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[Continued on next page]

(54) Title: PROCESS FOR THE FIXED-BED PRESSURE GASIFICATION OF CARBONACEOUS FUELS

(57) Abstract: A process for producing a synthesis gas containing hydrogen and carbon oxides by gasification of coke or coal with oxygen and steam in a fixed bed carried by a discharge grate and by producing an ash in a fixed-bed pressure gasification reactor, wherein liquid, hydrocarbonaceous by-products of the gasification, such as tars, oils, naphtha and phenols, are introduced into the fixed bed of the fixed- bed pressure gasification reactor.

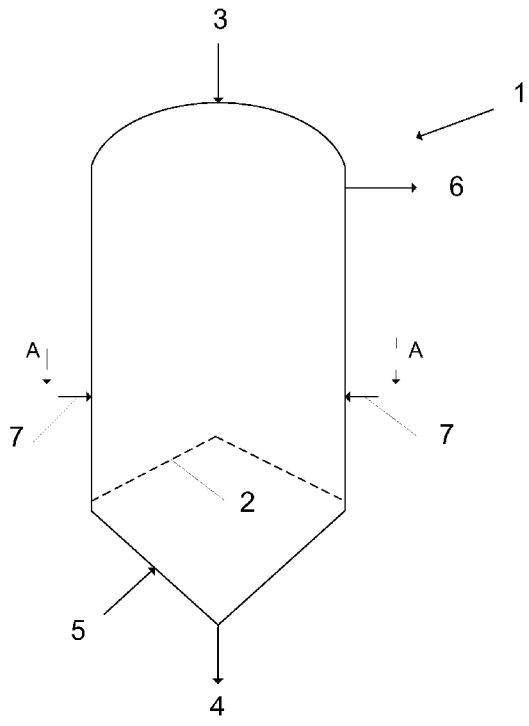


Fig. 1

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DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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Process for the Fixed-Bed Pressure Gasification of Carbonaceous Fuels

Field of the Invention

This invention relates to a process for producing a synthesis gas containing hydrogen and carbon oxides by gasification of carbonaceous fuels, in particular of coke or coal, with oxygen and steam in a fixed bed carried by a discharge grate and by producing a solid ash in a fixed-bed pressure gasification reactor, wherein the carbonaceous by-products obtained during the further processing of the raw synthesis gas discharged from the fixed-bed pressure gasification reactor, such as tars, oils, naphtha or phenols, can be utilized advantageously.

Prior art

By means of fixed-bed pressure gasification reactors solid fuel, such as coal, coke or other carbonaceous fuel, is gasified with steam and oxygen as gasification medium at elevated temperature and, in most cases, at overpressure to obtain a synthesis gas containing carbon monoxide and hydrogen, wherein a solid ash is obtained, which is discharged from the reactor via an ash discharge grate which in many cases is formed as rotary grate. This type of reactor frequently also is referred to as FBDB (= Fixed Bed Dry Bottom) pressure gasifier.

In the fixed bed, the fuel passes through the following temperature zones from top to bottom with a temperature rising in this direction:

- Drying zone: In the drying zone, moisture bound in or on the fuel is desorbed and discharged from the fixed-bed pressure gasification reactor with the raw synthesis gas stream.
- Pyrolysis zone: Here, highly volatile compounds are released from the fuel and expelled. There is effected a carbonization or coking of the fuel.
- Gasification zone: In the gasification zone the actual conversion of the fuel with the gasification medium is effected, which mostly contains air or oxygen as well as steam and possibly carbon dioxide as moderator, to obtain the target products of the gasification, namely hydrogen and carbon monoxide.
- Combustion zone: Here, the thermal energy necessary for the gasification, pyrolysis and drying is produced by combustion of a part of the fuel.

For further process details reference is made to the relevant literature, cf. Ullmanns Encyclopedia of Industrial Chemistry,Sixth Edition, Vol. 15, pages 367 ff. The gasification typically starts at temperatures of about 700 °C and proceeds with high speed at temperatures of 800 °C, cf. Ullmanns Encyklopädie der Technischen Chemie, 4th Edition (1977), Vol. 14, p. 384. Fig. 10 of this reference shows a typical temperature profile of the gas temperature in a fixed-bed pressure gasification reactor, in particular in the temperature zones discussed above.

