safeguarding these components from an excessive heating.

[0059] By virtue of the above-mentioned special features, the process and the micro-cogenerator according to the present invention advantageously allow to maximize the syngas combustion efficiency, minimize the production of polluting gases, maximize the heat exchange with the Stirling engine, minimize the entry of heat through unwanted points of the engine which would reduce the efficiency thereof, minimize the heat capacity of the elements close to the hot exchanger of the Stirling engine and reduce the thermal inertia in case of an emergency shutdown, make combustion safe under all circumstances, simplify construction and periodic maintenance.

[0060] 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

[0061]

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 or 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 according 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.

Figure 11 shows a cross-section of the combustion chamber of the burner shown in Figures 6 and 9.

Detailed description of the figures

[0062] With reference to Figure 1, a micro-cogenerator according to an embodiment of the present invention is globally indicated with reference numeral 1.

[0063] Said micro-cogenerator 1 comprises a pyrolytic gasifier 2, a burner 3, and a Stirling engine 4.

[0064] 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.

[0065] 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.

[0066] 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.

[0067] 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.

[0068] 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.

[0069] The reactor 7 of the pyrolytic gasifier 2 is shown in greater detail in Figure 3.

[0070] 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 with respect to said reaction chamber 17. Said reaction chamber 17 has truncated-cone shape and is advantageously made of a polycrystalline alumina fiber-based material. Preferably, said material comprises at least 70% by weight of polycrystalline alumina, preferably at least 75% by weight, more preferably at least 80% by weight, for example 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. Preferably, said material has a density comprised between 350 and 500 kg/m³.

[0071] For example, said polycrystalline alumina fiber-based material is produced by the company Unifrax under the trade name High Temperature Saffil® Rigidform™. Preferably, said material is produced by the company Unifrax under the trade name Saffil® 160 HD.

[0072] 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.

[0073] Said outer coating 71 has an annular shape and is advantageously made of a microporous insulating material. The latter preferably comprises silica, for example 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®.

[0074] 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.

[0075] 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.

[0076] 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.

[0077] 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.

[0078] The syngas feeding duct 13 has a gasket at the interface with the support plate 79 consisting of polycrystalline alumina fiber-based rings 82.

[0079] The hopper 14 is advantageously insulated from the unloading auger 12 by means of an element 83 made of said microporous insulating material.

[0080] 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.

[0081] 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.

[0082] The separation valve 23 of the biochar 9 is opened whenever it is necessary to expel the biochar 9, thus operating discontinuously.

[0083] 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.

[0084] 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.

[0085] 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. Therefore, the insert 27 fulfills the function of protecting the seal of the plate-like shutter 26 when the valve 22, 23 is in the fully open position.

[0086] 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.

[0087] As mentioned above, Figures 6-10 illustrate the assembly consisting of the burner 3 and the Stirling engine 4.

[0088] 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 36 is indicated with the as reference numeral 37 in Figure 8.

[0089] Furthermore, the pre-mixing flanges 35 allow partial cooling of the fuel syngas 8 by means of the combustion air 31.

[0090] 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.

[0091] 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.

[0092] 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.

[0093] A bell 44 and a means 45 made of porous ceramic material (porous ceramic means 45) are placed inside the combustion chamber 30 of the burner 3.

[0094] 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.

[0095] Said bell 44 comprises steel walls internally lined with a refractory insulating material, as further described below with reference to Figure 11. 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.

[0096] 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.

[0097] 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.

[0098] The bell 44 and the porous ceramic means 45 are most visible in Figure 11.

[0099] The bell 44 is open at the bottom and the hot exchanger of the Stirling engine is inserted in its inside (not shown in Figure 11). Said bell 44 is delimited by an upper wall 47 and side walls 48. Said walls 47, 48 are

made of steel and are internally lined with a refractory insulating material, e.g., based on polycrystalline alumina fiber. For example, said material is produced by the company Schupp under the trade name ITM-Fibermax®, preferably Blanket 1600-130.

[0100] Referring to the example in Figure 11, the upper steel wall 47 is internally coated with a layer 49 of polycrystalline alumina fiber-based material. In the specific example of Figure 11, said layer 49 is further coated, at its ends, with two layers 50 of polycrystalline alumina fiber-based material, which act as spacers defining a space 51 interposed therebetween for the passage of the mixture 37 of syngas and combustion air exiting the nozzle 36. Said layers 50 can have variable thickness and size; consequently, the space 51 interposed therebetween has variable thickness and inner diameter as well.

[0101] Always referring to the example in Figure 11, the steel side walls 48 are internally coated with first layers 52 of polycrystalline alumina fiber having a given thickness and with second layers 53 of polycrystalline alumina fiber having a different thickness, in this case a greater thickness. The porous ceramic means 45 is housed between said layers 52 of insulating material. Consequently, by means of said layers 52, the porous ceramic means 45 is thermally insulated from the bell 44. For example, the porous ceramic material from which the means 45 is made is produced by the company Lanik under the trade name Vukopor® S or Vukopor® HT.

[0102] The mixture 37 of fuel syngas 8 and combustion air 31, after crossing the space 51, enters the porous ceramic means 45 where it is combusted, generating hot combustion gases 32, which are then conveyed to the hot exchanger 38 of the Stirling engine (not shown in Figure 11).

[0103] In the example in Figure 11, the bell 44 comprises an additional element 54 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 54 mimics the shape of the upper dome of the hot exchanger 38 of the Stirling engine, visible in Figures 7, 8, 10.

[0104] 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.

[0105] 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).

[0106] 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.

[0107] 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.

[0108] 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).

[0109] 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.

[0110] 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.

[0111] 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.

[0112] 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.

[0113] 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.

[0114] 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.

[0115] 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.

[0116] 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.

[0117] 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.

[0118] 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.

[0119] 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.

[0120] 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 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.

[0121] 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.

[0122] The combustion fumes 34 are extracted through the extraction fan 59. Said combustion fumes 34 travel upward through the cavity 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 adjusts the air-syngas ratio 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. More specifically, the lambda probe 57 provides a signal based on which the aforementioned air-syngas ratio is accurately adjusted.

[0123] It is apparent that only one particular embodi-

ment of the present invention was described. The person skilled in the art will be able to make all the modifications needed to adapt both the micro-cogenerator 1 and the process of cogeneration to particular conditions, without, however, departing from the scope of protection as defined in the appended claims. 5

Claims

1. A process of cogeneration of electrical energy and heat starting from a renewable and sustainable energy source (6), preferably woody biomass, in a micro-cogenerator (1) comprising a pyrolytic gasifier (2), a burner (3), and a Stirling engine (4), said process comprising the following steps: 10 15

i) feeding said energy source (6) to the pyrolytic gasifier (2) which comprises a reaction chamber (17) inside which said energy source (6) reacts thus generating syngas (8) and biochar (9); 20
ii) feeding the syngas (8) generated during step i) to said burner (3) which comprises a combustion chamber (30) inside which the syngas (8) is burned in the presence of combustion air (31) thus generating hot combustion gases (32); 25
iii) subjecting said hot combustion gases (32) to heat exchange in a heat exchanger (38), so-called "hot exchanger", of the Stirling engine (4) adapted to generate electrical energy, obtaining exhaust fumes (34) deriving from said heat exchange, 30

during said step ii), the ratio of combustion air (31) to syngas (8) being adjusted based on a signal provided by a lambda probe (57) crossed by a flow of said exhaust fumes (34), by virtue of a valve (60) located on an inlet duct (41) of the combustion air (31), said process comprising a start-up phase of the micro-cogenerator (1) and a full operation phase (regime phase) following said start-up phase, and being **characterized in that** said start-up phase comprises a first step a) of detecting the presence of syngas (8) inside the burner (3) and a subsequent step b) of ignition of the burner (3), wherein: 35 40 45

said first step a) comprises calculating the integral over time of the temperature of the reaction chamber (17) of the pyrolytic gasifier (2) and calculating the integral over time of the value read by said lambda probe (57), during said step a) the calculated value of the integral over time of the temperature of the reaction chamber (17) is compared with a preset threshold value of said 50 55

integral, so-called first threshold value, and, when said first threshold value is exceeded, the calculated value of the integral over time of the value read by the lambda probe (57) is compared with a preset threshold value of said integral, so-called second threshold value, until it is exceeded, the exceeding of said second threshold value being an indication of the presence of syngas (8) and of the substantial absence of air (31) inside the burner (3), said second step b) is started when said second threshold value is exceeded and comprises an increasing supply of combustion air (31) into the combustion chamber (30) of said burner (3) until the ignition of a flame.

