(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) EP 3 366 753 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
23.10.2019 Bulletin 2019/43

(51) Int Cl.:
C10J 3/48 (2006.01) ***C10J 3/84*** (2006.01)
C10J 3/18 (2006.01) ***C10K 3/00*** (2006.01)
C10L 3/08 (2006.01)

(21) Application number: **18158095.2**

(22) Date of filing: **22.02.2018**

(54) **METHANATION SYSTEM AND METHOD FOR THE CONVERSION OF CARBONACEOUS MATERIAL INTO METHANE**

METHANISATIONSSYSTEM UND VERFAHREN ZUR KONVERTIERUNG VON KOHLENSTOFFMATERIAL IN METHAN

SYSTÈME DE MÉTHANATION ET PROCÉDÉ DE CONVERSION DE MATIÈRE CARBONÉE EN MÉTHANE

(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: **23.02.2017 EP 17157685**

(43) Date of publication of application:
29.08.2018 Bulletin 2018/35

(73) Proprietor: **B.A.T. Services**
9051 Sint-Denijs-Westrem (BE)

(72) Inventor: **DE LATHAUWER, Bart**
9051 Sint-Denijs-Westrem (BE)

(74) Representative: **De Clercq & Partners**
Edgard Gevaertdreef 10a
9830 Sint-Martens-Latem (BE)

(56) References cited:
EP-A1- 2 843 031
US-A1- 2007 266 633
US-A1- 2011 291 425
US-A1- 2012 210 645
US-A1- 2013 047 509

EP 3 366 753 B1

Description

FIELD OF INVENTION

[0001] The present invention relates to a methanation system suitable for the conversion of carbonaceous material into methane and a process for the conversion of carbonaceous material into methane.

BACKGROUND OF THE INVENTION

[0002] Gasification of organic material is one of the most effective ways to recover energy from biomass and/or waste material. For example, gasifying an amount of biomass to produce a syngas that can fuel a gas turbine is more energy efficient than burning the same amount of biomass to generate steam that drives a turbine.

[0003] Gasification is the thermochemical conversion of carbonaceous matter into a gaseous product (i.e. synthesis gas or syngas). Reactions take place at elevated temperatures (500-1400 °C) and a range of pressures (from atmospheric to 33 bar). The gasifying medium used may be air, pure oxygen, steam or a mixture of these. The main syngas components are H_2 and CO, with lower concentrations of CO_2, H_2O, CH_4, higher hydrocarbons and N_2. Several types of gasifiers are currently available for gasification processes such as fixed bed gasifiers, fluidized bed reactors and plasma gasifiers.

[0004] Fluidized bed gasifiers comprise a reactor bed that is fluidized through the inlet of gasses such as steam and oxidant. Feedstock particles are suspended in the bed material. These gasifiers employ back-mixing, and efficiently mix incoming feed particles with particles already undergoing gasification. Due to the thorough mixing within the gasifier, a constant temperature is sustained in the reactor bed. To sustain fluidization, feedstock of small particle size (less than 6 mm) is normally used.

[0005] Plasma torches are known in the art to be a source of thermal energy in gasification processes. Especially electro-arc torches are used, but these have a short lifetime. This leads to high maintenance cost and significant amounts of time that the installation is down. Gasification units using plasma torches do exist. For example, WO 2014/126895 discloses a gasifier wherein plasma torches are arranged around a catalytic bed, directly transferring thermal energy into the catalytic bed. One of the major disadvantages of these kinds of gasifiers is that the lifetime of the catalyst is particularly short because the catalyst particles are being heated to extreme temperatures by the plasma torches.

SUMMARY OF THE INVENTION

[0006] The invention aims to overcome at least some of the above mentioned problems. It is an objective of the invention to provide a methanation system that is highly efficient in converting carbonaceous material into methane or substitute natural gas. It is a further objective of the invention to re-use heat that is released during this conversion. The invention provides a methanation system (36) for the conversion of carbonaceous material into methane, comprising:

- a gasifier (1) for gasifying carbonaceous material into syngas, said gasifier being at least partially steam fed and comprising:
  - an internal volume (4) comprising an upper section (5), a middle section (6) and a lower section (7), and optionally a first connecting section (10), connecting said upper section (5) and said middle section (6) and/or optionally a second connecting section (11), connecting said middle section (6) and said lower section (7), wherein said upper section (5), middle section (6) and lower section (7) are arranged along the longitudinal direction of said gasifier (1), with the upper section (5) placed on top of the middle section (6) which is placed on top of the lower section (7);
  - one or more carbonaceous material inlets (2) configured to receive a carbonaceous material feed and fluidly connected to the internal volume (4);
  - a bed material comprising catalytic particles (9) inside the middle section (6) and/or lower section (7) and connected to at least one gas inlet (12) to fluidize the bed material;
  - a gas outlet (16), fluidly connected to the upper section (5) of the internal volume (4); and
  - at least one plasma system (8) configured inside the upper section (5) so that gas that leaves the gasifier (1) via the gas outlet (16) passes through a zone heated by said at least one plasma system (8);
- a first cooling unit (18, 29), comprising a hot gas inlet (19) and a cold gas outlet (20), wherein said hot gas inlet (19) is fluidly connected to the gas outlet (16) of said gasifier (1);
- a methanation unit (21), suitable to produce crude methane from syngas, comprising a syngas inlet (22) and a crude methane outlet (23), wherein said syngas inlet (22) is fluidly connected to said cold gas outlet (20) of the first cooling unit (18);
- a second cooling unit (24,28), comprising a hot methane inlet (25) and a cold methane outlet (26), wherein said hot methane inlet (25) is fluidly connected to said crude methane outlet (23) of the methanation unit (21);

wherein said first cooling unit and said second cooling unit independently comprise an economizer, an evaporator and/or a super-heater for steam production for the gasifier.

[0007] The herein described gasifier and gasification process used in the system and process of the invention produce in a highly efficient way high yields of a relatively clean syngas because crude syngas produced in the fluidized bed and/or via plasma gasification of the carbonaceous material have to travel through a zone heated by the at least one plasma system before leaving the gasifier, where tar components are subjected to thermal cracking and residual carbonaceous material is further gasified. This results in higher conversion yields of the carbonaceous material into syngas and cleaner syngas through destruction of tar components and removal of dust particles.

[0008] The lay-out of the methanation system of the invention is so that the heat that is released upon cooling the syngas before the methanation reaction and/or upon cooling the crude methane in order to condense and separate water is efficiently re-used for steam generation required for the gasifier.

[0009] The present invention will now be further described. In the following passages, different aspects of the invention are defined in more detail. Each aspect so defined may be combined with any other aspect or aspects unless clearly indicated to the contrary. In particular, any feature indicated as being preferred or advantageous may be combined with any other feature or features indicated as being preferred or advantageous.

DESCRIPTION OF THE FIGURES

[0010]

Figure 1 shows a schematic view of a gasifier as described herein.

Figure 2 shows a schematic view of an alternative gasifier as described herein.

Figure 3 shows a schematic view of a methanation system according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0011] Before the present method used in the invention is described, it is to be understood that this invention is not limited to particular gasifiers, methanation systems, electricity generating systems and processes, described, as such gasifiers, methanation systems, electricity generating systems and processes may, of course, vary. It is also to be understood that the terminology used herein is not intended to be limiting, since the scope of the present invention will be limited only by the appended claims.

[0012] When describing the gasifiers, methanation systems, electricity generating systems and processes of the invention, the terms used are to be construed in accordance with the following definitions, unless a context dictates otherwise.

[0013] As used herein, the singular forms "a", "an", and "the" include both singular and plural referents unless the context clearly dictates otherwise. By way of example, "a gasifier" means one gasifier or more than one gasifier.

[0014] The terms "comprising", "comprises" and "comprised of" as used herein are synonymous with "including", "includes" or "containing", "contains", and are inclusive or open-ended and do not exclude additional, non-recited members, elements or method steps. The terms "comprising", "comprises" and "comprised of" also include the term "consisting of".

[0015] The recitation of numerical ranges by endpoints includes all integer numbers and, where appropriate, fractions subsumed within that range (e.g. 1 to 5 can include 1, 2, 3, 4 when referring to, for example, a number of elements, and can also include 1.5, 2, 2.75 and 3.80, when referring to, for example, measurements). The recitation of end points also includes the end point values themselves (e.g. from 1.0 to 5.0 includes both 1.0 and 5.0). Any numerical range recited herein is intended to include all sub-ranges subsumed therein.

[0016] Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner, as would be apparent to a person skilled in the art from this disclosure, in one or more embodiments. Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art. For example, in the following claims and statements, any of the embodiments can be used in any combination.

