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[Continued on next page]

(54) Title: METHOD FOR HEATING A FUEL BED IN A FIXED-BED PRESSURE GASIFICATION REACTOR

(57) Abstract: A method for heating the fuel bed during start-up of a fixed-bed pressure gasification reactor, wherein the thermal energy necessary for heating the fuel bed is introduced into the fuel bed by flue gas generated outside the reactor as heat carrier.

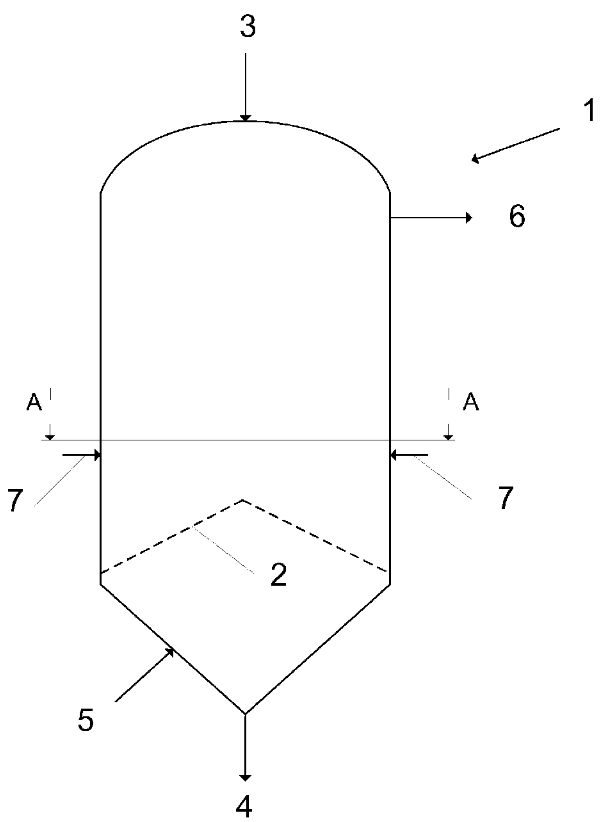

Fig. 1

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Method for Heating a Fuel Bed in a Fixed-Bed Pressure Gasification Reactor

Field of the Invention

This invention relates to a method for heating the carbonaceous fuel on start-up of a fixed-bed pressure gasification reactor for producing synthesis gas by converting the carbonaceous fuel, for example coal, coke or lumpy biomass, with sufficiently high carbon content by using oxygen, air and/or water vapor as gasification medium.

The invention also comprises a fixed-bed pressure gasification reactor which is suitable for carrying out the method according to the invention.

Prior art

By means of fixed-bed pressure gasification reactors solid, carbonaceous fuel, such as coal, coke or other lumpy biomass, is gasified with water vapor (subsequently simply referred to as steam) and oxygen or air in a shaft reactor under excess pressure to obtain a synthesis gas chiefly consisting of 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, cf. Ullmanns Encyclopedia of Industrial Chemistry, Sixth Edition, Vol. 15, page 369. This type of reactor frequently also is referred to as FBDB (= Fixed Bed Dry Bottom) pressure gasifier. Fuel is understood to be a carbonaceous feedstock which not only serves for generating heat, but also serves as educt for the formation of synthesis gas.

When heating the fuel bed it is desirable that the bottom side of the bed is heated up to ignition temperature as uniformly as possible over the cross-section. Ignition temperature here is understood to be the temperature at which after addition of the gasification medium, the same reacts with the carbon contained in the fuel to obtain carbon oxides and hydrogen.

On start-up of a fixed-bed pressure gasification reactor, the thermal energy necessary for heating the fuel bed up to ignition temperature is introduced into the bed either by means of high-pressure steam or by burning a highly flammable material, such as wood, in the reactor. The laid-open publication DE 4 013 739 A1, for example, teaches that for heating the fuel bed in the fixed-bed pressure gasification reactor an ignition fuel is supplied to the same and either is ignited already before being supplied or can be ignited by an ignition initial in the reactor. Alternatively, the fixed-bed pressure gasification reactor can be filled with fuel and thereafter be heated by means of steam up to above the self-ignition temperature of the gasification substance and finally can be ignited with an air-steam mixture. For heating up the fuel bed, DE 4 013 739 A1 finally proposes to supply an ignition start-up gasification medium mixture, wherein during heating the composition of the ignition start-up gasification medium mixture is chosen such that the oxygen content just is high enough to provide for a steady increase of the temperature level in the reactor, but on the other hand there cannot be produced an explosible gas mixture, even in the case of non-conversion of the oxygen content in the reactor. The ignition start-up gasification medium mixture is prepared in a sub-critical composition, wherein critical composition is understood to be the oxygen content in the gas mixture which in the case of non-conversion in the reactor would be sufficient to form an explosible gas mixture in the start-up raw gas or in the mixture of start-up raw gas and raw gas.