2. A process according to claim 1, comprising the generation of an ignition spark of said flame in step b) or comprising the generation of an ignition spark of said flame at the beginning of the start-up phase.
3. A process according to claim 1 or 2, wherein said start-up phase comprises a step c) of detecting the presence of said flame in the combustion chamber (30) of said burner (3), in said step c) the derivative of the temperature of the combustion chamber (30) with respect to time is compared with a preset threshold value of said derivative, the exceeding of which being an indication of the presence of the flame.
4. A process according to any one of the preceding claims, said regime phase being **characterized by** a lower value read by the lambda probe, i.e., a higher ratio of combustion air (31) to syngas (8), than the start-up phase, and said regime phase being started at the end of said step c).
5. A process according to any one of the preceding claims, wherein during step ii) the syngas (8) leaving the pyrolytic gasifier (2) is sucked into the combustion chamber (30) of the burner (3) by virtue of the presence of a vacuum generated by an appropriate extraction fan (59) for extraction of said exhaust fumes (34), and wherein during the start-up phase said extraction fan (59) is active with a speed proportional to the temperature of the reaction chamber (17) of the pyrolytic gasifier (2).
6. A process according to claim 5, wherein: 60 65 70 75

during the regime phase, the electric power of the micro-cogenerator (1) is compared with a target electric power thus obtaining a power delta, and wherein during the regime phase, the speed of the extraction fan (59) is increased

or decreased as a function of the power delta obtained, or

during the regime phase, the temperature of the burner is compared with a target temperature thus obtaining a temperature delta and the speed of the extraction fan is increased or decreased as a function of the temperature delta.

7. A process according to any one of the preceding claims, wherein during both the start-up phase and the regime phase, said energy source (6) is fed to the pyrolytic gasifier (2) through a loading auger (10), said loading auger (10) being started every time the fill level of a connecting element (20) between the loading auger (10) and the inlet (11) of the reaction chamber (17) of the pyrolytic gasifier (2) is below a preset threshold value, said fill level being detected by an appropriate sensor (21).

8. A process according to any one of the preceding claims, wherein the reaction chamber (17) of the pyrolytic gasifier (2) is brought to a gasification temperature, preferably between 1000°C and 1200°C, at which the energy source (6) reacts thus generating syngas (8) and biochar (9),

the reaction front of said energy source (6) being comprised between an upper limit and a lower limit,

said energy source (6) under reaction being supported by the biochar (9) which is accumulated inside the pyrolytic gasifier (2) as long as the integral over time of the temperature of the upper limit of the reaction front does not exceed a preset threshold value of said integral, and when said threshold value is exceeded, the biochar (9) is at least partially discharged through an unloading auger (12) causing the reaction front to lower so that it is comprised between said upper limit and said lower limit.

9. 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), so-called "hot exchanger", fed with said hot combustion gases (32), said Stirling engine (4) being adapted to generate electrical energy, 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 inlet of the burner (3) is adjusted, and a thermocouple (58) which measures the temperature of said exhaust fumes (34),

wherein said burner (3) comprises:

a combustion chamber (30) inside which the syngas (8) is burned in the presence of combustion air (31),

pre-mixing flanges (35) for the syngas (8) and the combustion air (31) upstream of the combustion chamber (30),

a means downstream of said pre-mixing flanges (35) adapted to convey the syngas (8) and the air (31) into the combustion chamber (30), said means being preferably a nozzle or a duct (36),

said micro-cogenerator (1) being **characterized in that** said combustion chamber (30) comprises:

a bell (44) open at the bottom inside which the hot exchanger (38) of the Stirling engine (4) is housed, said bell (44) being adapted to convey the hot combustion gases (32) into said hot exchanger (38) and comprising steel surfaces (47, 48) internally coated, at least partially, with a refractory insulating material (49, 50, 52, 53),

an element (45) made of a porous ceramic material housed in the upper part of the bell (44) above the hot exchanger (38) of the Stirling engine (4), said element (45) made of porous ceramic material being at least partially supported by the refractory insulating material (50, 52) and representing an optimized combustion volume inside which the syngas (8) is burned in the presence of combustion air (31).

10. A micro-cogenerator (1) according to claim 9, said bell (44) being formed by a cylinder open at the bottom comprising an upper surface and a lateral surface, or by a parallelepiped open at the bottom comprising an upper surface (47) and four lateral surfaces (48), said surfaces being made of steel and being internally coated, at least partially, with a refractory insulating material (49, 50, 52, 53).

11. A micro-cogenerator (1) according to claim 9 or 10, said combustion chamber (30) comprising a further element (54) made of refractory insulating material, said element (54) being interposed between said

element (45) made of porous ceramic material and said hot exchanger (38) of the Stirling engine (4).

12. A micro-cogenerator (1) according to any one of claims from 9 to 11, said refractory insulating material being a polycrystalline alumina fiber-based material comprising at least 70% by weight of polycrystalline alumina and/or said porous material comprising silicon carbide, alumina and silica. 5
13. A micro-cogenerator (1) according to any one of claims from 9 to 12, comprising a cooling ring (40) downstream of the hot exchanger (38) of the Stirling engine (4) inside which a cooling fluid flows, said cooling ring (40) being adapted to prevent the thermal transfer downstream of said hot exchanger (38). 15
14. A micro-cogenerator (1) according to any one of claims from 9 to 13, wherein said exhaust fumes (34) leaving the hot exchanger (38) of the Stirling engine (4) are evacuated by traveling upwards in a gap (46) which is present between said bell (44) and said combustion chamber (30). 20
15. A micro-cogenerator (1) according to claim 14, comprising an extraction fan (59) connected to said exchanger (56) for the recovery of heat from the exhaust fumes (34), said extraction fan (59) being such as to extract the exhaust fumes (34) thus creating a vacuum inside the burner (3) and, in turn, to adjust the inflow of the syngas (8) coming from the gasifier (2) and of the combustion air (31) into the burner (3) itself. 25 30
16. A micro-cogenerator (1) according to any one of claims 9 to 15, wherein said pyrolytic gasifier (2) comprises: 35
 - a reactor (7) comprising a reaction chamber (17) inside which said energy source (6) is gasified in the presence of air thus generating syngas (8) and biochar (9), 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), the reaction front being comprised between said heater (18) and said thermocouple (19), 40
 - a loading auger (10) for feeding said renewable source (6) into the reactor (7), 45
 - a connecting element (20) between the loading auger (10) and the reactor (7) provided with a sensor (21) adapted to detect the level of the renewable source (6) present in its inside, 50
 - an unloading auger (12) for the evacuation of the biochar (9), 55
 - a hopper (14) connecting the reactor (7) and the unloading auger (12), said hopper (14) forming a

collection volume of the syngas (8) produced in the reactor (7),
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).

Patentansprüche

1. Verfahren einer Kraft-Wärme-Kopplung elektrischer Energie und Wärme, welches von einer erneuerbaren und nachhaltigen Energiequelle (6) startet, bevorzugt einer holzartigen Biomasse, in einem Mikro-Blockheizkraftwerk (1), welches einen pyrolytischen Vergaser (2), einen Brenner (3) und einen Stirlingmotor (4) umfasst, wobei das Verfahren die folgenden Schritte umfasst: 10
 - i) Zuführen der Energiequelle (6) zu dem pyrolytischen Vergaser (2), welcher eine Reaktionskammer (17) umfasst, innerhalb welcher die Energiequelle (6) reagiert, wodurch Synthesegas (8) und Biokohle (9) erzeugt wird;
 - ii) Zuführen des Synthesegases (8), welches während des Schritts (1) erzeugt wird, zu dem Brenner (3), welcher eine Verbrennungskammer (30) umfasst, innerhalb welcher das Synthesegas (8) in der Anwesenheit von Verbrennungsluft (31) verbrannt wird, wodurch heiße Verbrennungsgase (32) erzeugt werden;
 - iii) Aussetzen einem Wärmeaustausch der heißen Verbrennungsgase (32) in einem Wärmeaustauscher (38), einem sogenannten "heißen Austauscher", des Stirlingmotors (4), welcher dazu angepasst ist, elektrische Energie zu erzeugen, wobei Abgase (34) erhalten werden, welche von dem Wärmeaustausch stammen, 15
- wobei, während des Schritts ii), das Verhältnis Verbrennungsluft (31) zu Synthesegas (8) auf Grundlage eines Signals angepasst wird, welches durch eine Lambda-sonde (57) bereitgestellt ist, welche von einem Fluss der Abgase (34) durchkreuzt wird, mittels eines Ventils (60), welches an einer Einlassdurchführung (41) der Verbrennungsluft (31) angeordnet ist, wobei das Verfahren eine Hochlaufphase des Mikro-Blockheizkraftwerks (1) und eine Vollbetriebsphase (Stabilitätsphase) umfasst, welche auf die Hochlaufphase folgt, und **dadurch gekennzeichnet ist, dass** die Hochlaufphase einen ersten Schritt a) eines Detektierens der Anwesenheit von Synthesegas (8) innerhalb des Brenners (3) und einen darauffolgenden Schritt b) eines Zündens des Brenners (3) umfasst, wobei: 20 25 30 35 40 45 50 55