Beside the target products carbon monoxide and hydrogen, the raw synthesis gas after leaving the reactor however also contains by-products obtained during the gasification, such as tars, oils, naphtha as well as phenols, which all contain hydrocarbons or consist of hydrocarbons and at ambient conditions are present in liquid form or during processing of the raw synthesis gas are obtained in liquid form, in a form dissolved in liquid or in a form dispersed in liquid (for example as emulsion in water). All of these by-products subsequently are to be understood as liquid by-products.

In addition, the raw gas contains dust entrained from the fixed bed, consisting of fuel and ash particles, and also ammonia which likewise is separated in the course of the processing of the raw synthesis gas and is obtained as valuable

substance, cf. Ullmanns Encyclopedia of Industrial Chemistry, Sixth Edition, Vol. 15, page 437, Fig. 75.

In particular in smaller gasification plants it is not always economic to process the liquid by-products into a saleable state, for example with increased purity and/or liberated from solid particles. In these cases, the by-products must be disposed of properly, whereby disposal costs are incurred.

DE-OS 2607745 presents a process in which the dust-containing tars separated from the gas condensate are disposed of by recirculating them into the fixed-bed pressure gasification reactor. In this process it is disadvantageous that the recirculated mass merely is charged onto the surface of the fixed bed of the reactor. The tars contained in the mass in this way are evaporated before they reach the gasification zone of the fixed bed. The evaporated tars are discharged from the fixed-bed pressure gasification reactor with the raw synthesis gas and again washed out from the gas condensate, so that they merely are circulated between reactor and gas scrubber.

The document DE 19509570 A1 teaches a process for the pyrolysis and fixed-bed pressure gasification of carbonaceous substances. Among other things, a tar-oil-solids-water mixture is applied there onto the surface of the fuel bed by means of lances. A part of the applied substances is pyrolyzed, but a significant amount in turn is discharged from the fixed-bed pressure gasification reactor with the raw synthesis gas.

The document DE 102013202356 A1 teaches a process and an apparatus for the fixed-bed pressure gasification of solid fuels with increased performance and a widened usage spectrum of solid fuels. It is disclosed there that powdery fuels as secondary fuels are formed to a fuel strand by means of a briquetting press and subsequently are pressed into the fixed-bed pressure gasification reactor. A tar-oil-solids mixture obtained during the fixed-bed pressure gasification serves as agglomeration aid. Since the addition of the formed secondary fuel is effected into

the drying and pyrolysis zone of the fixed-bed pressure gasification reactor, the above-described disadvantages of the discharge of volatile constituents with the raw synthesis gas exist again.

Therefore, it is the object of the invention to provide a process which is capable of recirculating the by-products into the fixed-bed pressure gasification reactor such that they are converted there into synthesis gas.

Description of the Invention

The object is solved by a process for the gasification of solid carbonaceous fuels, in particular of coke or coal, with gasification media in a fixed-bed pressure gasification reactor, comprising a gasification medium inlet, a product gas outlet, a fuel bed of solid carbonaceous fuel arranged on an ash discharge grate, a fuel supply device, an ash discharge device; wherein a raw synthesis gas containing hydrogen and carbon oxides is obtained, discharged from the fixed-bed pressure gasification reactor through the product gas outlet and subsequently processed to a pure synthesis gas, characterized in that carbonaceous by-products (liquid by-products) of the gasification, such as tars, oils, naphtha and phenols, which during processing of the raw synthesis gas are obtained in liquid form, in a form dissolved in liquid or in a form dispersed in liquid, are introduced into the gasification zone and/or the combustion zone of the fixed-bed pressure gasification reactor and likewise at least partly converted to hydrogen and/or carbon oxides.

Further advantageous aspects of the process according to the invention can be found in sub-claims 2 to 13.