In these methods for reaching the ignition temperature it is disadvantageous that for reaching very high ignition temperatures, as they do exist in some types of coal and coke, they are very expensive in technical terms.

High-pressure steam, mostly in superheated form, usually is employed only up to a steam temperature of about 430 °C. Higher temperatures would require an uneconomically high technical effort for steam generation and for transferring the steam into the reactor. Since this steam is introduced into the fuel bed along the same route as the steam used in the gas production, i.e. through the rotary grate, the rotary grate would be exposed to the high temperature. The consequence would be a higher thermal wear and/or a more expensive construction of the rotary grate.

The method to produce the heat via the combustion of an ignition fuel, such as wood, in the reactor also requires a large technical effort and in addition a large expenditure of time. These methods also involve the risk that the fuel bed is heated up to the ignition temperature only non-uniformly over the cross-section, and as a result, in the starting phase of the gas generation, the oxygen introduced into the fixed bed with the steam is converted only incompletely.

On the other hand, a continuous tracking of the oxygen content in the ignition start-up gasification medium mixture in dependence on the desired increase in temperature, as it is proposed in DE 4 013 739 A1, only is to be realized with great expenditure in terms of measurement and control. A deviation from the ideal composition of the ignition start-up gasification medium mixture in direction of high oxygen contents in turn involves the risk of the formation of critical, i.e. explosible gas mixtures.

In the starting phase, i.e. until an almost complete conversion of the oxygen introduced into the fuel bed is effected, the raw synthesis gas produced must be discharged via a torch, in order to exclude the input of oxygen into the operational gas distribution network and hence a risk of explosion. Therefore, the synthesis gas production cannot utilize the fuel in the starting phase and there is less impact on the environment.

It has therefore been the object to provide a method which avoids the above-mentioned disadvantages.

Description of the Invention

The object is solved by a method for heating the fuel bed on start-up of a fixed-bed pressure gasification reactor, comprising the following method steps:
(a) providing a fixed-bed pressure gasification reactor, comprising a gasification medium inlet, a product gas outlet, a fuel bed of solid carbonaceous fuel, which is arranged on an ash discharge grate, a fuel supply means, and an ash discharge means;
(b) introducing hot heating gas into the fuel bed and discharging the cooled heating gas from the fixed-bed pressure gasification reactor via the product gas outlet;
(c) carrying out step (b), until at least in a part of the fuel bed the ignition temperature of the fuel is reached,
wherein the heating gas used in step (b) is flue gas generated outside the fixed-bed pressure gasification reactor.

Further advantageous aspects of the method according to the invention can be found in sub-claims 2 to 12.

According to the procedure known already from the prior art, reaching of the ignition temperature is determined indirectly from the temperature and the concentration ratio of carbon monoxide to carbon dioxide of the gas leaving the reactor.
The ignition temperature (also ignition point, self-ignition temperature, inflammation temperature or inflammation point) is that temperature to which a substance or a contact surface must be heated, so that a combustible substance (solid, liquid, its vapors or gas) ignites itself in the presence of air exclusively due

to its temperature - i.e. without ignition source such as an ignition spark. It is differently high for each substance and in many cases dependent on the pressure. For determining the ignition temperature for example of coal various methods exist, which have long since been known to the skilled person, cf. for example Ray W. Arms, The Ignition Temperature of Coal, Bulletin No. 128, University of Illinois Bulletin Vol. XIX, No. 33, 10.04.1922.

The flue gas is generated in a flue gas generation plant located outside the fixed-bed pressure gasification reactor by combustion of a carbonaceous fuel, for example of natural gas or of synthesis gas already produced before and stored temporarily. The adjustment of the mixing ratio of oxygen to fuel is made such that no free oxygen (O_2) is contained in the flue gas produced. A content of O_2 traces is uncritical.