- der erste Schritt a) ein Berechnen des Zeitintegrals der Temperatur der Reaktionskammer (17) des pyrolytischen Vergasers (2) und ein Berechnen des Zeitintegrals des Wertes umfasst, welcher durch die Lambdasonde (57) gelesen wird, wobei, während des Schritts a), der berechnete Wert des Zeitintegrals der Temperatur der Reaktionskammer (17) mit einem vorfestgesetzten Schwellenwert des Integrals, dem sogenannten ersten Schwellenwert, verglichen wird, und, wenn der erste Schwellenwert überschritten wird, der berechnete Wert des Zeitintegrals des Wertes, welcher durch die Lambdasonde (57) gelesen wird, mit einem vorfestgesetzten Schwellenwert des Integrals, dem sogenannten zweiten Schwellenwert, verglichen wird, bis er überschritten wird, wobei die Überschreitung des zweiten Schwellenwerts eine Anzeichen für die Anwesenheit von Synthesegas (8) und die wesentliche Abwesenheit von Luft (31) innerhalb des Brenners (3) ist, wobei der zweite Schritt b) gestartet wird, wenn der zweite Schwellenwert überschritten wird, und eine erhöhte Zufuhr von Verbrennungsluft (31) in die Verbrennungskammer (30) des Brenners (3) umfasst, bis zu der Zündung einer Flamme.
2. Verfahren nach Anspruch 1, welches das Erzeugen eines Zündungsfunkens der Flamme in dem Schritt b) umfasst oder die Erzeugung eines Zündungsfunkens der Flamme zu Beginn der Hochlaufphase umfasst.
3. Verfahren nach Anspruch 1 oder 2, wobei die Hochlaufphase einen Schritt c) eines Detektierens der Anwesenheit der Flamme in der Verbrennungskammer (30) des Brenners (3) umfasst, wobei, in dem Schritt c), die Ableitung nach Zeit der Temperatur der Verbrennungskammer (30) mit einem vorfestgesetzten Schwellenwert der Ableitung verglichen wird, wobei das Überschreiten davon ein Anzeichen der Anwesenheit der Flamme ist.
4. Verfahren nach einem der vorhergehenden Ansprüche, wobei die Stabilitätsphase durch einen niedrigeren Wert, welcher durch die Lambdasonde gelesen wird, d.h., ein höheres Verhältnis von Verbrennungsluft (31) zu Synthesegas (8), als die Hochlaufphase gekennzeichnet ist, und wobei die Stabilitätsphase zu dem Ende des Schritts c) gestartet wird.
5. Verfahren nach einem der vorhergehenden Ansprüche, wobei, während des Schritts ii), das Synthesegas (8), welches den pyrolytischen Vergaser (2) verlässt, in die Verbrennungskammer (30) des Brenners (3) mittels der Anwesenheit eines Vakuums gesaugt wird, welches durch ein geeignetes Absauggebläse (59) für das Absaugen der Abgase (34) erzeugt wird, und wobei, während der Hochlaufphase, das Absauggebläse (59) mit einer Geschwindigkeit aktiv ist, welche proportional zu der Temperatur der Reaktionskammer (17) des pyrolytischen Vergasers (2) ist.
6. Verfahren nach Anspruch 5, wobei:
- während der Stabilitätsphase, die elektrische Leistung des Mikro-Blockheizkraftwerks (1) mit einer elektrischen Zielleistung verglichen wird, wodurch ein Leistungsdelta erhalten wird, und wobei, während der Stabilitätsphase, die Geschwindigkeit des Absauggebläses (59) in Funktion des erhaltenen Leistungsdeltas erhöht oder verringert wird, oder
- während der Stabilitätsphase, die Temperatur des Brenners mit einer Zieltemperatur verglichen wird, wodurch ein Temperaturdelta erhalten wird, und die Geschwindigkeit des Absauggebläses in Funktion des Temperaturdeltas erhöht oder verringert wird.
7. Verfahren nach einem der vorhergehenden Ansprüche, wobei, während sowohl der Hochlaufphase als auch der Stabilitätsphase, die Energiequelle (6) dem pyrolytischen Vergaser (2) durch eine Ladeförderschnecke (10) zugeführt wird, wobei die Ladeförderschnecke (10) jedes Mal gestartet wird, wenn der Füllpegel eines Verbindungselements (20) zwischen der Ladeförderschnecke (10) und dem Einlass (11) der Reaktionskammer (17) des pyrolytischen Vergasers (2) unter einem vorfestgesetzten Schwellenwert ist, wobei das Fülllevel durch einen geeigneten Sensor (21) detektiert wird.
8. Verfahren nach einem der vorhergehenden Ansprüche, wobei die Reaktionskammer (17) des pyrolytischen Vergasers (2) auf eine Vergasungstemperatur gebracht wird, bevorzugt zwischen 1000°C und 1200°C, bei welcher die Energiequelle (6) reagiert, wodurch Synthesegas (8) und Biokohle (9) erzeugt werden,
- wobei die Reaktionsfront der Energiequelle (6) zwischen einer oberen Grenze und einer unteren Grenze umfasst ist, wobei die Energiequelle (6) unter Reaktion von der Biokohle (9) unterstützt wird, welche innerhalb des pyrolytischen Vergasers (2) akkumuliert wird, solange das Zeitintegral der Temperatur

der oberen Grenze der Reaktionsfront einen vorfestgesetzten Schwellenwert des Integrals nicht überschreitet, und, wenn der Schwellenwert überschritten wird, die Biokohle (9) wenigstens teilweise durch eine Entladeförderschnecke (12) abgeführt wird, wodurch verursacht wird, dass die Reaktionsfront abgesenkt wird, sodass sie zwischen der oberen Grenze und der unteren Grenze umfasst ist.

9. Mikro-Blockheizkraftwerk (1), umfassend:

einen pyrolytischen Vergaser (2), welcher dazu angepasst ist, Synthesegas (8) und Biokohle (9) aus einer erneuerbaren und nachhaltigen Energiequelle (6) zu produzieren, bevorzugt aus holzartiger Biomasse,

einen Brenner (3), welcher dazu angepasst ist, das Synthesegas (8), welches durch den pyrolytischen Vergaser (2) produziert ist, aufzunehmen und heiße Verbrennungsgase (32) zu erzeugen,

einen Stirlingmotor (4), welcher einen Wärmeaustauscher (38) umfasst, einen sogenannten "heißen Austauscher", welchem die heißen Verbrennungsgase (32) zugeführt werden, wobei der Stirlingmotor (4) dazu angepasst ist, elektrische Energie zu erzeugen,

ein Abgassystem (33), welches dazu angepasst ist, Abgase (34) zu empfangen, welche den heißen Austauscher (38) des Stirlingmotors (4) verlassen,

wobei das Abgassystem (33) einen Austauscher (56) für die Rückgewinnung der Wärme von den Abgasen (34), eine Lambdasonde (57), welche ein Signal bereitstellt, auf Grundlage welchem das Verhältnis von Luft (31) zu Synthesegas (8) an dem Einlass des Brenners (3) angepasst wird, und einen Temperaturfühler (58) umfasst, welcher die Temperatur der Abgase (34) misst,

wobei der Brenner (3) umfasst:

eine Verbrennungskammer (30), innerhalb welcher das Synthesegas (8) in Anwesenheit von Verbrennungsluft (31) verbrannt wird,

Vormischflansche (35) für das Synthesegas (8) und die Verbrennungsluft (31), stromaufwärts der Verbrennungskammer (30),

ein Mittel, stromabwärts der Vormischflansche (35), welches dazu angepasst ist, das Synthesegas (8) und die Luft (31) in die Verbrennungskammer (30) zu befördern, wobei das Mittel bevorzugt eine Düse oder eine Durchführung (36) ist,

wobei das Mikro-Blockheizkraftwerk (1) **dadurch gekennzeichnet ist, dass** die Ver-

brennungskammer (30) umfasst:

eine Glocke (44), welche an dem Boden offen ist, innerhalb welcher der heiße Austauscher (38) des Stirlingmotors (4) untergebracht ist, wobei die Glocke (44) dazu angepasst ist, die heißen Verbrennungsgase (32) in den heißen Austauscher (38) zu befördern, und Stahlflächen (47, 48) umfasst, welche innen, wenigstens teilweise, mit einem hitzebeständigen isolierenden Material (49, 50, 52, 53) beschichtet sind,

ein Element (45), welches aus einem porösen Keramikmaterial gefertigt ist, welches in dem oberen Teil der Glocke (44) oberhalb des heißen Austauschers (38) des Stirlingmotors (4) untergebracht ist, wobei das Element (45), welches aus einem porösen Keramikmaterial gefertigt ist, wenigstens teilweise durch das hitzebeständige isolierende Material (50, 52) getragen ist, und ein optimiertes Verbrennungsvolumen repräsentiert, innerhalb welchem das Synthesegas (8) in der Anwesenheit von Verbrennungsluft (31) verbrannt wird.

10. Mikro-Blockheizkraftwerk (1) nach Anspruch 9, wobei die Glocke (44) durch einen Zylinder, welcher an dem Boden offen ist, welcher eine obere Fläche und eine Seitenfläche umfasst, oder durch ein Parallelepiped gebildet ist, welches an dem Boden offen ist, welches eine obere Fläche (47) und vier Seitenflächen (48) umfasst, wobei die Flächen aus Stahl gefertigt sind und innen, wenigstens teilweise, mit einem hitzebeständigen isolierenden Material (49, 50, 52, 53) beschichtet sind.