[0017] Unless otherwise defined, all terms used in disclosing the invention, including technical and scientific terms, have the meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. By means of further guidance, definitions for the terms used in the description are included to better appreciate the teaching of the present invention.

[0018] The term "gasifier" refers to a system that can turn a carbonaceous material into a gas, in particular a syngas. The system can be housed in one unit or can be a series of subunits connected to each other with pipes and conduits.

[0019] The term "carbonaceous material" refers to a material that is rich in carbon. The carbonaceous material may be in any form, such as in liquid and/or solid form. Preferably the carbonaceous material used in the invention is selected from the list comprising waste, biomass such as animal waste and plant materials, oil, refined oil, crude oil, coal or cokes. More preferably the carbonaceous material is waste or biomass, most preferably biomass.

[0020] The term "bed material" refers to a mixture of particles making up a reaction bed.

[0021] The term "cross-section" may refer to the intersection between the internal volume and a plane perpendicular to the longitudinal direction of the gasifier.

[0022] In the context of the present invention, the term "crude syngas" refers to the syngas produced by gasification of a carbonaceous material in a fluidized bed and/or by plasma gasification of a carbonaceous material. Typically, the carbonaceous material is not completely gasified in these reactions, leaving residual carbonaceous material into the crude syngas. The crude syngas may further comprise contaminants such as tar components, but also inorganic material, bed material and/or catalyst.

[0023] With "polishing" or "cleaning" crude syngas is meant herein further converting residual carbonaceous material into syngas, the destruction of tar components and/or the removal of particulate matter or dust.

[0024] The term "tar" refers to any component that is released from the carbonaceous material during gasification different from syngas. Tar can comprise light organic compounds such as methylene and ethylene but also aromatic compounds such as benzene, xylene and anthracene.

[0025] The term "char" refers to the part of the carbonaceous material feed that cannot be gasified. When the carbonaceous material is derived from a biological source, the term "bio-char" is appropriate.

[0026] A first aspect relates to a gasifier that can be used in the system and process of the invention, the gasifier comprising:

- an internal volume comprising an upper section, a middle section and a lower section, and optionally a first connecting section, connecting said upper section and said middle section, and/or a second connecting section, connecting said middle section and said lower section;
- a carbonaceous material inlet, configured to receive a carbonaceous material feed and fluidly connected to the internal volume;
- a bed material, configured inside the middle section and/or lower section and connected to at least one gas inlet to fluidize the bed;
- a gas outlet, fluidly connected to the upper section,
- at least one plasma system inside the upper section,

wherein said at least one plasma system is configured so that the gas, in particular the syngas, that leaves the gasifier via the gas outlet passes through a zone heated by said at least one plasma system, preferably through the plasma flame.

[0027] The upper section may function as a gasification/thermal cracking zone to polish the crude syngas, the middle section may function as a container for the fluidized bed, and the lower section may function as a collector of char. When not enough char is present to fill the lower section, this lower section might also contain some of the fluidized bed.

[0028] Thus, a gasifier as described herein may comprise:

- an internal volume;
- a carbonaceous material inlet for receiving a carbonaceous material feed, wherein said inlet is fluidly connected to the internal volume;
- a bed material inside the internal volume and connected to at least one gas inlet to fluidize the bed material, wherein the bed material is positioned in said internal volume to receive the carbonaceous material that is fed into the internal volume via the carbonaceous material inlet;
- a (syn)gas outlet for enabling the (syn)gas produced in the internal volume to leave the gasifier, wherein said (syn)gas outlet is fluidly connected to the internal volume;
- at least one plasma system inside the internal volume, wherein said at least one plasma system is configured so that the gas, in particular the syngas, that leaves the gasifier via the gas outlet passes through a zone heated by said at least one plasma system, preferably through the plasma flame(s).

[0029] In embodiments, the bed material is contained in the internal volume of the gasifier between the at least one gas inlet to fluidize the bed material and the at least one plasma system.

[0030] The carbonaceous material inlet may be positioned so that the carbonaceous material enters the internal volume between the at least one plasma system and the fluidized bed material.

[0031] Preferably, the gasifier is in the form of a cyclone or funnel-shaped with the wider opening at the upper section. In embodiments, the lower section has a smaller cross-section than the middle section and said middle section has a smaller cross-section than the upper section.

[0032] In an embodiment, the cross-section of the middle section varies along the longitudinal direction of said gasifier within a range of 20%, preferably within a range of 10%, more preferably within a range of 5%, even more preferably within a range of 2% and is most preferably a constant value. This has the advantage that a stable fluidized bed can be generated in this middle section. Indeed, if the shape containing a fluidized bed is too conical, the fluidized bed get disturbed and hotspots occur.

[0033] In embodiments, a first connecting section is present, connecting said upper section and said middle section, and/or a second connecting section, connecting said middle section and said lower section. Preferably said first connection section and/or said second connection section may be a frustoconical connecting section.

This has the advantage that the upper section, middle section and/or lower section may be tube-shaped or tubes, while the frustoconical connecting sections ensure that solid particles can easily roll down the internal surface of the gasifier. This simplifies the construction of the gasifier.

[0034] Preferably, said upper section, middle section and lower section are arranged along the longitudinal direction of said gasifier, with the upper section placed on top of the middle section which is placed on top of the lower section and this preferably when the gasifier is configured in working conditions.

[0035] Such a gasifier as described herein has the advantage that the at least one plasma flame is generated above the fluidized bed. This way a zone is created with a comparative high temperature above the fluidized bed. Tar present in the crude syngas that is produced in the fluidized bed will undergo thermal cracking due to the high temperature in said zone. Also residual carbonaceous material present in the crude syngas is further gasified in said zone, resulting in more efficient gasification of the carbonaceous material and far less solid particles in the zone of the upper section above said plasma flame. Hence far less solid particles and tar are reaching the gas outlet, resulting in cleaner syngas. Moreover, a syngas is produced in the plasma system that is rich in H_2 and CO.

[0036] In embodiments, at least 2, preferably at least 3 and more preferably at least 4 plasma systems are arranged in the upper section and/or in the first connecting section. These 2 or more plasma systems may be arranged in a circle following the contours of the internal volume. These 2 or more plasma systems may also be arranged at different levels.

[0037] In an embodiment, the at least one plasma system, such as the two or more plasma systems, is orientated under an acute angle with the longitudinal direction of the gasifier, and this with the plasma flame outlet pointing towards the middle section or the lower section.

[0038] In some embodiments, the internal volume, in particular the upper section of the internal volume, comprises a constriction at or near the at least one plasma system. Preferably, said constriction reduces the inner diameter of the internal volume, in particular of the upper section of the internal volume, at or near said at least one plasma system by at least 10% to at most 80%, more preferably at least 20% to at most 70%, even more preferably at least 30% to at most 60%, and most preferably at least 40% to at most 50%. This constriction forces the produced syngas to pass through or in close proximity of the plasma flames, thereby inducing a further thermal cracking and a reduction of tar.

[0039] In a preferred embodiment, the plasma system is a microwave-induced plasma system, wherein a microwave generator produces an electromagnetic field through with a gas mixture is fed, thereby ionizing the gas and generating plasma. This has the advantage that a stable plasma is produced, that can transfer a large amount of energy to the internal volume and the carbonaceous material. The durability of a microwave induced plasma system is significantly higher than other plasma systems, such as electro-arc plasma systems. This makes the whole gasifier robust and low in maintenance.

[0040] Preferably, the at least one plasma system comprises a gas inlet, to receive the plasma gasses. Preferably, these plasma gasses are selected from the list comprising steam, air, oxygen gas, air enriched with oxygen gas, carbon dioxide or mixtures thereof, more preferably selected from the list comprising steam, air, oxygen gas, air enriched with oxygen gas or mixtures thereof and most preferably is the plasma gas steam.

[0041] In a preferred embodiment, said carbonaceous material inlet is fluidly connected to the upper section, middle section and/or the first connecting section of the gasifier, preferably fluidly connected to the upper section and/or first connecting section, more preferably fluidly connected to the upper section. Also preferably, the carbonaceous material is introduced in the near proximity of the at least one plasma system, such that the elevated temperature caused by the plasma flame can gasify at least partially the freshly added carbonaceous material before it enters the fluidized bed. Thus, the carbonaceous material inlet may be positioned so that the carbonaceous material enters the internal volume in the near proximity of, and preferably above, the at least one plasma system. This way, larger carbonaceous material particles can be added to the gasifier than conventional gasifiers. In certain embodiments, the carbonaceous material comprises particles with a diameter up to 10 cm, such as up to 9, 8, 7, or 6 cm, preferably up to 5 cm, such as up to 4.5, 4.0, 3.5, or 3.0 cm.