The temperature of the flue gas is adjusted by addition of carbon dioxide or water vapor as moderators.

The use of flue gas instead of steam as heat carrier is less expensive in technical terms, since there is not required a system for steam generation.

Flue gas temperatures up to 1200 °C can economically be achieved with reasonable technical effort. Due to these high temperatures, the ignition temperature in the fuel is reached very much faster and more securely than in the case of heating with the far lower temperatures by the conventional method. The heating phase in which the gas must be discharged via a waste gas disposal system, for example a torch, thereby can be shortened or even be omitted completely. When the gas produced in the heating phase already is to be fed into the operational gas distribution network, the pressure of the flue gas used for heating must correspond to the operating pressure of the gas grid, i.e. the combustion gases must be fed into the flue gas generation plant with the corresponding pressure. In this case, it therefore is favorable to operate the combustion chamber at the operating pressure of the gas grid or of the fixed-bed pressure gasification reactor.

Preferred Aspects of the Invention

Since the high temperature of the flue gas would expose the ash discharge grate to high thermal loads, an advantageous aspect of the invention is characterized in that the flue gas is introduced into the fuel bed above the ash discharge grate. The inlet ideally should be located at the height of or rather closely above the upper limit of the ash or slag bed, as it is obtained in the production operation. This height frequently is 50 to 100 cm above the highest point of the grate. The height concretely chosen in the individual case is derived from experiences made with the respective fuel and from the respective reactor size. Particularly favorable vertical distances between the flue gas inlet and the highest point of the ash discharge grate were found to be distances of 1 to 500 cm, preferably 10 to 200 cm, most preferably 20 to 100 cm.

Due to the fact that the introduction of the hot flue gas is effected at a certain distance above the grate, the grate on the one hand is protected against the high gas temperature, and on the other hand the method according to the invention also can be used for reheating a cold fuel bed, when the flue gas is introduced into the bed above the ash layer.

Another advantageous aspect of the invention is characterized in that the flue gas is introduced into the fuel bed via flue gas inlets, i.e. inlets in the reactor wall, which are uniformly distributed around the circumference of the reactor. It often is recommendable to arrange the inlets at the same height above the grate; however, it is also possible to install them at different heights, in order to be able to react to different operational circumstances.

Particularly preferably, the flue gas inlets are arranged spatially separate from the gasification medium inlet. Both material streams, i.e. the flue gas stream and the gasification medium stream, thereby can be introduced into the fixed-bed pressure gasification reactor separate from each other at respectively suitable points of addition. This has certain advantages with regard to the control and distribution of the material streams over the reactor cross-section and reduces the risk of the formation of explosible gas mixtures. In addition, it is not necessary then to guide the heating gas over the ash discharge grate which only can withstand a limited thermal load.

In a particular aspect of the invention, the flue gas inlets in the reactor wall are formed as nozzles or tuyères, or nozzles can be installed therein, through which the flue gas is introduced into the fuel bed.

The nozzles favorably should guide the flue gas as gas jet radially to the inside, into the fuel bed. It may be favorable to guide the gas jet into the fuel bed at an angle inclined in direction of the ash discharge grate. Since the points of addition for the flue gas are vertically spaced from the feed grate, the fuel layer present between the flue gas inlets and the ash discharge grate also is heated in this way. In addition, the route of the flue gas through the fuel bed thus is prolonged, so that an improved heat transfer is obtained. In any case, however, the design limits of the ash discharge grate must be taken into account, in order to avoid overheating and hence a damage of the ash discharge grate. With very small distances between the flue gas addition points and the ash discharge grate it therefore is recommendable to choose a very small angle of inclination of the gas jet or to introduce the same into the fuel bed parallel to the ash discharge grate.

In a particularly preferred aspect of the invention the vertical distance between a flue gas inlet and the highest point of the ash discharge grate is 1 to 500 cm, preferably 10 to 200 cm, most preferably 20 to 100 cm. These distance values are empirical values which are based on the usual sizes of fixed-bed pressure gasification reactors. The smaller the overall height of a fixed-bed pressure gasification reactor, the smaller the distance chosen between the flue gas inlets and the upper edge of the ash discharge grate, in order to fully utilize the smaller existing space.