11. Mikro-Blockheizkraftwerk (1) nach Anspruch 9 oder 10, wobei die Verbrennungskammer (30) ein weiteres Element (54) umfasst, welches aus einem hitzebeständigen isolierenden Material gefertigt ist, wobei das Element (54) zwischen dem Element (45), welches aus einem porösen Keramikmaterial gefertigt ist, und dem heißen Austauscher (38) des Stirlingmotors (4) eingefügt ist.

12. Mikro-Blockheizkraftwerk (1) nach einem der Ansprüche 9 bis 11, wobei das hitzebeständige isolierende Material ein polykristallines faserbasiertes Aluminiumoxidmaterial ist, welches wenigstens 70 Gew.-% polykristallines Aluminiumoxid umfasst, und/oder das poröse Material Siliziumkarbid, Aluminiumoxid und Siliziumoxid umfasst.

13. Mikro-Blockheizkraftwerk (1) nach einem der Ansprüche 9 bis 12, welches einen Kühlungsring (40) umfasst, stromabwärts des heißen Austauschers (38) des Stirlingmotors (4), innerhalb welchem ein Kühlungsfluid fließt, wobei der Kühlungsring (40) dazu angepasst ist, die thermische Übertragung stromabwärts des heißen Austauschers (38) zu verhindern. 5
14. Mikro-Blockheizkraftwerk (1) nach einem der Ansprüche 9 bis 13, wobei die Abgase (34), welche den heißen Austauscher (38) des Stirlingmotors (4) verlassen, durch ein Fortbewegen aufwärts in einen Spalt (46) abgeführt werden, welcher zwischen der Glocke (44) und der Verbrennungskammer (30) vorzufinden ist. 10
15. Mikro-Blockheizkraftwerk (1) nach Anspruch 14, welches ein Absauggebläse (59) umfasst, welcher mit dem Austauscher (56) zu der Rückgewinnung von Wärme von den Abgasen (34) verbunden ist, wobei das Absauggebläse (59) derart beschaffen ist, um die Abgase (34) abzusaugen, wodurch ein Vakuum innerhalb des Brenners (3) erzeugt wird, und um wiederum das Einstromen des Synthesegases (8), welches von dem Vergaser (2) kommt, und der Verbrennungsluft (31) in den Brenner (3) selbst anzupassen. 20
16. Mikro-Blockheizkraftwerk (1) nach einem der Ansprüche 9 bis 15, wobei der pyrolytische Vergaser (2) umfasst: 25
- einen Reaktor (7), welcher eine Reaktionskammer (17), in welcher die Energiequelle (6) in der Anwesenheit von Luft vergast wird, wodurch Synthesegas (8) und Biokohle (9) erzeugt wird, ein elektrisches Heizelement (18), welches dazu angepasst ist, die Reaktionskammer (17) auf die Vergasungstemperatur zu erwärmen, und ein Thermoelement (19) umfasst, welcher dazu angepasst ist, die Temperatur in dem oberen Teil der Reaktionskammer (17) zu überwachen, wobei die Reaktionsfront zwischen dem Heizelement (18) und dem Thermoelement (19) umfasst ist, 30
- eine Ladeförderschnecke (10) für ein Zuführen der erneuerbaren Quelle (6) in den Reaktor (7), ein Verbindungselement (20) zwischen der Ladeförderschnecke (10) und dem Reaktor (7), welches mit einem Sensor (21) bereitgestellt ist, welcher dazu angepasst ist, den bestehenden Pegel der erneuerbaren Quelle (6) in seinem inneren zu detektieren, 35
- eine Entladeförderschnecke (12) für das Abführen der Biokohle (9), 40
- einen Trichter (14), welcher den Reaktor (7) und die Entladeförderschnecke (12) verbindet, wo- 45

bei der Trichter (14) ein Sammelvolumen des Synthesegases (8) bildet, welches in dem Reaktor (7) produziert wird, eine Verbindungsdurchführung (13) zwischen dem Trichter (14) und dem Brenner (3), von welchem das Synthesegas (8) abgesaugt wird und dem Brenner (3) zugeführt wird.

Revendications

1. Processus de cogénération d'énergie électrique et de chaleur à partir d'une source d'énergie renouvelable et durable (6), de préférence une biomasse ligneuse, dans un micro-cogénérateur (1) comprenant un gazéifieur pyrolytique (2), un brûleur (3), et un moteur Stirling (4), ledit processus comprenant les étapes suivantes :

- i) l'amenée de ladite source d'énergie (6) au gazéifieur pyrolytique (2) qui comprend une chambre de réaction (17) à l'intérieur de laquelle ladite source d'énergie (6) réagit, générant ainsi du gaz de synthèse (8) et du biocharbon (9) ;
- ii) l'amenée du gaz de synthèse (8) généré pendant l'étape i) dans ledit brûleur (3) qui comprend une chambre de combustion (30) à l'intérieur de laquelle le gaz de synthèse (8) est brûlé en présence d'air de combustion (31), générant ainsi des gaz de combustion chauds (32) ;
- iii) la soumission desdits gaz de combustion chauds (32) à un échange de chaleur dans un échangeur de chaleur (38), appelé « échangeur chaud », du moteur Stirling (4) adapté pour générer de l'énergie électrique, obtenant alors des gaz d'échappement (34) dérivant dudit échange de chaleur,

pendant ladite étape ii), le rapport de l'air de combustion (31) au gaz de synthèse (8) étant ajusté sur la base d'un signal fourni par une sonde lambda (57) traversée par un écoulement desdits gaz d'échappement (34), grâce à une soupape (60) située sur une conduite d'admission (41) de l'air de combustion (31),

ledit processus comprenant une phase de démarrage du micro-cogénérateur (1) et une phase de fonctionnement à pleine capacité (phase de plein régime) suivant ladite phase de démarrage, et étant **caractérisé en ce que** ladite phase de démarrage comprend une première étape a) de détection de la présence de gaz de synthèse (8) à l'intérieur du brûleur (3) et une étape suivante b) d'allumage du brûleur (3), dans lequel :

ladite première étape a) comprend le calcul de l'intégrale dans le temps de la température de la chambre de réaction (17) du gazéifieur pyrolytique (2) et le calcul de l'intégrale dans le temps de la valeur lue par ladite sonde lambda (57), pendant ladite étape a), la valeur calculée de l'intégrale dans le temps de la température de la chambre de réaction (17) est comparée à une valeur de seuil prédéfinie de ladite intégrale, appelée première valeur de seuil, et, lorsque ladite première valeur de seuil est dépassée, la valeur calculée de l'intégrale dans le temps de la valeur lue par la sonde lambda (57) est comparée à une valeur de seuil prédéfinie de ladite intégrale, appelée deuxième valeur de seuil, jusqu'à ce qu'elle soit dépassée, le dépassement de ladite deuxième valeur de seuil étant une indication de la présence de gaz de synthèse (8) et de l'absence substantielle d'air (31) à l'intérieur du brûleur (3), ladite deuxième étape b) démarre lorsque ladite deuxième valeur de seuil est dépassée et comprend une fourniture croissante d'air de combustion (31) dans la chambre de combustion (30) dudit brûleur (3) jusqu'à l'allumage d'une flamme.

2. Processus selon la revendication 1, comprenant la génération d'une étincelle d'allumage de ladite flamme dans l'étape b) ou comprenant la génération d'une étincelle d'allumage de ladite flamme au début de la phase de démarrage.
3. Processus selon la revendication 1 ou 2, dans lequel ladite phase de démarrage comprend une étape c) de détection de la présence de ladite flamme dans la chambre de combustion (30) dudit brûleur (3), dans ladite étape c), la dérivée de la température de la chambre de combustion (30) par rapport au temps est comparée à une valeur de seuil prédéfinie de ladite dérivée, dont le dépassement est une indication de la présence de la flamme.
4. Processus selon l'une quelconque des revendications précédentes, ladite phase de plein régime étant **caractérisée par** une valeur inférieure lue par la sonde lambda, c'est-à-dire, un rapport de l'air de combustion (31) au gaz de synthèse (8) plus élevé que la phase de démarrage, et ladite phase de plein régime démarrant à la fin de ladite étape c).
5. Processus selon l'une quelconque des revendications précédentes, dans lequel pendant l'étape ii), le

gaz de synthèse (8) quittant le gazéifieur pyrolytique (2) est aspiré dans la chambre de combustion (30) du brûleur (3) grâce à la présence d'un vide généré par un ventilateur d'extraction (59) approprié pour l'extraction desdits gaz d'échappement (34), et dans lequel pendant la phase de démarrage, ledit ventilateur d'extraction (59) est actif avec une vitesse proportionnelle à la température de la chambre de réaction (17) du gazéifieur pyrolytique (2).

6. Processus selon la revendication 5, dans lequel :

pendant la phase de plein régime, la puissance électrique du micro-cogénérateur (1) est comparée à une puissance électrique cible, obtenant ainsi un delta de puissance, et dans lequel pendant la phase de plein régime, la vitesse du ventilateur d'extraction (59) est augmentée ou diminuée en fonction du delta de puissance obtenu, ou pendant la phase de plein régime, la température du brûleur est comparée à une température cible, obtenant ainsi un delta de température, et la vitesse du ventilateur d'extraction est augmentée ou diminuée en fonction du delta de température.