As carbonaceous fuels coke and coal are preferred due to their favorable combustion and gasification properties. The process according to the invention however also comprises the gasification of biomass with sufficiently high carbon content, when the same can form a mechanically and hydrodynamically stable fuel bed under gasification conditions. As during the conversion of the latter

particularly high amounts of liquid by-products are obtained, the application of the process according to the invention here offers particular advantages.

As gasification medium oxygen or air, preferably in conjunction with steam or carbon dioxide, is used as moderator.

As ash discharge grate, a rotary grate can be used for example. The construction and use of this apparatus is known per se to the skilled person. With regard to the temperature control in the fixed-bed pressure gasification reactor, the thermal design limits for rotary grates are to be taken into account. Admissible maximum temperatures for rotary grates lie in the range from 300 to 400 °C. This also limits the inlet temperature of the gasification medium which is added via a gasification medium inlet arranged below the rotary grate, so that the gasification medium passes the rotary grate before it gets into the fuel bed.

The processing of the raw synthesis gas to a pure synthesis gas is known per se and described in the relevant literature, cf. Ullmanns Encyklopädie der Technischen Chemie, 4th Edition (1977), Vol. 14, p. 449 ff. Liquid by-products obtained thereby in particular include tar fractions, hydrocarbon fractions, e.g. naphtha, phenol-containing liquids and oil fractions. The oil fractions in part consist of tramp oils which are utilized as processing aids and for example serve for lowering the viscosity and improving the filterability of tar fractions.

As explained already in the discussion of the prior art, by-products obtained during the gasification, which contain hydrocarbons or consist of hydrocarbons and at ambient conditions are present in liquid form or during processing of the raw synthesis gas are obtained in liquid form, in a form dissolved in liquid or in a form dispersed in liquid (for example as emulsion in water), subsequently are to be understood as liquid by-products.

The transition between the above-discussed temperature zones of the fixed-bed pressure gasification reactor of course is fluent. These zones are not to be

regarded as discrete regions with sharp transitions to the adjacent zones, but rather are defined idealized. For the definition of the gasification zone it is decisive that in this zone a significant conversion of the fuel to synthesis gas constituents is effected, or the gasification reaction proceeds with sufficient speed of reaction. The location of this zone inside the fixed-bed pressure gasification reactor therefore of course is dependent on its geometry and other construction as well as on its operating parameters, such as the mass flow rates and inlet temperatures of gasification medium and fuel, the composition of the gasification medium, the ash discharge mass flow rate and the operating pressure. According to experience, however, at temperatures above 700 °C a noticeable and at temperatures above 800 °C a significant conversion of the fuel with the gasification medium to synthesis gas constituents is effected.

Preferred Aspects of the Invention

The process according to the invention preferably is carried out such that at least a part of the liquid by-products introduced into the fixed-bed pressure gasification reactor gets into a region in which the gas temperature is at least 700 °C, preferably at least 800 °C. As explained above, at temperatures above 700 °C a noticeable and at temperatures above 800 °C a significant conversion of the fuel with the gasification medium to synthesis gas constituents is achieved. This is achieved in that the liquid by-products are introduced into the fixed-bed pressure gasification reactor in the region of the gasification and/or combustion zone by pumping, injecting or spraying, wherein in the case of injecting or spraying a propellant gas is used. The introduction into the fixed-bed pressure gasification reactor by injecting or spraying in particular is suitable for liquid by-products with low viscosity under the conditions of addition. For injecting or spraying the liquid by-products a propellant gas advantageously is used, which with respect to the by-products and the reactions taking place in the gasification reactor can show an either inert or reactive behavior. As inert propellant gas, nitrogen can be used for example. It is, however, particularly advantageous when in the case of injecting or spraying a reactive propellant gas is used, for example the gasification medium or one or more of its constituents. The separate provision of propellant gas thereby

can be omitted, a further conversion to synthesis gas constituents is effected, and the product gas is not contaminated by extraneous propellant gas constituents.