[0042] In an embodiment, said carbonaceous material inlet comprises a pressurized gas inlet, preferably configured to be able to propel the carbonaceous material into the internal volume. By propelling the carbonaceous material, the material can be directed to a certain region in the gasifier such as the hot region in the proximity of, such as just above or just below, the plasma flame, or even in the plasma flame. This results in an efficient first gasification, so that the carbonaceous material almost directly loses at least part of its mass. When the gasification is performed under the plasma flame, an additional advantage is that the formed tar has to pass through the zone heated by the at least one plasma flame before leaving the gasifier, so that the tar itself undergoes a thermal cracking, leading to cleaner syngasses above the plasma flame.

[0043] In a preferred embodiment, the gasifier described herein further comprises at least one filter that is covering at least partially the gas outlet. More preferably is the gas outlet completely covered by one or more filters in a way that gasses, in particular syngas, can pass through the filter before leaving the gasifier and larger particles present in the syngas, including tar components, are retained by the filter. The at least one filter thus has a further cleaning effect, further removing solid particles and tar particles from the syngas. This way the syngas is ready for further use without the need for downstream purifiers and/or scrubbers, and less or substantially no tar deposition occurs downstream from the gasifier.

[0044] Preferably, said at least one filter is configured inside the internal volume of the gasifier, preferably in the upper section of the internal volume, more preferably downstream (downstream being defined by the gas flow thought the gasifier) from the at least one plasma system. This allows particles that are retained by the filter to fall back in the internal volume, passing through the heated zone by the at least one plasma flame before entering the bed material, so that these will be gasified further, contributing to a higher yield.

[0045] The at least one filter may be a ceramic filter, more preferably a ceramic candle filter. The at least one filter may be a catalytic filter, meaning a filter that comprises a catalyst. The catalytic material may be iron catalyst or nickel catalyst, preferably a nickel-calcium catalyst, an iron/olivine catalyst or an MgO-Al_2O_3 supported nickel catalyst. The catalyst is capable of at least partially gasifying at least part of the material that is retained by the filter. Gasifying this retained material results in a higher yield and reduces the clogging up of the filters, what further reduces the maintenance and the gasifier down time. Advantageously the catalytic reactions that occur on the filter are endothermic so that gasses that pass through the filter are cooled down by the catalytic reactions. This has the advantage that less hot gases need to be handled downstream of the gasifier.

[0046] The gasifier described herein further comprises a bed material in the internal volume, in particular in the middle section and/or lower section. The main purpose of the presence of the bed material is heat storage and heat transfer between the particles undergoing gasification. In this way large temperature peaks are avoided and a nearly uniform temperature distribution can be observed

[0047] In a preferred embodiment, the bed material is connected to at least one gas inlet, preferably at least one steam inlet and at least one inlet for air, oxygen gas, air enriched with oxygen gas or carbon dioxide or mixtures thereof. The at least one steam inlet preferably functions as primary gas inlet to create the fluidized bed, and the at least one inlet for air, oxygen gas, air enriched with oxygen gas or carbon dioxide or mixtures thereof as secondary gas inlet, to maintain the desired temperature in the fluidized bed. By varying the ratio of steam to other gasses that are added to the fluidized bed, the composition of the syngas that is produced can be influenced. Preferably, the ratio of steam to other gasses is regulated to ensure that the molar ratio of H2/CO in the syngas is from 2/1 to 4/1, more preferably from 2.2/1 to 3.8/1, more preferably 2.4/1 to 3.6/1, even more preferably 2.6/1 to 3.4/1, still even more preferably from 2.8/1 to 3.2/1, and most preferably from 2.9/1 to 3.1/1, such as 3.0/1.

[0048] Preferably is the at least one gas inlet fluidly connected to the middle section, the second connecting section or the lower section, more preferably to the middle section or the second connecting section. Also preferably, is the steam inlet placed lower in the gasifier than the inlet for air, oxygen gas, air enriched with oxygen gas or carbon dioxide or mixtures thereof. Said at least one gas inlet is preferably configured so that the bed material is suspended or fluidized upon addition of gasses trough said at least one gas inlet. Heat transfer is optimal in a fluidized bed and an intense contact is present between the carbonaceous material and the gas or steam that is added to the gasifier through said at least one gas inlet.

[0049] The bed material comprises catalytic particles. For example, the bed material may comprise particles comprising a metal based catalyst, preferably an iron based catalyst or a nickel based catalyst, more preferably is the catalyst nickel dispersed on alumina (Al_2O_3) or an iron-olivine catalyst, preferably an iron-olivine catalyst with an iron content from 5 to 45% by weight, more preferably from 7 to 35% by weight, even more preferably from 10 to 25% by weight, most preferably 20% by weight. These catalytic particles significantly speed up the gasification process. The presence of the catalyst particles also influence the composition of the syngas produced, for example less carbon dioxide is being generated and reduced amounts of methane and tar are generated when using catalytic particles. The iron based catalysts have the additional advantage that these are considered environmentally safe and thus they can be left in the char or biochar. In still other embodiments, the bed material comprises a mixture of inert particles and catalytic particles.

[0050] In certain embodiments, sorbents for the removal of heavy metals, alkali, and/or sour gas are added to the internal volume, or to the fluidized bed. Preferably the sorbents are placed in a bed, preferably a fixed bed inside the internal volume. Preferably the sorbents are selected from the list of bauxite, kaolinite, zeolite, lime, slag lime, Ba-based sorbents, aluminosilicate or mixtures hereof.

[0051] In embodiments, the average temperature of the fluidized bed is between 400°C and 1000°C, preferably between 500°C and 900°C, more preferably between 600°C and 875°C, even more preferably between 700°C and 850°C and most preferably between 750°C and 825°C.

[0052] In a preferred embodiment, the bed material is connected to a char outlet in the lower section. Via said char outlet, char, but also non-reacted and/or heavy carbonaceous material, and bed material, can be removed from the gasifier, preferably without having to shut down the gasifier. When carbonaceous material is used coming from a biological source, biochar is leaving the gasifier. This biochar can be used in agricultural applications.

[0053] The invention relates to a methanation system for the conversion of carbonaceous material into methane, comprising:

- a gasifier, suitable for gasifying carbonaceous material into syngas, said gasifier being at least partially steam fed, and wherein said gasifier comprises a syngas outlet;
- a first cooling unit, comprising a hot gas inlet and a cold gas outlet, wherein said hot gas inlet is fluidly connected to the syngas outlet of said gasifier;
- a methanation unit, suitable to produce crude methane from syngas, comprising a syngas inlet and a crude methane outlet, wherein said syngas inlet is fluidly connected to said cold gas outlet of the first cooling unit;
- a second cooling unit, comprising a hot methane inlet and a cold methane outlet, wherein said hot methane inlet is fluidly connected to said crude methane outlet of the methanation unit;

wherein said first cooling unit and said second cooling unit comprise an economizer, evaporator and/or superheater for steam production for the gasifier.

[0054] The term "methanation system" refers to a system that can convert a carbonaceous material into methane gas or a gas that is rich in methane, preferably a gas comprising more than 50 volume % methane, more preferably a gas comprising more than 75 volume % methane, and most preferably a gas comprising more than 90 volume % methane. In the case biomass is used as carbonaceous material, the term "bio-methanation" is appropriate. The produced methane is then referred to as "bio-methane". Other frequently used terms to refer to methane gas that is produced instead of being mined is substitute natural gas or synthetic natural gas or SNG.

[0055] The term "methanation unit" refers to a unit that can convert syngas, in particular hydrogen and carbon oxides, preferably carbon monoxide, into methane and water.

[0056] In preferred embodiments, the methanation unit is a fluidized bed methanator. Fluidized bed methanators comprise a reactor bed that is fluidized through the inlet of gasses such as steam and oxidant. Accordingly, fluidized bed methanators typically comprise an internal volume comprising a bed material, and at least a gas inlet fluidly connected to said internal volume and in fluid connection with said bed material. In a preferred embodiment, the methanation unit comprises a catalyst bed, preferably a fluidized catalyst bed. Said catalyst bed may comprise iron-based or nickel based catalytic particles. Because the conversion of syngas into methane is exothermic, the fluidized bed ensures a good heat transfer and heat transport, avoiding hotspots that could damage the unit or the catalyst. A good removal of the heat will also thermodynamically favor the conversion reaction. Preferably said fluidized bed is held in a section of the methanation unit that is cooled, more preferably water cooled.