In many cases of application it furthermore is favorable and therefore subject-matter of a preferred aspect of the invention, when the outlet sides of the flue gas inlets, i.e. for example of the nozzles or tuyères, end with the inner wall of the fixed-bed pressure gasification reactor, i.e. do not protrude into the reactor interior space. In this way, the nozzles are not mechanically stressed by the fuel bed sinking down in the reactor.

However, it may also be expedient to have the nozzles protrude into the reactor, in order to keep the hot flue gas away from the reactor inner wall.

In a further aspect of the invention it is provided that at least two, preferably two to ten flue gas inlets are provided each with the same angular distances from each other. In this way, a particularly homogeneous heating of the fuel bed is achieved. The larger the diameter of the fixed-bed pressure gasification reactor, the more flue gas inlets should be provided.

In a particular aspect of the invention the flue gas inlets all lie on the same horizontal plane and are connected via a ring gas conduit. In this way, a homogeneous distribution of the flue gas on the individual flue gas inlets can be ensured.

A preferred aspect of the invention provides that the flue gas is generated in a combustion chamber which is spatially separate from the fixed-bed pressure gasification reactor, but is in fluid connection with the same. Fluid connection is understood to be any kind of connection which enables a fluid, for example the flue gas stream, to flow from the one to the other of the two regions, regardless of any interposed regions or components. This aspect is advantageous, because it provides an increased flexibility in the erection of the fixed-bed pressure gasification reactor and combustion chamber. It may even be considered to design the combustion chamber in a mobile fashion, so that after start-up of a fixed-bed pressure gasification reactor it can be utilized for the succeeding start-up of a further, spatially separate fixed-bed pressure gasification reactor.

It is particularly advantageous, when the combustion chamber is operated at the normal working pressure of the fixed-bed pressure gasification reactor. In this way, heating of the fuel bed by means of flue gases can be effected already at the succeeding working pressure of the fixed-bed pressure gasification reactor. A further pressure increase during start-up of the fixed-bed pressure gasification reactor therefore is not necessary.

In a further aspect of the invention, raw synthesis gas from a gas accumulator, for example a gasometer, is supplied to the combustion chamber as fuel. In this way it is avoided that valuable fuel, for example natural gas, must be consumed for the flue gas generation.

The invention also relates to a fixed-bed pressure gasification reactor, comprising a gasification medium inlet, a product gas outlet, a fuel bed arranged on an ash discharge grate, a fuel supply means, and an ash discharge means, characterized by a combustion chamber which is spatially separate from the fixed-bed pressure gasification reactor, but in fluid connection with the same, and flue gas inlets.

In a particular aspect of the fixed-bed pressure gasification reactor according to the invention at least two, preferably two to ten flue gas inlets each with the same angular distances are provided, which particularly preferably are designed as nozzles or tuyères and are arranged above the ash discharge grate.

Exemplary embodiments and numerical examples

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,

Fig. 2 shows a cross-section through a fixed-bed pressure gasification reactor at the height of the flue gas supply.

Fig. 1 by way of example shows how the flue gas inlets are distributed around 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 means 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.

During the heating method according to the invention, flue gas is charged to the fuel bed arranged on the ash discharge grate 2, which is not shown in Fig. 1, via the flue gas inlets 7, which flue gas has been generated by combustion of raw synthesis gas in an external combustion chamber (not shown in Fig. 1). The temperature of the flue gas must lie above the ignition temperature of the fuel used. The higher it is, the lower the flue gas mass flow can be chosen for reaching a particular heating effect. What should be taken into account, however, are the temperature design limits with regard to the materials used in the flue gas path and in the fixed-bed pressure gasification reactor.

The combustion chamber and the fixed-bed pressure gasification reactor already are at a pressure of 40 bar, absolute, i.e. the future working pressure during the gasification operation. The flue gas traverses the fuel bed and heats the same by direct heat exchange to temperatures above the ignition temperature of the coal used. Via the product gas outlet 6, the cooled flue gas is discharged from the fixed-bed pressure gasification reactor and supplied to the waste gas disposal, for example to a torch system.