7. Processus selon l'une quelconque des revendications précédentes, dans lequel, pendant à la fois la phase de démarrage et la phase de plein régime, ladite source d'énergie (6) est amenée au gazéifieur pyrolytique (2) par l'intermédiaire d'une vis sans fin de chargement (10), ladite vis sans fin de chargement (10) démarrant à chaque fois que le niveau de remplissage d'un élément de liaison (20) entre la vis sans fin de chargement (10) et l'entrée (11) de la chambre de réaction (17) du gazéifieur pyrolytique (2) se trouve en-dessous d'une valeur de seuil prédéfinie, ledit niveau de remplissage étant détecté par un capteur (21) approprié.
8. Processus selon l'une quelconque des revendications précédentes, dans lequel la chambre de réaction (17) du gazéifieur pyrolytique (2) est amenée à une température de gazéification, de préférence entre 1000 °C et 1200°C, à laquelle la source d'énergie (6) réagit, pour générer du gaz de synthèse (8) et du biocharbon (9),

le front de réaction de ladite source d'énergie (6) étant compris entre une limite supérieure et une limite inférieure, ladite source d'énergie (6) subissant une réaction étant supportée par le biocharbon (9) qui est accumulé à l'intérieur du gazéifieur pyrolytique (2) tant que l'intégrale dans le temps de la température de la limite supérieure du front de réaction ne dépasse pas une valeur de seuil pré-

définie de ladite intégrale, et lorsque ladite valeur de seuil est dépassée, le biocharbon (9) est au moins en partie déchargé par l'intermédiaire d'une vis sans fin de déchargement (12), ce qui fait que le front de réaction baisse de façon à être compris entre ladite limite supérieure et ladite limite inférieure.

9. 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 générer des gaz de combustion chauds (32),
un moteur Stirling (4) comprenant un échangeur de chaleur (38), appelé « échangeur chaud », alimenté avec lesdits gaz de combustion chauds (32), ledit moteur Stirling (4) étant adapté pour générer de l'énergie électrique,
un système d'échappement (33) adapté pour recevoir les gaz d'échappement (34) quittant l'échangeur chaud (38) du moteur Stirling (4), dans lequel ledit système d'échappement (33) comprend un échangeur (56) permettant de récupérer la chaleur desdits gaz d'échappement (34), une sonde lambda (57) qui fournit un signal sur la base duquel le rapport de l'air (31) au gaz de synthèse (8) à l'entrée du brûleur (3) est ajusté, et un thermocouple (58) qui mesure la température desdits gaz d'échappement (34),
dans lequel ledit brûleur (3) comprend :

une chambre de combustion (30) à l'intérieur de laquelle le gaz de synthèse (8) est brûlé en présence d'air de combustion (31), des ailettes de prémélange (35) du gaz de synthèse (8) et de l'air de combustion (31) en amont de la chambre de combustion (30),
un moyen en aval desdites ailettes de prémélange (35) adapté pour transporter le gaz de synthèse (8) et l'air (31) dans la chambre de combustion (30), ledit moyen étant de préférence une buse ou une conduite (36),
ledit micro-cogénérateur (1) étant **caractérisé en ce que** ladite chambre de combustion (30) comprend :

une cloche (44) ouverte au niveau du fond et à l'intérieur de laquelle l'échangeur chaud (38) du moteur Stirling (4)

est logé, ladite cloche (44) étant adaptée pour transporter les gaz de combustion chauds (32) dans ledit échangeur chaud (38) et comprenant des surfaces en acier (47, 48) revêtues intérieurement, au moins en partie, avec un matériau isolant réfractaire (49, 50, 52, 53),
un élément (45) composé d'un matériau céramique poreux logé dans la partie supérieure de la cloche (44) au-dessus de l'échangeur chaud (38) du moteur Stirling (4), ledit élément (45) composé de matériau céramique poreux étant au moins en partie supporté par le matériau isolant réfractaire (50, 52) et représentant un volume de combustion optimisé à l'intérieur duquel le gaz de synthèse (8) est brûlé en présence d'air de combustion (31).

10. Micro-cogénérateur (1) selon la revendication 9, ladite cloche (44) étant formée par un cylindre ouvert au niveau du fond et comprenant une surface supérieure et une surface latérale, ou par un parallélépipède ouvert au niveau du fond et comprenant une surface supérieure (47) et quatre surfaces latérales (48), lesdites surfaces étant composées d'acier et étant revêtues intérieurement, au moins en partie, d'un matériau isolant réfractaire (49, 50, 52, 53).

11. Micro-cogénérateur (1) selon la revendication 9 ou 10, ladite chambre de combustion (30) comprenant un autre élément (54) composé de matériau isolant réfractaire, ledit élément (54) étant interposé entre ledit élément (45) composé de matériau céramique poreux et ledit échangeur chaud (38) du moteur Stirling (4).

12. Micro-cogénérateur (1) selon l'une quelconque des revendications 9 à 11, ledit matériau isolant réfractaire étant un matériau à base de fibre d'alumine polycristalline comprenant au moins 70 % en poids d'alumine polycristalline et/ou ledit matériau poreux comprenant du carbure de silicium, de l'alumine et de la silice.

13. Micro-cogénérateur (1) selon l'une quelconque des revendications 9 à 12, comprenant une bague de refroidissement (40) en aval de l'échangeur chaud (38) du moteur Stirling (4) à l'intérieur de laquelle s'écoule un fluide de refroidissement, ladite bague de refroidissement (40) étant adaptée pour empêcher le transfert thermique en aval dudit échangeur chaud (38).

14. Micro-cogénérateur (1) selon l'une quelconque des revendications 9 à 13, dans lequel lesdits gaz d'é-

échappement (34) quittant l'échangeur chaud (38) du moteur Stirling (4) sont évacués en se déplaçant vers le haut dans un interstice (46) qui est présent entre ladite cloche (44) et ladite chambre de combustion (30).

5

15. Micro-cogénérateur (1) selon la revendication 14, comprenant un ventilateur d'extraction (59) relié audit échangeur (56) pour la récupération de chaleur à partir des gaz d'échappement (34), ledit ventilateur d'extraction (59) étant tel qu'il extrait les gaz d'échappement (34), créant ainsi un vide à l'intérieur du brûleur (3) et, en conséquence, ajuste l'arrivée du gaz de synthèse (8) provenant du gazéificateur (2) et de l'air de combustion (31) dans le brûleur (3) lui-même.

10

15

16. Micro-cogénérateur (1) selon l'une quelconque des revendications 9 à 15, dans lequel ledit gazéifieur pyrolytique (2) comprend :

20

un réacteur (7) comprenant une chambre de réaction (17) à l'intérieur de laquelle ladite source d'énergie (6) est gazéifiée en présence d'air,

25

générant ainsi du gaz de synthèse (8) et du biocharbon (9), un dispositif de chauffage électrique (18) adapté pour chauffer la chambre de réaction (17) à la température de gazéification, et un thermocouple (19) adapté pour surveiller la température dans la partie supérieure de la chambre de réaction (17), le front de réaction étant compris entre ledit dispositif de chauffage (18) et ledit thermocouple (19),

30

une vis sans fin de chargement (10) pour l'amenée de ladite source renouvelable (6) dans le réacteur (7),

35

un élément de liaison (20) entre la vis sans fin de chargement (10) et le réacteur (7), doté d'un capteur (21) adapté pour détecter le niveau de la source renouvelable (6) présente dans son intérieur,

40

une vis sans fin de déchargement (12) pour l'évacuation du biocharbon (9),

une trémie (14) reliant le réacteur (7) et la vis sans fin de déchargement (12), ladite trémie (14) formant un volume de collecte du gaz de synthèse (8) produit dans le réacteur (7),

45

une conduite de liaison (13) entre ladite trémie (14) et le brûleur (3), à partir de laquelle le gaz de synthèse (8) est aspiré et amené dans ledit brûleur (3).