[0057] The methane that is generated in the methanation system can be injected into the natural gas grid, or it can be used to produce electricity, or stored for later use (e.g. compressed bio-methane for e.g. vehicles).

[0058] The first cooling unit in the methanation system described herein cools down the syngas leaving the gasifier before it enters the methanation unit. The optimal temperature for the methanation reaction is lower than the temperature of the syngas leaving the gasifier and methanation is an exothermic reaction. Hence, without cooling the gas entering the methanation unit, the temperature inside the methanation unit would be too extreme for the catalyst and the building materials of the methanation unit itself. In preferred embodiments, the heat that is released from the gas stream in this first cooling unit is used for steam production. Accordingly, in embodiments, the first cooling unit is an economizer, an evaporator and/or a super-heater.

[0059] The second cooling unit in the methanation system described herein may serve as a water separator, removing the water from the effluent from the methanation unit to produce a relative dry methane gas that can be further used. Accordingly, in embodiments, said second cooling unit comprises a condenser, preferably a condensing economizer or a condensing evaporator. In preferred embodiments, the heat that this second cooling unit extracts from the gas stream is used in steam production. Accordingly, in embodiments, the second cooling unit is an economizer, an evaporator and/or a superheater.

[0060] The term "economizer" as used herein refers to a heat exchange device that heat fluids, such as water, up to but not normally beyond the boiling point of that fluid.

[0061] The term "evaporator" as used herein refers to a heat exchange device wherein the heat is used to turn a fluid such as water into a gaseous state such as water vapor.

[0062] The term "super-heater" as used herein refers to a heat exchange device that heats steam to temperatures above 100 °C.

[0063] In embodiments, the second cooling unit comprises an economizer and evaporator for steam production. In embodiments, the first cooling unit comprises an evaporator and a super-heater for steam production. In embodiments, the first cooling unit comprises an evaporator and a super-heater for steam production and the second cooling unit comprises an evaporator and a super-heater for steam production. In embodiments, the first cooling unit comprises an evaporator and a superheater for steam production and the second cooling unit comprises an evaporator and an economizer for steam production.

[0064] In embodiments wherein the heat that is released in the first and/or second cooling units is used to produce steam, the energy efficiency of the whole methanation system is optimized, as the necessary cooling is used to produce steam that can be used for other purposes. In preferred embodiments, the steam, in particular the super-heated steam, is used at least partially to feed the gasifier of the methanation system, in particular a fluidized bed and/or a plasma system of the gasifier.

[0065] In a preferred embodiment, the second cooling unit comprises a condenser, suitable to separate at least partially water from the crude methane leaving the methanation unit. In embodiments, the second cooling unit comprises a condensing economizer or a condensing evaporator. In embodiments, the separated water is fed back into the methanation system as cooling liquid or heat transfer medium and transformed into steam by passing through the economizer, the evaporator and/or the super-heater. In embodiments, the water outlet of the condenser is fluidly connected with the heat transfer medium inlet of the second cooling unit and/or of the first cooling unit. The water outlet of the condenser collects the water that is separated from the crude methane. In particular embodiments, the separated water is fed into the condenser as cooling liquid or heat transfer medium and transformed into steam by passing through the economizer, the evaporator and/or the super-heater. In particular embodiments, the water outlet of the condenser is fluidly connected with the inlet of the heat transfer medium of said condenser.

[0066] Preferably the second cooling unit of the methanation system described herein comprises one or more of said economizer, evaporator and super-heater, more preferably an economizer and an evaporator. Preferably, the first cooling unit of the methanation system described herein comprises one or more of said economizer, evaporator and super-heater, more preferably an evaporator and a super-heater. An additional water cooler may be placed to cool the separated water that leaves the second cooling unit before entering the second cooling unit as cooling liquid. Hence, the methanation system as described herein may further comprise a cooler that is positioned between the water outlet of the condenser and the inlet of the heat transfer medium of the second cooling unit and/or the first cooling unit, or between the water outlet of the condenser and the inlet of the heat transfer medium of the condensor.

[0067] In a preferred embodiment, a steam drum is placed between the super-heater and the one or more evaporators.

[0068] In a preferred embodiment of the methanation system is the gasifier a gasifier according to an embodiment of the first aspect of the invention.

[0069] In some embodiments, the following features of the methanation unit can be arranged from downstream to upstream, downstream and upstream being defined by the gas flow thought the methanation system: a fluidized reactor bed of the gasifier (9); at least one plasma system (8); optionally a filter of the gasifier (17); a first evaporator (29); a super-heater (18); a fluidized bed methanator(21); optionally a filter of the methanation unit (31); a second evaporator (28); a condenser (24).

[0070] The advantage of the methanation system described herein is its high energy efficiency as described elsewhere herein. A further advantage is that steam is consumed during the gasification of carbonaceous material in the gasifier, but water vapor/steam is generated during the methanation step in the methanation unit, resulting in a system wherein only little amount of water need to be added to the methanation system to maintain the water quantity in the system.

[0071] In the processes described herein, crude syngas that is generated during the gasification of carbonaceous material in the fluidized bed and/or by plasma gasification of carbonaceous material, passes through a region that is heated by at least one plasma torch. Passing through this region with elevated temperature, will cause thermal cracking of tar components in the raw syngas and further gasification of any residual carbonaceous material. This results in a higher efficiency in syngas production and in a cleaner syngas that is about to leave the gasifier.

[0072] The plasma system used in the process may be a microwave induced plasma system as described elsewhere herein.

[0073] In further embodiments, the (partially) polished syngas produced in step d) is passed through a filter before being drained from the gasifier to further polish the syngas. Preferably is said filter a catalytic filter as described elsewhere herein.

[0074] Preferably, the gasifier used in the process for the gasification of carbonaceous material as taught herein is a gasifier as described above.

[0075] The invention relates to a process for the conversion of a carbonaceous material into methane gas, comprising the steps of:

a) feeding carbonaceous material to a gasifier (1) via a carbonaceous material inlet (2) of said gasifier (1);
b) passing said carbonaceous material through a zone heated by at least one plasma system (8), thereby partially gasifying said carbonaceous material into a crude syngas before entering the fluidized bed (9);
c) gasifying said carbonaceous material in a fluidized bed comprising catalytic particles (9) inside said gasifier (1), thereby producing a crude syngas;
d) passing the crude syngas produced in steps b) and c) through a zone heated by at least one plasma system (8) to polish the crude syngas at least partially;
e) optionally passing the at least partially polished syngas obtained in step d) through a filter to further polish the syngas;
f) draining the polished syngas produced in steps d) and e) from the gasifier (1) via a gas outlet (16);
g) converting the polished syngas at least partially into crude methane in a methanation unit (21), preferably a fluidized bed methanator,

wherein the polished syngas that is drained from the gasifier (1) is passed through a first cooling unit and wherein the crude methane that is leaving the methanation unit (21) is passed through a second cooling, wherein said first cooling unit and said second cooling unit independently comprise an economizer, an evaporator and/or a super-heater for steam production for the gasifier (1).

EXAMPLES

Example 1

[0076] Figure 1 shows a gasifier 1 suitable for use in the invention. Carbonaceous material enters the gasifier 1 via the carbonaceous material inlets 2. Conduits 3 connect the carbonaceous material inlets 2 with the internal volume 4 of the gasifier. The internal volume 4 i is subdivided into an upper section 5, a middle section 6 and a lower section 7. The upper section 5 is connected to the middle section 6 by a first connecting section 10. The middle section 6 is connected to the lower section 7 by a second connecting section 11. The diameter of the upper section 5 is larger than the diameter of the middle section 6 and the diameter of middle section 6 is larger than the diameter of the lower section 7. Plasma systems 8 are configured in the upper section 5. In this example the carbonaceous material inlets 2 are placed above the plasma flames, but alternatively, the carbonaceous material inlets 2 can be placed at the same level of the plasma flames or below the plasma flames. The fluidized catalytic bed 9 is housed in the middle section 6 and the second connecting section 11. Steam is supplied via the primary steam inlet 12 to the bed 9. Oxygen rich gas is supplied to the fluidized bed 9 via the secondary gas inlet 13. This oxygen rich gas regulates the temperature of the fluidized bed, as this allows part of the carbonaceous material to burn and release heat. Plasma gasses, such as steam, are supplied via plasma gas inlets 14. Char can be collected in the lower section 7, and can be removed via char outlet 15. The syngas outlet 16 is covered by catalytic candle filters 17.