When using a propellant gas, the liquid by-products can be delivered according to the principle of the propulsive jet pump, so that a further pump for delivering the liquid by-products possibly can be omitted.

When the viscosity allows, injecting or spraying of the liquid by-products advantageously is carried out such that they are atomized to a fine aerosol. In this way, a high penetration depth into the fixed bed of fuel and a high conversion to synthesis gas constituents are ensured.

Liquid by-products with a viscosity still high under the conditions of addition preferably are introduced into the fixed-bed pressure gasification reactor by pumping, wherein here as well the addition according to the invention is effected into the region of the gasification and/or combustion zone.

In a preferred aspect of the invention, injecting or spraying of the liquid by-products into the fixed-bed pressure gasification reactor is effected via at least one nozzle installed in the wall of the reactor and directed radially into the reactor space, wherein when several nozzles are used, the same preferably are distributed on the circumference of the reactor at equal distances from each other and preferably at the same height. Due to this symmetric arrangement of the nozzles a homogeneous distribution of the liquid by-products on the individual nozzles can be ensured. In terms of construction, the nozzles can correspond to the tuyères known from the blast-furnace process for pig iron production, cf. Ullmanns Encyclopedia of Industrial Chemistry, Sixth Edition, Vol. 18, page 493.

Another particular aspect of the invention consists in that the nozzle orifices terminate with the lining of the inner reactor wall, so that they do not protrude into the inner reactor space. In this way, the mechanical load of the nozzle orifice by the material of the fixed bed sinking down is reduced.

Another particular aspect of the invention consists in that carbon dioxide, steam, air or oxygen or arbitrary mixtures of these components are used as propellant gases. In the case of the addition of carbon dioxide or steam the gas rather serves as propellant, in the case of the addition of air or oxygen the propellant gas supports the oxidation and hence the gasification of the injected liquid by-products due to its oxygen content. It is advantageous that in all cases mentioned a further conversion of the propellant gas constituents can be effected in the gasification reactor or the propellant gas constituents anyway are present as components in the raw synthesis gas. The introduction of extraneous components into the process thus is avoided.

In a particularly preferred aspect of the invention, the nozzles are installed in the reactor wall at a vertical distance of 1.0 to 2.0 m, preferably 1.5 m above the highest point of the discharge grate at the same distance from each other on the circumference of the reactor. With a suitable setting and adjustment of the flow rates of fuel, oxygen and steam, the gasification zone of the fixed bed is located at this distance. The injected material thus gets into the gasification zone and together with the material of the fixed bed is converted to synthesis gas constituents. It was found to be particularly favorable when the jet direction of the nozzles is directed downwards at an angle deviating from the horizontal between 0 to 30°, preferably 0 to 20°, most preferably 0 to 10°. The residence time of the liquid by-products introduced into the fixed-bed pressure gasification reactor thereby is increased in the hot regions and their total path through the reactor is extended, which leads to an improved conversion of the liquid by-products to synthesis gas constituents. On the other hand, it thereby is avoided that the part of the fixed bed located above the nozzles is loosened up too much and that the nozzle jets possibly reach the ash layer and the grate.

Another particular aspect of the invention consists in that the nozzle exit velocity based on the amount of propellant gas exiting from the nozzle is between 50 and 150 m/s, preferably between 80 and 120 m/s. The volume of the injected liquid by-products is neglected in the calculation. In this velocity range a sufficient

penetration depth of the nozzle jet into the fixed bed is given, so that high residence times and conversions of the liquid by-products are achieved.