50

55

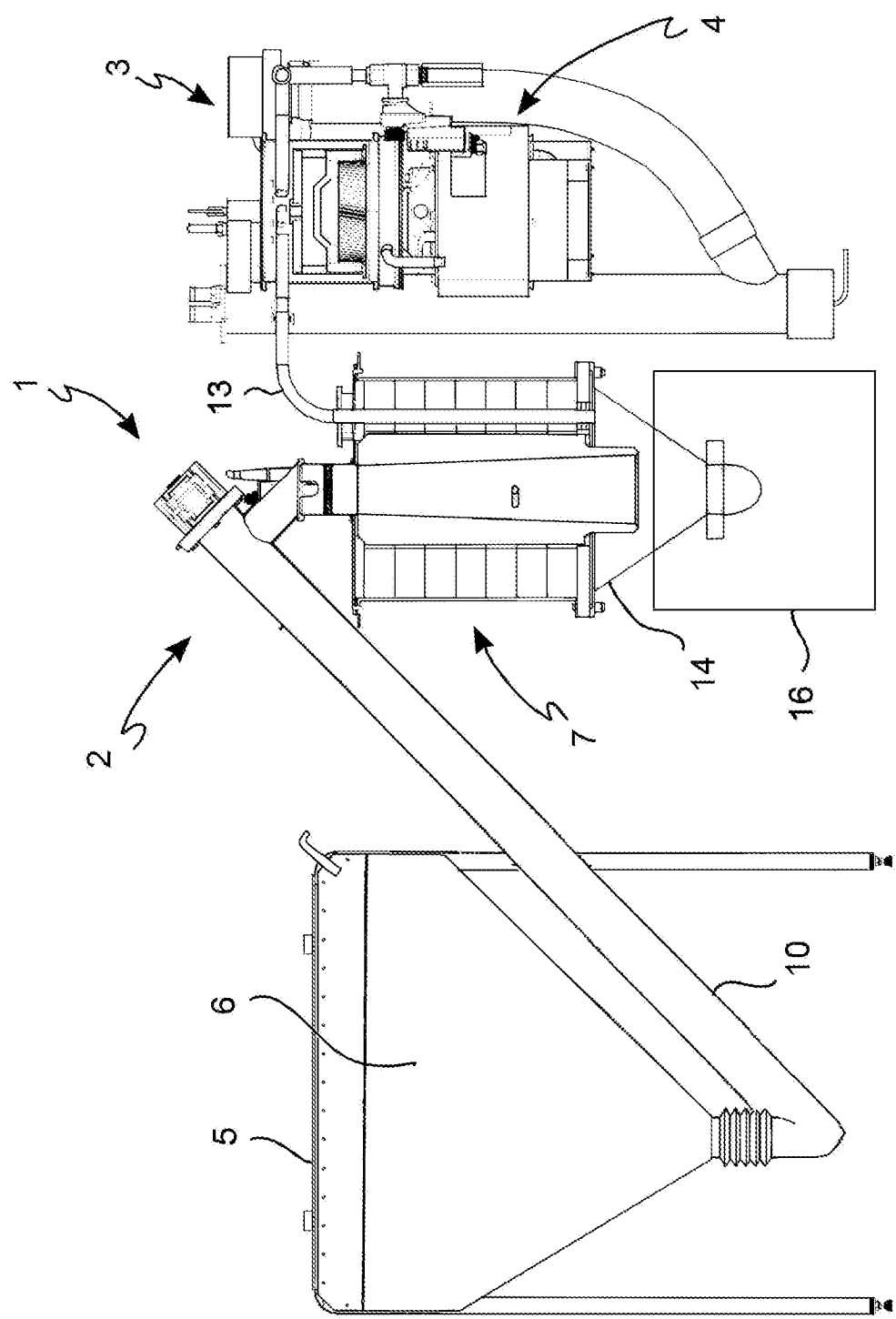


FIG. 1

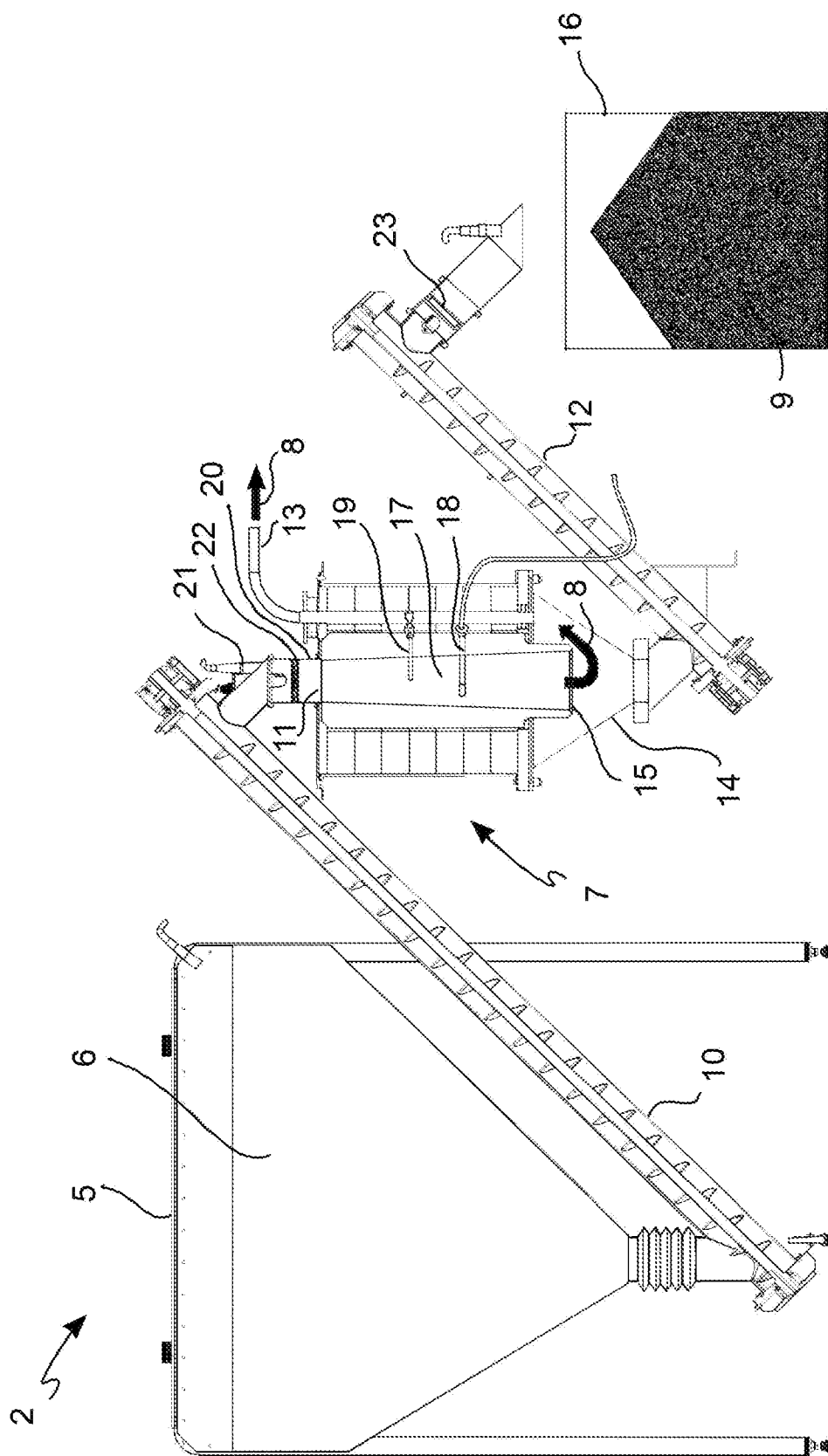


FIG. 2

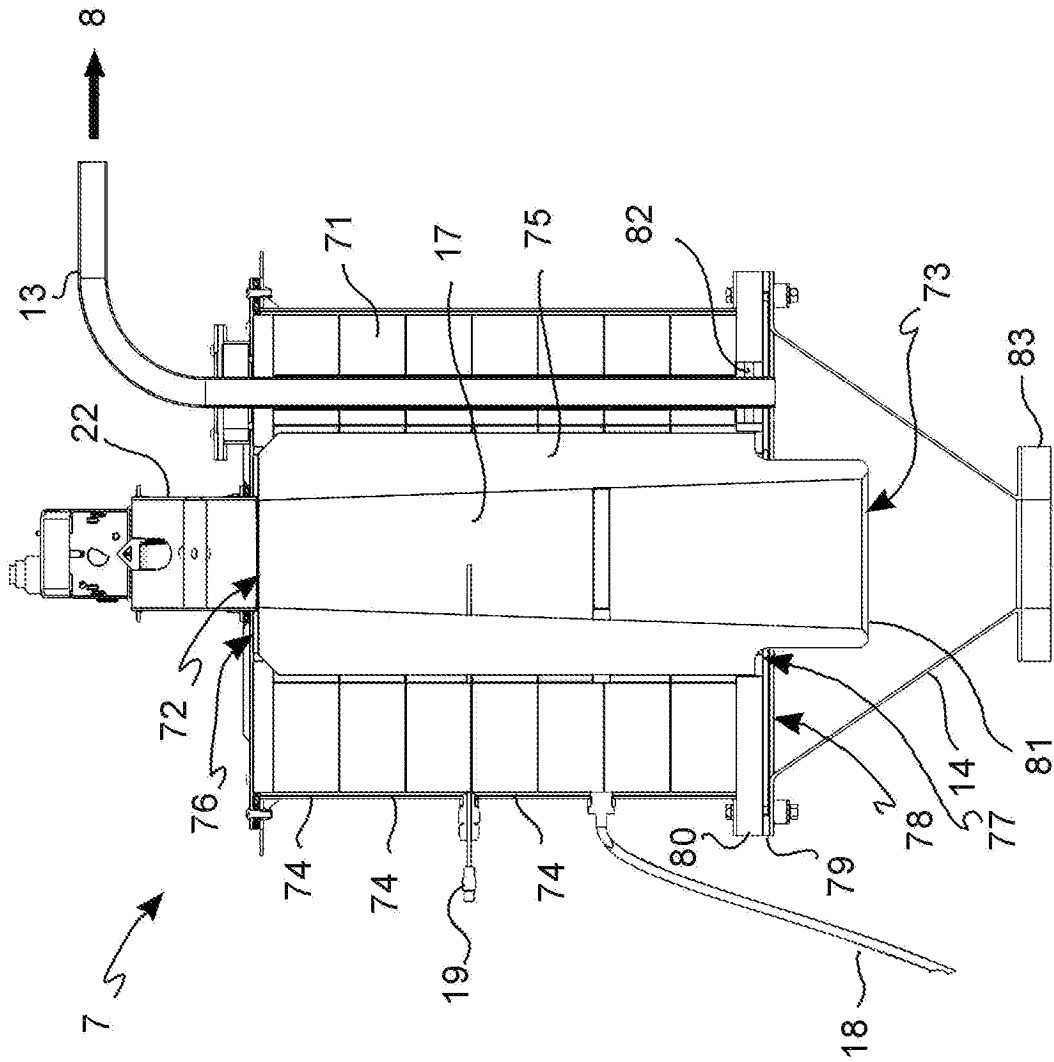


FIG. 3

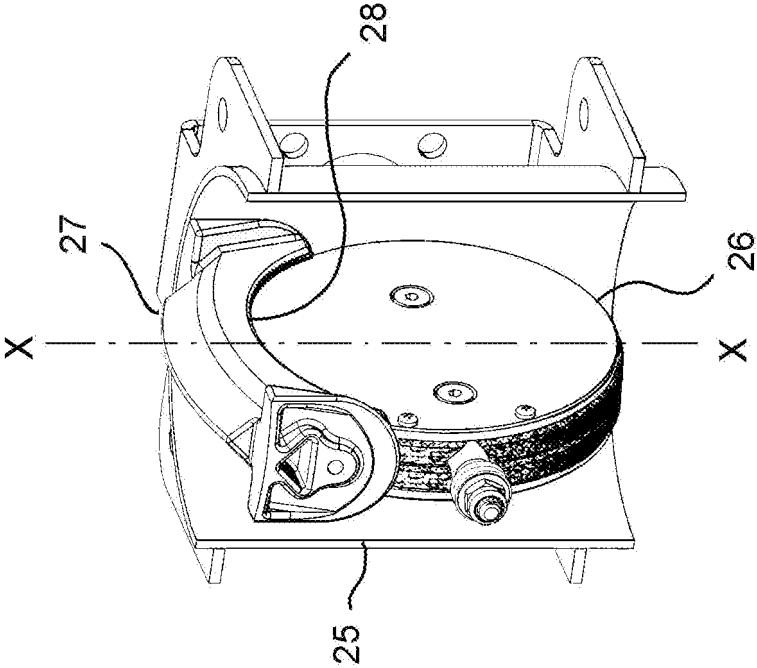