Example 2

[0077] In an alternative example, the carbonaceous material inlets 2 are placed in the proximity of the plasma system 8 to ensure that the carbonaceous material that enters the upper section 5 is heated by the plasma flame so that the carbonaceous material is at least partially gasified before entering the bed 9. A schematic view of this gasifier is shown in Figure 2.

Example 3

[0078] Figure 3 shows a schematic view of a methanation system 36 according to an embodiment of the invention. Syngas produced in the gasifier 1 of example 1 leaves the gasifier 1 trough syngas outlet 16, the temperature of the syngas is about 800 °C at this point, the hot syngas is passing through a first cooling unit comprising a first evaporator 29, reducing the temperature of the syngas to about 500 °C, and a super-heater 18, wherein the temperature of the syngas is further lowered to about 350°C when the syngas leaves the first cooling unit by the cold gas outlet 20. This syngas is then entered into the methanation unit 21 via the syngas inlet 22, where it enters a fluidized bed 33, which comprises a nickel catalyst. The syngas is converted into methane and water in an exothermic reaction. Cooling facilities are foreseen in the wall holding the fluidized bed 33. The solid particles of the fluidized bed can be removed via the solids outlet 30 at the bottom of the methanation unit. A filter 31 is covering the crude methane outlet 23 of the methanation unit 21. The methanation unit itself has an upper section 32, a middle section 33 and a lower section 34, wherein the diameter of the upper section 32 is larger than the diameter of the middle section 33 and the diameter of the middle section 33 is larger than the diameter of the lower section 34. The crude, wet methane is leaving the methanation unit 21 via crude methane outlet 23 at a temperature of around 400°C and is passed through a second cooling unit comprising a second evaporator 28, that cools down the wet methane to about 100°C, and a condenser 24, which separates the water from the methane. The dry methane is leaving the second cooling unit via the cold methane outlet 26.

[0079] The water that is separated from the methane in the condensor 24 undergoes an extra cooling step and is fed back into the condensor 24, but as cooling liquid. The condenser 24 functions as an economizer for the water, heating up the water to about 90°C. This water is then fed into the second evaporator 28, where it is converted into saturated vapor. This saturated vapor is lead to a steam drum 35, where the liquid is separated from the vapor phase. The liquid enters into the first evaporator 29, and is further converted into vapor, that is fed back into the steam drum 35. The vapor phase in the steam drum 35 is fed into the super-heater 18, where the temperature of the water vapor is raised to about 400°C and the water vapor is turned into steam. This steam is fed into the gasifier 1, as primary gas to create the fluidized bed via gas inlet 12, and/or as plasma gas via plasma gas inlet 14.

Claims

1. Methanation system (36) for the conversion of carbonaceous material into methane, comprising:

    - a gasifier (1) for gasifying carbonaceous material into syngas, said gasifier being at least partially steam fed and comprising:

        - an internal volume (4) comprising an upper section (5), a middle section (6) and a lower section (7), and optionally a first connecting section (10), connecting said upper section (5) and said middle section (6) and optionally a second connecting section (11), connecting said middle section (6) and said lower section (7), wherein said upper section (5), middle section (6) and lower section (7) are arranged along the longitudinal direction of said gasifier (1), with the upper section (5) placed on top of the middle section (6) which is placed on top of the lower section (7);

- one or more carbonaceous material inlets (2) configured to receive a carbonaceous material feed and fluidly connected to the internal volume (4);

- a bed material (9) comprising catalytic particles, inside the middle section (6) and/or lower section (7) and connected to at least one gas inlet (12) to fluidize the bed material;

- a gas outlet (16), fluidly connected to the upper section (5) of the internal volume (4); and

- at least one plasma system (8) configured inside the upper section (5) so that gas that leaves the gasifier (1) via the gas outlet (16) passes through a zone heated by said at least one plasma system (8);

- a first cooling unit (18, 29), comprising a hot gas inlet (19) and a cold gas outlet (20), wherein said hot gas inlet (19) is fluidly connected to the gas outlet (16) of said gasifier (1);

- a methanation unit (21), suitable to produce crude methane from syngas, comprising a syngas inlet (22) and a crude methane outlet (23), wherein said syngas inlet (22) is fluidly connected to said cold gas outlet (20) of the first cooling unit (18);

- a second cooling unit (24,28), comprising a hot methane inlet (25) and a cold methane outlet (26), wherein said hot methane inlet (25) is fluidly connected to said crude methane outlet (23) of the methanation unit (21);

wherein said first cooling unit and said second cooling unit independently comprise an economizer, an evaporator and/or a super-heater for steam production for the gasifier.

2. Methanation system (36) according to claim 1, wherein the at least one plasma system (8) of the gasifier (1) is a microwave-induced plasma system.

3. Methanation system (36) according to any one of claims 1 or 2, wherein at least one filter (17), preferably a catalytic filter, more preferably a filter comprising a nickel-based or an iron-based catalyst, at least partially covers the gas outlet (16) of the gasifier (1), preferably wherein said at least one filter (17) is configured inside the internal volume (4) of the gasifier (1).

4. Methanation system (36) according to any one of claims 1 to 3, wherein the bed material (9) of the gasifier (1) comprises particles comprising a nickel based catalyst or iron based catalyst.

5. Methanation system (36) according to any one of claims 1 to 4, wherein the lower section (7) of the internal volume (4) of the gasifier (1) has a smaller cross-section than the middle section (6), and wherein the middle section (6) has a smaller cross-section than the upper section (5).

6. Methanation system (36) according to any one of claims 1 to 5, wherein said methanation unit (21) is a fluidized bed methanator.

7. Methanation system (36) according to any one of claims 1 to 6, wherein the second cooling unit comprises an economizer (24) and an evaporator (28) for steam production and/or wherein the first cooling unit comprises an evaporator (29) and a super-heater (18) for steam production.

8. Methanation system (36) according to any one of claims 1 to 7, wherein the second cooling unit comprises a condenser (24) for separating at least partially water from the crude methane.

9. Methanation system (36) according to claim 8, wherein said water that is separated from the crude methane is fed back into the condenser (24) as cooling liquid and at least partially converted into steam via passing through said first cooling unit and said second cooling unit.

10. Methanation system (36) according to claim 9, further comprising a cooler for cooling the water that is separated from the crude methane by the condenser (24) before said water is fed back into the condenser (24) as cooling liquid.

11. Process for converting carbonaceous material into methane, comprising the steps of:

a) feeding carbonaceous material to a gasifier (1) via a carbonaceous material inlet (2) of said gasifier (1);

b) gasifying said carbonaceous material in a fluidized bed (9) comprising catalytic particles inside said gasifier (1), thereby producing a crude syngas;

c) passing the crude syngas produced in step b) through a zone heated by at least one plasma system (8) to polish the crude syngas at least partially;

d) optionally passing the at least partially pol-

ished syngas through a filter to further polish the syngas;
e) draining the polished syngas produced in step c) and optionally in step d) from the gasifier (1) via a gas outlet (16);
f) converting the polished syngas at least partially into crude methane in a methanation unit (21), preferably a fluidized bed methanator,

wherein the polished syngas that is drained from the gasifier (1) is passed through a first cooling unit and wherein the crude methane that is leaving the methanation unit (21) is passed through a second cooling unit, wherein said first cooling unit and said second cooling unit independently comprise an economizer, an evaporator and/or a super-heater for steam production for the gasifier (1).

12. Process according to claim 10, wherein said process is carried out in a methanation system (36) according to any one of claims 1 to 10.

13. Process according to any one of claims 11 or 12, further comprising the step:
g) at least partially removing water from the crude methane obtained in step f).

14. Process according to claim 13, wherein the water that is removed in step g) is fed back in the methanation system (36) as cooling liquid and converted into steam via passing through said first and second cooling units.

15. Process according to claim 14, wherein the water removed in step g) is further subjected to an extra cooling step before it is fed back into the methanation system (36).