Another particularly preferred aspect of the invention consists in that the local temperature of the fixed bed on the inside of the reactor wall is determined by means of two rows of temperature sensors installed on the circumference of the reactor, wherein the temperature sensors within one row are spaced from each other at equal distances, wherein the vertical distance to the highest point of the discharge grate is 0.5 to 2.5 m, preferably 1.0 to 2.0 m, for the upper row, and the vertical distance to the highest point of the discharge grate is 0 to 0.5 m, preferably 0.25 m for the lower row, and wherein the quantity of the ash discharged via the discharge grate per unit time is adjusted such that a temperature between 700 and 1300 °C is measured by the upper row of temperature sensors, and a temperature between 300 and 400 °C is measured by the lower row. In this way, the vertical location of the gasification zone of the fixed bed is adjusted such that the nozzle jets reach the gasification zone and the result is a sufficient residence time of the introduced liquid by-products in the gasification zone. The large temperature ranges in both cases are due to the different properties of the possible fuels used. When the temperature of the upper sensor row lies in the stated range of 700 to 1300 °C, this shows that the gasification zone, as required, lies at the height of the nozzles.

When the temperature of the lower sensor row lies in the required range of 300 to 400 °C, it hence is ensured that a sufficiently thick ash zone lies above the discharge grate and the discharge grate thus is protected from too high temperatures.

When using a rotary grate, for example, the quantity of the ash discharged via the discharge grate per unit time can be controlled by the speed of revolution.

Another particular aspect of the invention provides that the intermixed liquid by-products are introduced into the fixed-bed pressure gasification reactor. In this

way, the viscosity of e.g. viscous, dust-laden tars is lowered by addition of oils, so that they become more flowable, whereby the wear of the nozzle orifices is reduced. It is, however, also possible to separately introduce different liquid by-products into the fixed-bed pressure gasification reactor via separate nozzles each. In this way, the wear can be limited to certain nozzles or the nozzles can optimally be designed corresponding to the liquid by-product to be introduced, for example by using particularly abrasion-resistant materials.

The by-products recirculated into the reactor according to the invention are liquid, although in part loaded with dust, so that they can be pumped to the nozzles by using displacement pumps, e.g. multi-head plunger or membrane pumps. Depending on the quality of the dust contained in the tar, it may be required to separate or comminute larger dust particles before introducing the tar. This can be done by using mechanical separation methods known per se from the fixed-bed gasification of coal in connection with the processing of tar products, e.g. the filtration, or by using comminution or homogenization methods.

Another particular aspect of the invention consists in that the inner wall of the reactor in the surroundings of the nozzle orifices is protected by panels, wherein the panels are made of ceramic material in which cooling elements made of metal, such as tubes, are contained, which are traversed by a cooling medium such as water. In this way, the inner wall of the reactor in the surroundings of the nozzle orifices is protected from too much exposure to heat. As a result of operating failures, such as a damage of the nozzle orifice, the nozzle jet can be deflected and come close to the reactor wall.

Exemplary Embodiments

Further developments, advantages and possible applications of the invention can also be taken from the following description of non-limiting exemplary embodiments and numerical examples as well as the drawings. All features described and/or illustrated form the invention per se or in any combination, independent of their inclusion in the claims or their back-reference.

In the drawings:

Fig. 1 shows a longitudinal section through a fixed-bed pressure gasification reactor with inlets for liquid by-products according to the invention,

Fig. 2 shows a cross-section through the fixed-bed pressure gasification reactor at the height of the inlets for the liquid by-products.

Fig. 1 by way of example shows how the inlets for liquid by-products are distributed on the circumference of the fixed-bed pressure gasification reactor 1 at the same height. Fuel, in the present example lump coal, is supplied to the fixed-bed pressure gasification reactor via the fuel addition 3. The ash obtained as by-product of the gasification is discharged from the fixed-bed pressure gasification reactor via the ash discharge device 6. The gasification medium, in the present example steam and air or oxygen, is introduced into the fixed-bed pressure gasification reactor below the ash discharge grate 2, which in the present example is designed as rotary grate, via the gasification medium inlet 5 after completion of the heating method. The raw synthesis gas produced thereby is discharged from the fixed-bed pressure gasification reactor via the product gas outlet 6 and supplied to the further processing.

Via the inlets 7 liquid by-products, in the present case a tar-oil-naphtha mixture, are introduced into the fixed bed of the fixed-bed pressure gasification reactor. The inlets are designed as nozzles and directed downwards at an angle deviating from the horizontal by 10°. The nozzles are installed in the reactor wall at a vertical distance of 1.5 m above the highest point of the rotary grate at the same distance from each other on the circumference of the reactor. The nozzle orifices terminate with the lining of the inner reactor wall and hence do not protrude into the inner reactor space.