FIG. 5

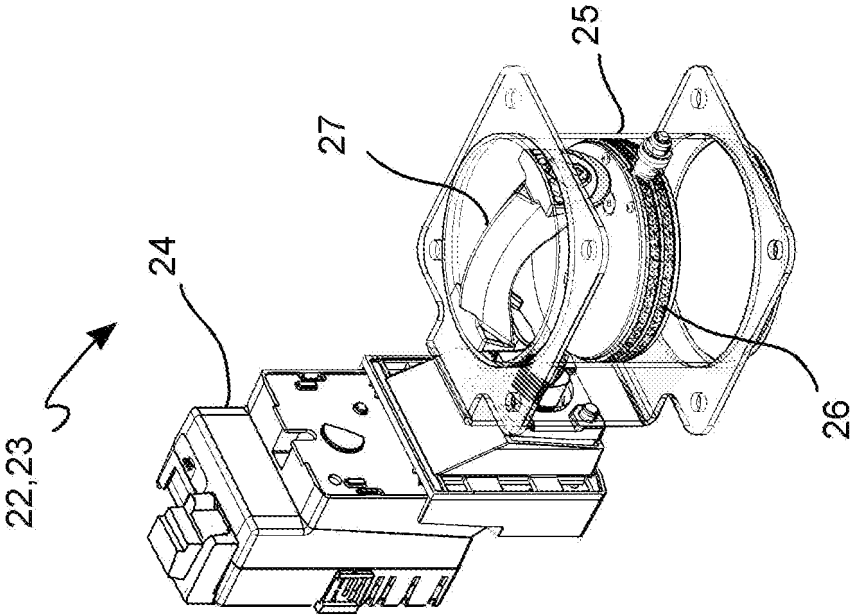
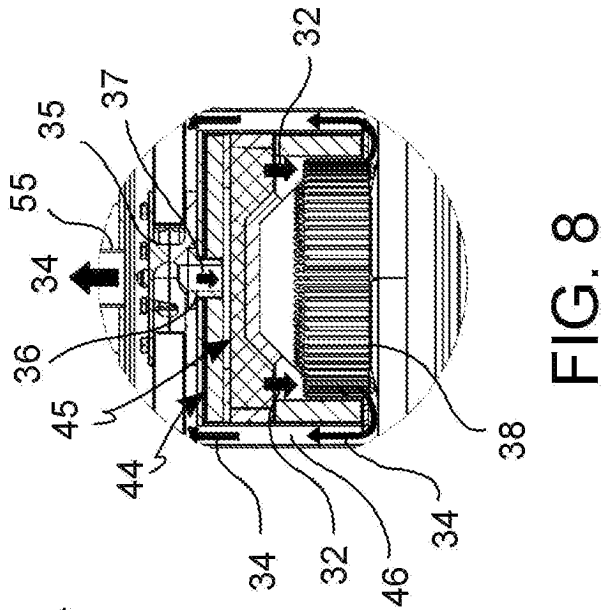
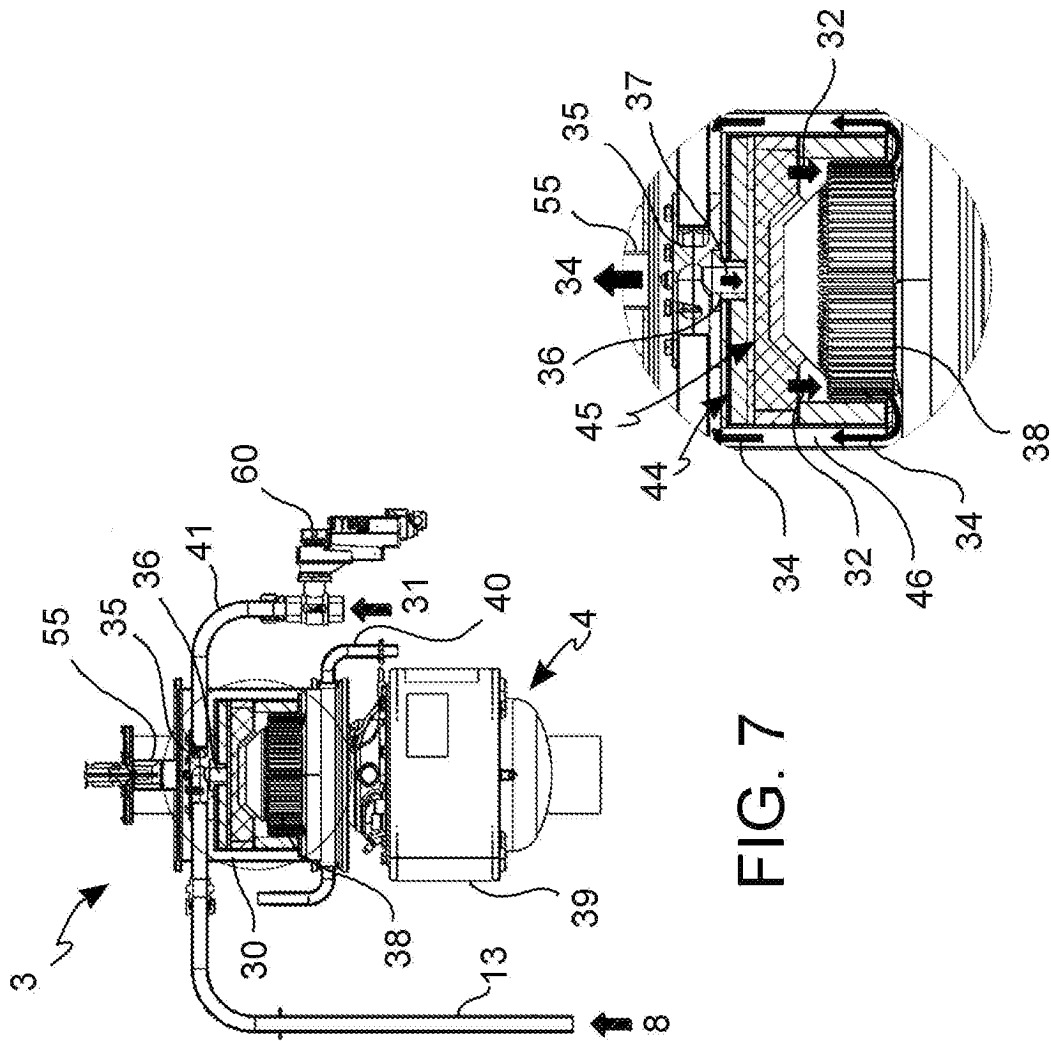
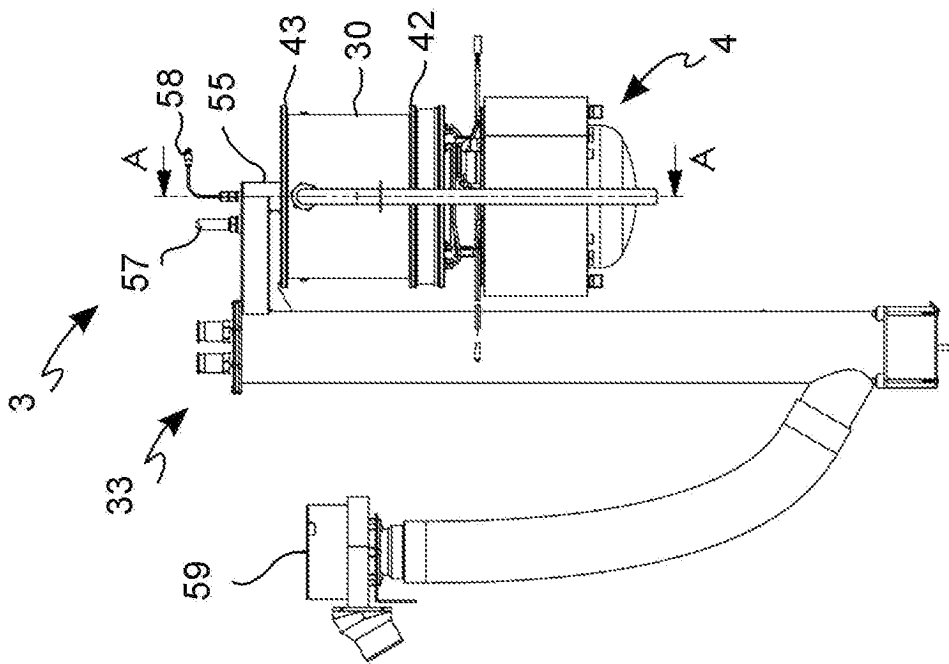