Patentansprüche

1. Methanisierungssystem (36) zur Konvertierung von Kohlenstoffmaterial in Methan, umfassend:

- einen Vergaser (1) zum Vergasen von Kohlenstoffmaterial zu Syngas, wobei der Vergaser mindestens teilweise dampfgespeist ist und umfasst:

- ein Innenvolumen (4), umfassend einen oberen Abschnitt (5), einen mittleren Abschnitt (6) und einen unteren Abschnitt (7) und gegebenenfalls einen ersten Verbindungsabschnitt (10), der den oberen Abschnitt (5) und den mittleren Abschnitt (6) verbindet, und gegebenenfalls einen zweiten Verbindungsabschnitt (11), der den mittleren Abschnitt (6) und den unteren Abschnitt (7) verbindet, wobei der obere Abschnitt (5), der mittlere Abschnitt (6) und der untere Abschnitt (7) entlang der Längsrichtung des Vergasers (1) angeordnet sind, wobei der obere Abschnitt (5) über dem mittleren Abschnitt (6) platziert ist, der über dem unteren Abschnitt (7) platziert ist;
- einen oder mehrere Kohlenstoffmaterialeinlässe (2), die ausgestaltet sind, um eine Kohlenstoffmaterialeiinspeisung aufzunehmen, und die fließtechnisch mit dem Innenvolumen (4) verbunden sind;
- ein Bettenmaterial (9), das katalytische Partikel umfasst, in dem mittleren Abschnitt (6) und/oder dem unteren Abschnitt (7), und verbunden mit mindestens einem Gaseinlass (12), um das Bettenmaterial zu verwirbeln;
- einen Gasauslass (16), der fließtechnisch mit dem oberem Abschnitt (5) des Innenvolumens (4) verbunden ist; und
- mindestens ein Plasmasystem (8), das in dem oberen Abschnitt (5) ausgestaltet ist, so dass Gas, welches den Vergaser (1) über den Gasauslass (16) verlässt, eine Zone passiert, die durch das mindestens eine Plasmasystem (8) geheizt wird;

- eine erste Kühleinheit (18, 29), die einen Heißgaseinlass (19) und einen Kaltgasauslass (20) umfasst, wobei der Heißgaseinlass (19) fließtechnisch mit dem Gasauslass (16) des Vergasers (1) verbunden ist;
- eine Methanisierungseinheit (21), die geeignet ist, um Rohmethan aus Syngas zu produzieren, umfassend einen Syngaseinlass (22) und einen Rohmethanauslass (23), wobei der Syngaseinlass (22) fließtechnisch mit dem Kaltgasauslass (20) der ersten Kühleinheit (18) verbunden ist;
- eine zweite Kühleinheit (24, 28), die einen Heißmethaneinlass (25) und einen Kaltmethanauslass (26) umfasst, wobei der Heißmethaneinlass (25) fließtechnisch mit dem Rohmethanauslass (23) der Methanisierungseinheit (21) verbunden ist;

wobei die erste Kühleinheit und die zweite Kühleinheit unabhängig einen Vorwärmer, einen Verdampfer und/oder einen Überhitzer zur Dampfproduktion für den Vergaser umfassen.

2. Methanisierungssystem (36) nach Anspruch 1, wobei das mindestens eine Plasmasystem (8) des Vergasers (1) ein mikrowelleninduziertes Plasmasystem ist.

3. Methanisierungssystem (36) nach einem der Ansprüche 1 oder 2, wobei mindestens ein Filter (17), vorzugsweise ein katalytischer Filter, bevorzugter ein Filter, der einen auf Nickel basierenden oder auf Eisen basierenden Katalysator umfasst, mindestens teilweise den Gasauslass (16) des Vergasers (1) bedeckt, wobei vorzugsweise der mindestens eine Filter (17) in dem Innenvolumen (4) des Vergasers (1) ausgestaltet ist.

4. Methanisierungssystem (36) nach einem der Ansprüche 1 bis 3, wobei das Bettenmaterial (9) des Vergasers (1) Partikel umfasst, die einen auf Nickel basierenden oder auf Eisen basierenden Katalysator umfassen.

5. Methanisierungssystem (36) nach einem der Ansprüche 1 bis 4, wobei der untere Abschnitt (7) des Innenvolumens (4) des Vergasers (1) einen kleineren Querschnitt als der mittlere Abschnitt (6) hat, und wobei der mittlere Abschnitt (6) einen kleineren Querschnitt als der obere Abschnitt (5) hat.

6. Methanisierungssystem (36) nach einem der Ansprüche 1 bis 5, wobei die Methanisierungseinheit (21) ein Wirbelbettmethanisierer ist.

7. Methanisierungssystem (36) nach einem der Ansprüche 1 bis 6, wobei die zweite Kühleinheit einen Vorwärmer (24) und einen Verdampfer (28) zur Dampfproduktion umfasst, und/oder wobei die erste Kühleinheit einen Verdampfer (29) und einen Überhitzer (18) zur Dampfproduktion umfasst.

8. Methanisierungssystem (36) nach einem der Ansprüche 1 bis 7, wobei die zweite Kühleinheit einen Kondensierer (24) zum mindestens teilweisen Trennen von Wasser von dem Rohmethan umfasst.

9. Methanisierungssystem (36) nach Anspruch 8, wobei das Wasser, welches von dem Rohmethan getrennt wird, als Kühlflüssigkeit zurück in den Kondensierer (24) gespeist wird und mindestens teilweise in Dampf umgewandelt wird, indem es die erste Kühleinheit und die zweite Kühleinheit passiert.

10. Methanisierungssystem (36) nach Anspruch 9, ferner umfassend einen Kühler zum Kühlen des Wassers, das durch den Kondensierer (24) von dem Rohmethan getrennt wird, bevor das Wasser als Kühlflüssigkeit zurück in den Kondensierer (24) gespeist wird.

11. Verfahren zum Konvertieren von Kohlenstoffmaterial in Methan, umfassend die Schritte:

a) Einspeisen von Kohlenstoffmaterial in einen Vergaser (1) über einen Kohlenstoffmaterialeinlass (2) des Vergasers (1);
b) Vergasen des Kohlenstoffmaterials in einem Wirbelbett (9), das katalytische Partikel umfasst, in dem Vergaser (1), wodurch ein rohes Syngas produziert wird;
c) Passieren des in Schritt b) produzierten rohen Syngases durch eine Zone, die durch mindestens ein Plasmasystem (8) erhitzt wird, um das rohe Syngas mindestens teilweise zu reinigen;
d) gegebenenfalls Passieren des mindestens teilweise gereinigten Syngases durch einen Filter, um das Syngas weiter zu reinigen;
e) Ablassen des in Schritt c) und gegebenenfalls Schritt d) produzierten gereinigten Syngases aus dem Vergaser (1) über einen Gasauslass (16);
f) Konvertieren des gereinigten Syngases mindestens teilweise in Rohmethan in einer Methanisierungseinheit (21), vorzugsweise einem Wirbelbettmethanisierer,

wobei das gereinigte Syngas, welches aus dem Vergaser (1) abgelassen wird, eine erste Kühleinheit passiert, und wobei das Rohmethan, das die Methanisierungseinheit (21) verlässt, eine zweite Kühleinheit passiert, wobei die erste Kühleinheit und die zweite Kühleinheit unabhängig einen Vorwärmer, einen Verdampfer und/oder einen Überhitzer zur Dampfproduktion für den Vergaser (1) umfassen.

12. Verfahren nach Anspruch 10, wobei das Verfahren in einem Methanisierungssystem (36) gemäß einem der Ansprüche 1 bis 10 durchgeführt wird.

13. Verfahren nach einem der Ansprüche 11 bis 12, ferner umfassend den Schritt:
g) mindestens teilweise Entfernen von Wasser aus dem in Schritt f) erhaltenen Rohmethan.

14. Verfahren nach Anspruch 13, wobei das Wasser, welches in Schritt g) entfernt wird, als Kühlflüssigkeit in das Methanisierungssystem (36) rückgespeist wird und in Dampf konvertiert wird, indem es die erste und zweite Kühleinheit passiert.

15. Verfahren nach Anspruch 14, wobei das in Schritt g) entfernte Wasser ferner einem zusätzlichen Kühlschritt unterzogen wird, bevor es in das Methanisierungssystem (36) rückgespeist wird.