As propellant gas, superheated high-pressure steam is used, to which technical oxygen can be admixed. The amount of propellant gas exiting from the nozzle, based on the nozzle exit velocity, roughly is 100 m/s.

On the inside of the reactor wall, the fixed-bed pressure gasification reactor is equipped with two rows of temperature sensors installed on the circumference of the reactor (not shown in the Figure), wherein the temperature sensors within one row are spaced from each other at equal distances. The vertical distance to the highest point of the rotary grate is 1.8 m for the upper row of temperature sensors, and 0.25 m for the lower row. By adjusting a corresponding speed of revolution, the amount of ash discharged via the rotary grate per unit time is adjusted such that a temperature between 700 and 1300 °C is measured by the upper row temperature sensors and a temperature between 300 and 400 °C by the lower row.

Industrial Applicability

The invention provides an economic process for disposing of the by-products obtained during the gasification. The process according to the invention is particularly suitable for application in smaller gasification plants. The processing of the liquid by-products into a saleable state thereby can be omitted and the disposal costs for these by-products are reduced.

List of Reference Numerals

[1] fixed-bed pressure gasification reactor

[2] ash discharge grate

[3] fuel supply device

[4] ash discharge device

[5] gasification medium inlet

[6] product gas outlet

[7] inlets for liquid by-products

Claims:

1. A process for the gasification of solid carbonaceous fuels, in particular of coke or coal, with gasification media in a fixed-bed pressure gasification reactor, comprising a gasification medium inlet, a product gas outlet, a fuel bed of solid carbonaceous fuel arranged on an ash discharge grate, a fuel supply device, an ash discharge device; wherein a raw synthesis gas containing hydrogen and carbon oxides is obtained, discharged from the fixed-bed pressure gasification reactor through the product gas outlet and subsequently processed to a pure synthesis gas, **characterized in that** carbonaceous by-products (liquid by-products) of the gasification, such as tars, oils, naphtha and phenols, which during the processing of the raw synthesis gas are obtained in liquid form, in a form dissolved in liquid or in a form dispersed in liquid, are introduced into the gasification zone and/or the combustion zone of the fixed-bed pressure gasification reactor and likewise at least partly converted to hydrogen and/or carbon oxides.
2. The process according to claim 1, **characterized in that** at least a part of the liquid by-products introduced into the fixed-bed pressure gasification reactor gets into a region in which the gas temperature is at least 700 °C, preferably at least 800 °C.
3. The process according to claim 1 or 2, **characterized in that** the liquid by-products are introduced into the fixed-bed pressure gasification reactor by pumping, injecting or spraying, wherein in the case of injecting or spraying a propellant gas is used.
4. The process according to claim 3, **characterized in that** injecting or spraying of the liquid by-products into the fixed-bed pressure gasification reactor is effected via at least one nozzle installed in the wall of the reactor and directed radially into the reactor space, wherein when several nozzles are used, the same preferably are distributed on the circumference of the reactor at equal distances from each other and preferably at the same height.
5. The process according to claim 4, **characterized in that** the nozzle orifices terminate with the lining of the inner reactor wall, so that they do not protrude into the inner reactor space.