FIG. 4



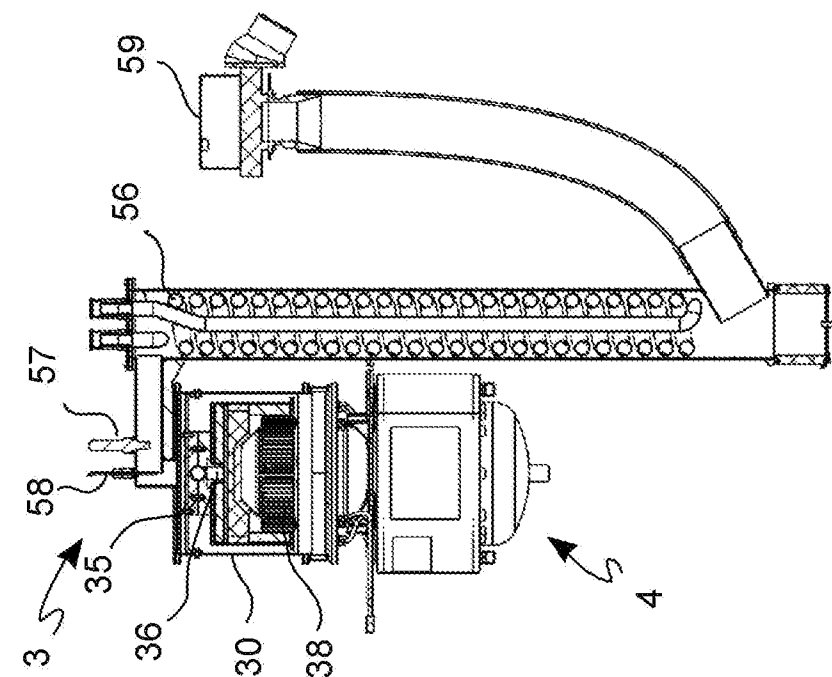


FIG. 10

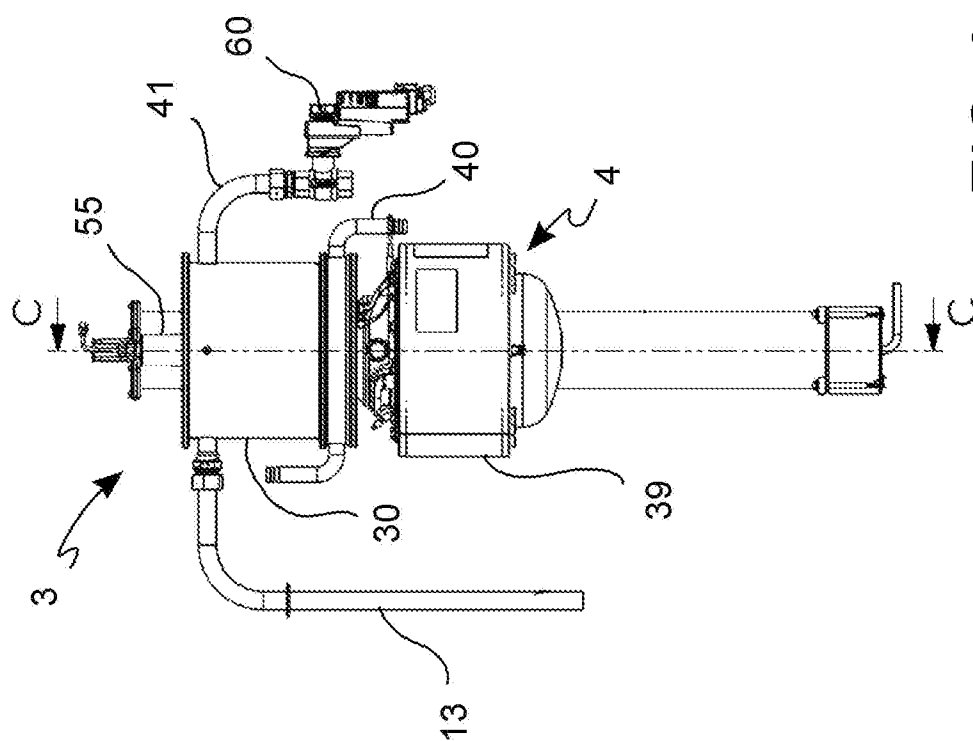


FIG. 9

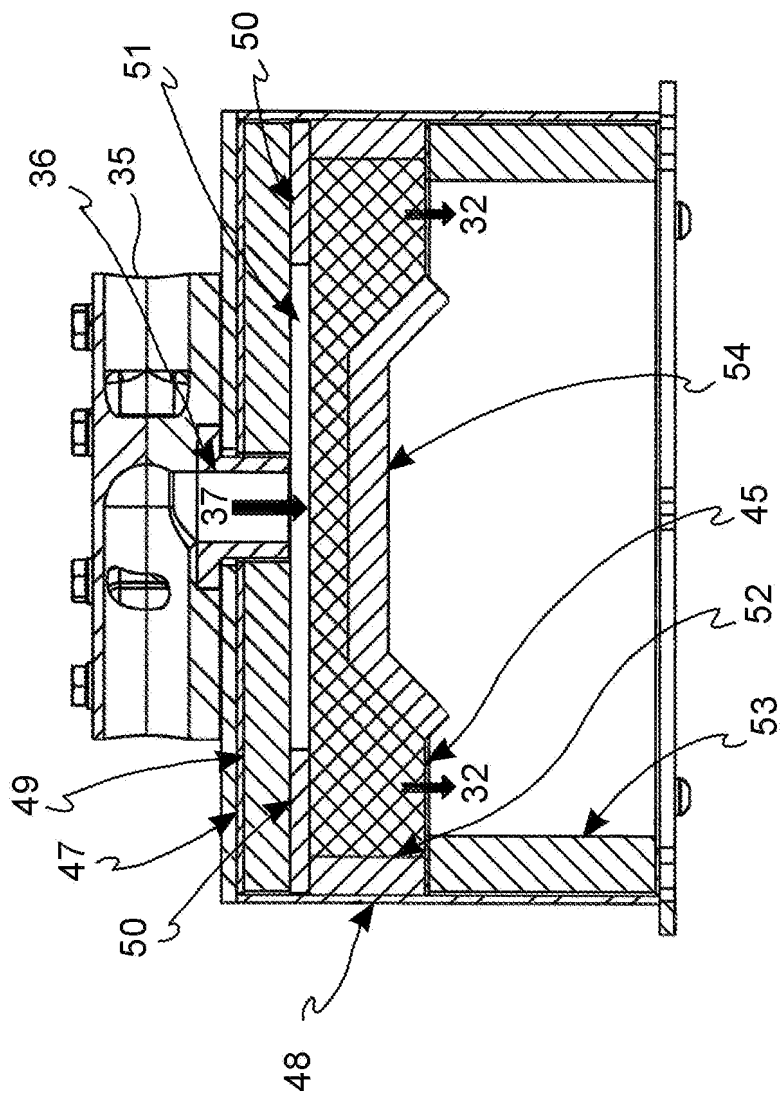


FIG. 11

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 20090078176 A [0006]
- US 20060089516 A [0006]
- JP 2005274123 A [0006]
- EP 2522708 A [0006]