Revendications

1. Système de méthanation (36) pour la conversion de matière carbonée en méthane, comprenant:

- un gazogène (1) pour gazéifier de la matière carbonée en gaz de synthèse, ledit gazogène étant au moins partiellement alimenté en vapeur d'eau et comprenant:

- un volume interne (4) comprenant une section supérieure (5), une section centrale (6) et une section inférieure (7), et éventuellement une première section de raccordement (10), raccordant ladite section supérieure (5) et ladite section centrale (6), et éventuellement une deuxième section de raccordement (11), raccordant ladite section centrale (6) et ladite section inférieure (7), lesdites section supérieure (5), section centrale (6) et section inférieure (7) étant disposées le long de la direction longitudinale dudit gazogène (1) avec la section supérieure (5) placée au-dessus de la section centrale (6) qui est placée au-dessus de la section inférieure (7);
- une ou plusieurs entrées de matière carbonée (2) configurées pour recevoir une charge de matière carbonée et raccordées fluidiquement au volume interne (4);
- un matériau de lit (9) comprenant des particules catalytiques, à l'intérieur de la section centrale (6) et/ou de la section inférieure (7), et raccordé à au moins une entrée de gaz (12) pour fluidifier le matériau de lit;
- une sortie de gaz (16), raccordée fluidiquement à la section supérieure (5) du volume interne (4); et
- au moins un système de plasma (8) configuré à l'intérieur de la section supérieure (5) de telle sorte que le gaz qui quitte le gazogène (1) par la sortie de gaz (16) passe à travers une zone chauffée par ledit au moins un système de plasma (8);

- une première unité de refroidissement (18, 29), comprenant une entrée de gaz chaud (19) et une sortie de gaz froid (20), ladite entrée de gaz chaud (19) étant raccordée fluidiquement à la sortie de gaz (16) dudit gazogène (1);
- une unité de méthanation (21), appropriée pour produire du méthane brut à partir de gaz de synthèse, comprenant une entrée de gaz de synthèse (22) et une sortie de méthane brut (23), ladite entrée de gaz de synthèse (22) étant raccordée fluidiquement à ladite sortie de gaz froid (20) de la première unité de refroidissement (18);
- une deuxième unité de refroidissement (24, 28), comprenant une entrée de méthane chaud (25) et une sortie de méthane froid (26), ladite entrée de méthane chaud (25) étant raccordée fluidiquement à ladite sortie de méthane brut (23) de l'unité de méthanation (21);

dans lequel ladite première unité de refroidissement et ladite deuxième unité de refroidissement comprennent indépendamment un économiseur, un évaporateur et/ou un surchauffeur pour la production de vapeur d'eau pour le gazogène.

2. Système de méthanation (36) selon la revendication 1, dans lequel l'au moins un système de plasma (8) du gazogène (1) est un système de plasma induit par micro-ondes.

3. Système de méthanation (36) selon l'une quelconque des revendications 1 et 2, dans lequel au moins un filtre (17), de préférence un filtre catalytique, mieux un filtre comprenant un catalyseur à base de nickel ou à base de fer, recouvre au moins partiellement la sortie de gaz (16) du gazogène (1), de préférence dans lequel ledit au moins un filtre (17) est configuré à l'intérieur du volume interne (4) du gazogène (1).

4. Système de méthanation (36) selon l'une quelconque des revendications 1 à 3, dans lequel le matériau de lit (9) du gazogène (1) comprend des particules comprenant un catalyseur à base de nickel ou un catalyseur à base de fer.

5. Système de méthanation (36) selon l'une quelconque des revendications 1 à 4, dans lequel la section inférieure (7) du volume interne (4) du gazogène (1) a une plus petite section transversale que la section centrale (6), et dans lequel la section centrale (6) a une plus petite section transversale que la section supérieure (5).

6. Système de méthanation (36) selon l'une quelconque des revendications 1 à 5, dans lequel ladite unité de méthanation (21) est un réacteur de méthanation à lit fluidisé.

7. Système de méthanation (36) selon l'une quelconque des revendications 1 à 6, dans lequel la deuxième unité de refroidissement comprend un économiseur (24) et un évaporateur (28) pour la production de vapeur d'eau et/ou dans lequel la première unité de refroidissement comprend un évaporateur (29) et un surchauffeur (18) pour la production de vapeur d'eau.

8. Système de méthanation (36) selon l'une quelconque des revendications 1 à 7, dans lequel la deuxième unité de refroidissement comprend un condenseur (24) pour séparer au moins partiellement l'eau du méthane brut.

9. Système de méthanation (36) selon la revendication 8, dans lequel ladite eau qui est séparée du méthane brut est réintroduite dans le condenseur (24) comme liquide de refroidissement et au moins partiellement transformée en vapeur d'eau par passage à travers ladite première unité de refroidissement et ladite deuxième unité de refroidissement.

10. Système de méthanation (36) selon la revendication 9, comprenant en outre un refroidisseur pour refroidir l'eau qui est séparée du méthane brut par le condenseur (24) avant que ladite eau soit réintroduite dans le condenseur (24) comme liquide de refroidissement.

11. Procédé de conversion de matière carbonée en méthane, comprenant les étapes consistant à:

a) introduire de la matière carbonée dans un gazogène (1) par une entrée de matière carbonée (2) dudit gazogène (1);
b) gazéifier ladite matière carbonée dans un lit fluidisé (9) comprenant des particules catalytiques à l'intérieur dudit gazogène (1), pour produire ainsi un gaz de synthèse brut;
c) faire passer le gaz de synthèse brut produit à l'étape b) à travers une zone chauffée par au moins un système de plasma (8) pour purifier au moins partiellement le gaz de synthèse brut;
d) éventuellement, faire passer le gaz de synthèse au moins partiellement purifié à travers un filtre pour purifier encore le gaz de synthèse;
e) évacuer le gaz de synthèse purifié produit à l'étape c) et éventuellement à l'étape d) du gazogène (1) par une sortie de gaz (16);
f) convertir au moins partiellement le gaz de synthèse purifié en méthane brut dans une unité de méthanation (21), de préférence un réacteur de méthanation à lit fluidisé,

dans lequel le gaz de synthèse purifié qui est évacué du gazogène (1) est passé à travers une première unité de refroidissement et dans lequel le méthane brut qui quitte l'unité de méthanation (21) est passé à travers un deuxième unité de refroidissement, ladite première unité de refroidissement et ladite deuxième unité de refroidissement comprenant indépendamment un économiseur, un évaporateur et/ou un surchauffeur pour la production de vapeur d'eau pour le gazogène (1).

12. Procédé selon la revendication 10, ledit procédé étant réalisé dans un système de méthanation (36) selon l'une quelconque des revendications 1 à 10.

13. Procédé selon l'une quelconque des revendications 11 et 12, comprenant en outre l'étape suivante:
g) retirer au moins partiellement l'eau du méthane brut obtenu à l'étape f).

14. Procédé selon la revendication 13, dans lequel l'eau qui est retirée à l'étape g) est réintroduite dans le système de méthanation (36) comme liquide de refroidissement et transformée en vapeur d'eau par passage à travers lesdites première et deuxième unités de refroidissement.

15. Procédé selon la revendication 14, dans lequel l'eau retirée à l'étape g) est en outre soumise à une étape de refroidissement supplémentaire avant d'être réintroduite dans le système de méthanation (36).