6. The process according to claims 3 to 5, **characterized in that** carbon dioxide, steam, air or oxygen or arbitrary mixtures of these components are used as propellant gases.
7. The process according to claims 3 to 6, **characterized in that** the nozzles are installed in the reactor wall at a vertical distance of 1.0 to 2.0 m, preferably 1.5 m above the highest point of the discharge grate at the same distance from each other on the circumference of the reactor.
8. The process according to claims 3 to 7, **characterized in that** the jet direction of the nozzles is directed downwards at an angle deviating from the horizontal between 0 to 30°, preferably 0 to 20°, most preferably 0 to 10°.
9. The process according to any of claims 3 to 8, **characterized in that** the nozzle exit velocity based on the amount of propellant gas exiting from the nozzle is between 50 and 150 m/s, preferably between 80 and 120 m/s.
10. The process according to any of claims 3 to 9, **characterized in that** the local temperature of the fixed bed on the inside of the reactor wall is determined by means of two rows of temperature sensors installed on the circumference of the reactor, wherein the temperature sensors within one row are spaced from each other at equal distances, wherein the vertical distance to the highest point of the discharge grate is 0.5 to 2.5 m, preferably 1.0 to 2.0 m, for the upper row, and the vertical distance to the highest point of the discharge grate is 0 to 0.5 m, preferably 0.25 m for the lower row, and wherein the quantity of the ash discharged via the discharge grate per unit time is adjusted such that a temperature between 700 and 1300 °C is measured by the upper row of temperature sensors, and a temperature between 300 and 400 °C is measured by the lower row.
11. The process according to any of the preceding claims, **characterized in that** the intermixed liquid by-products are introduced into the fixed-bed pressure gasification reactor.
12. The process according to any of the preceding claims, **characterized in that** different liquid by-products are separately introduced into the fixed-bed pressure gasification reactor via separate nozzles each.

13. The process according to at least one of the preceding claims, **characterized in that** the inner wall of the fixed-bed pressure gasification reactor in the surroundings of the nozzle orifices is protected by panels, wherein the panels are made of ceramic material in which cooling elements made of metal, such as tubes, are contained, which can be traversed by a cooling medium such as water.