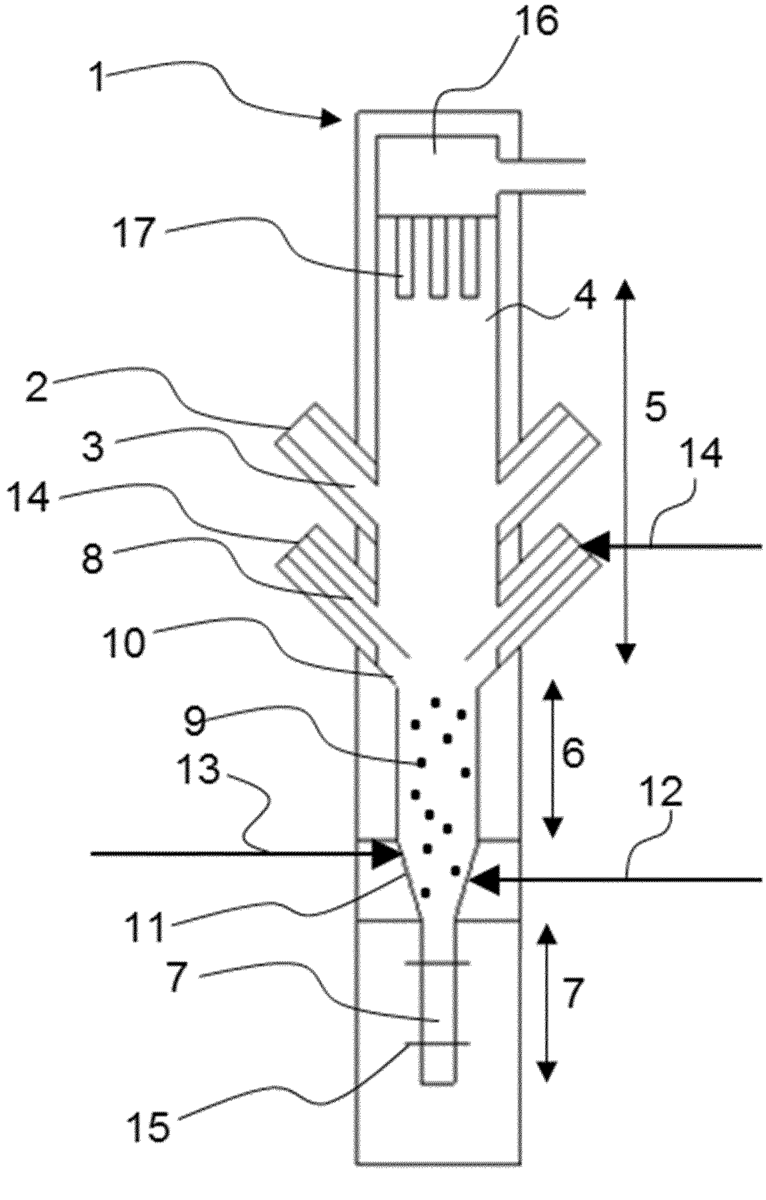

FIG. 1

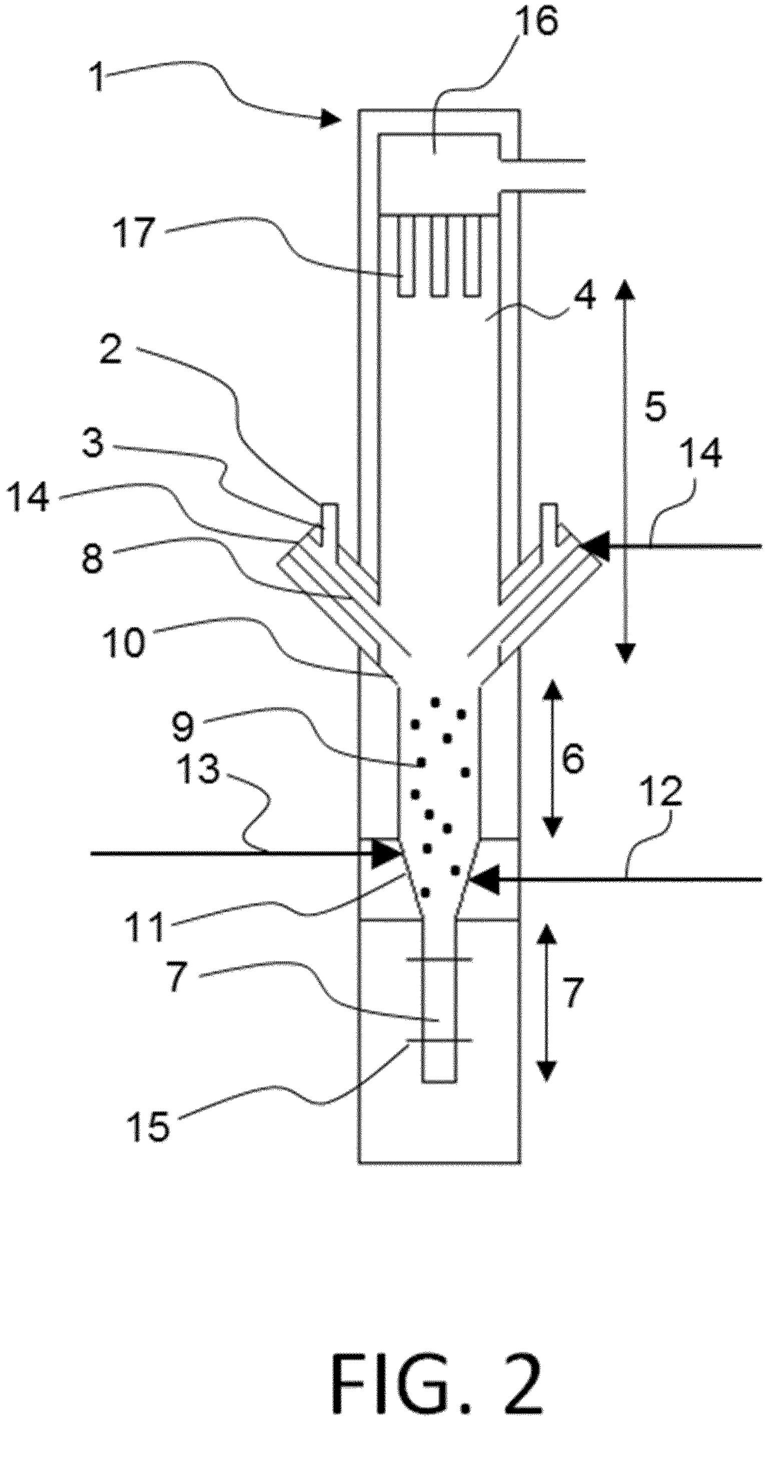

FIG. 2

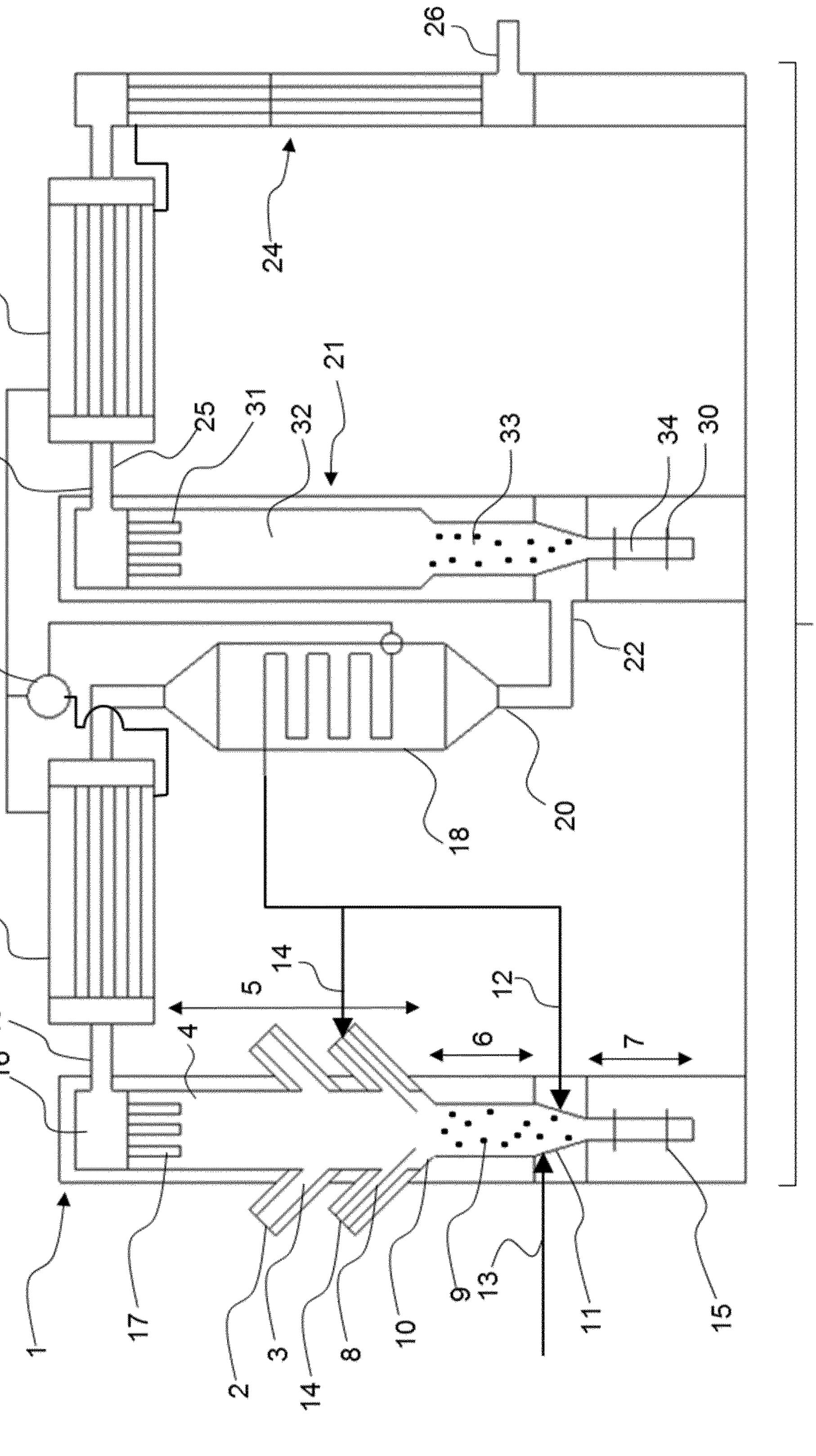
1
2
3
4
5
6
7
8
9
10
11
12
13
14
14
15
16
17
18
19
20
21
22
23
24
25
26
28
29
30
31
32
33
34
35
36

FIG. 3

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- WO 2014126895 A **[0005]**