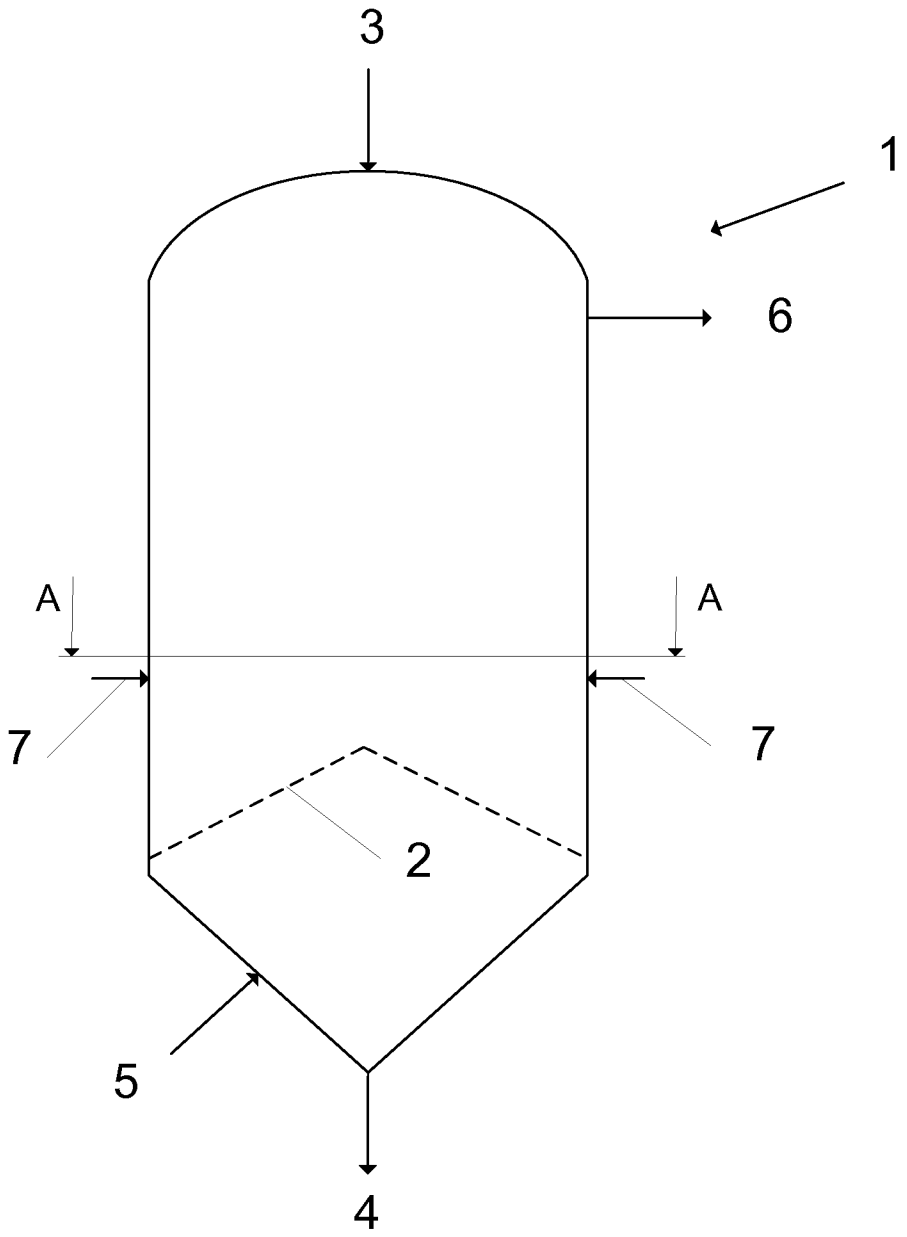


Fig. 1

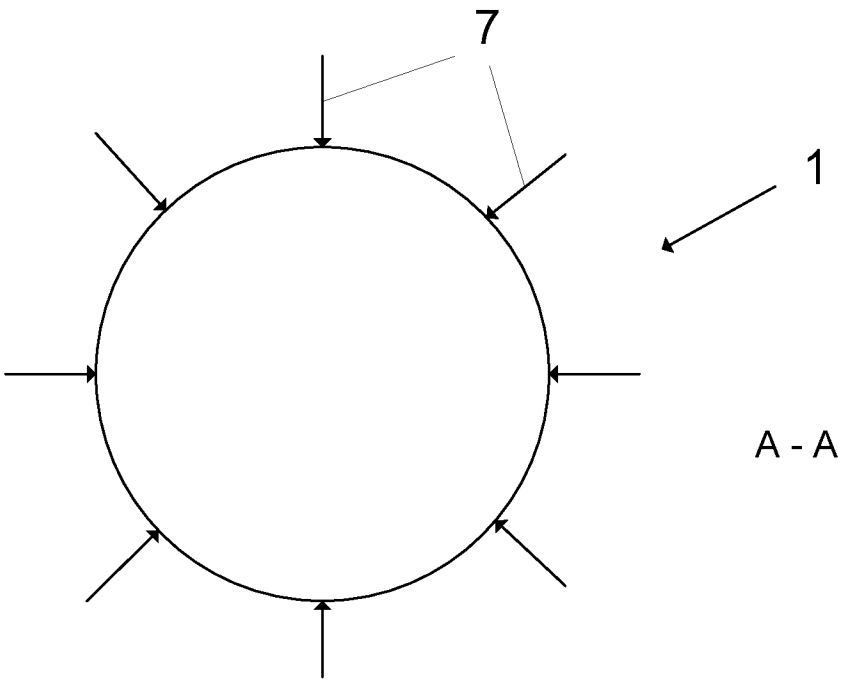


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/076040

A. CLASSIFICATION OF SUBJECT MATTER
INV. C10J3/02 C10J3/42
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2012 202129 A1 (UNIV FREIBERG TECH BERGAKAD [DE]) 14 August 2013 (2013-08-14) paragraph [0009]; figure 1 paragraph [0036] - paragraph [0050]; figure 1	1-13
A	DE 10 2007 035301 A1 (LURGI GMBH [DE]) 29 January 2009 (2009-01-29) the whole document	1-13
A	EP 2 666 845 A1 (DOGRU MURAT [GB]) 27 November 2013 (2013-11-27) the whole document	1-13
A	US 2010/148122 A1 (BRETON DAVID L [US] ET AL) 17 June 2010 (2010-06-17) the whole document	1-13

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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