After the temperature of the fuel bed has exceeded the ignition temperature at least at some points, the flue gas supply is interrupted or reduced and the gasification medium is supplied. Reaching of the required ignition temperature can be checked for example by measuring the temperature of the flue gas leaving the fixed-bed pressure gasification reactor. When the same reaches or exceeds the ignition temperature of the fuel used as determined by preliminary examinations, it can be assumed that at least a part of the fuel bed has reached or even exceeded the ignition temperature. Alternatively or in addition, reaching of the ignition temperature can be checked by continuously determining the concentration ratio of CO and CO_2 in the flue gas leaving the fixed-bed pressure gasification reactor. For this purpose, the usual methods of the online gas analysis can be used. After start of the supply of gasification medium, the fixed-bed pressure gasification reactor is in normal operation.

By way of example, the following steps can be performed during heating and start-up of the fixed-bed pressure gasification reactor:

Step 1: Preheating the fixed-bed pressure gasification reactor with flue gas from an external combustion chamber without excess of O_2 for safety reasons, pressure in combustion chamber and fixed-bed pressure gasification reactor 30 to 40 bar, absolute. Typical upper pressure limit: 60 bar, absolute.
Step 2: Thoroughly heating the fuel bed with flue gases, addition of a small excess of O_2 during the flue gas generation, hence start of gasification, continuous monitoring of the gas quality by online gas analysis of the gas leaving the fixed-bed pressure gasification reactor, reduction of the flue gas stream.
Step 3: After reaching the ignition temperature: Starting the fixed-bed pressure gasification reactor by addition of water vapor/air as gasification medium via the

rotary grate (start-up gasification operation). Stepwise increase of the gasification medium mass flow.

Step 4: Switching the gasification medium to steam/O_2, addition via the rotary grate (start-up low-load operation). Stepwise increase of the O_2 concentration in the gasification medium.

Step 5: Normal operation is reached when the raw synthesis gas produced is free from O_2, the CO_2 concentration in the raw synthesis gas is < 35 vol-%, and the CO concentration in the raw synthesis gas is > 15 vol-%. Terminating the flue gas addition except for a small purge stream.

Fig. 2 shows a cross-section through the fixed-bed pressure gasification reactor 1 along the horizontal plane A-A. As an example, eight flue gas inlets are shown. The number of flue gas inlets concretely suitable in the individual case chiefly depends on the diameter of the fixed-bed pressure gasification reactor, the height of the fuel bed, the fuel used and the properties of the flue gas.

Industrial Applicability

The invention provides a method with which heating and start-up of a fixed-bed pressure gasification reactor is accelerated and hence the amount of gases discharged to the environment via the torch during the start-up operation is reduced.

List of Reference Numerals

[1] fixed-bed pressure gasification reactor

[2] ash discharge grate

[3] fuel supply means

[4] ash discharge means

[5] gasification medium inlet

[6] product gas outlet

[7] flue gas inlet

Claims:

1. A method for heating the fuel bed on start-up of a fixed-bed pressure gasification reactor, comprising the following method steps:
(a) providing a fixed-bed pressure gasification reactor, comprising a gasification medium inlet, a product gas outlet, a fuel bed of solid carbonaceous fuel, which is arranged on an ash discharge grate, a fuel supply means, an ash discharge means;
(b) introducing hot heating gas into the fuel bed and discharging the cooled heating gas from the fixed-bed pressure gasification reactor via the product gas outlet;
(c) carrying out step (b), until at least in a part of the fuel bed the ignition temperature of the fuel is reached,
characterized in that the heating gas used in step (b) is flue gas generated outside the fixed-bed pressure gasification reactor.
2. The method according to claim 1, **characterized in** that the flue gas is introduced into the fuel bed above the ash discharge grate.
3. The method according to claim 2, **characterized in that** the flue gas is introduced into the fuel bed via flue gas inlets which are distributed around the circumference of the fixed-bed pressure gasification reactor.
4. The method according to claim 3, **characterized in that** the flue gas inlets are spatially separate from the gasification medium inlet.
5. The method according to claim 4, **characterized in that** the flue gas inlets are designed as nozzles or tuyères and arranged such that the flue gas is guided into the fuel bed radially to the inside and at an angle inclined in direction of the ash discharge grate.
6. The method according to claim 5, **characterized in that** the vertical distance between a flue gas inlet and the highest point of the ash discharge grate is 1 to 500 cm, preferably 10 to 200 cm, most preferably 20 to 100 cm.
7. The method according to any of the preceding claims, **characterized in that** the outlet sides of the flue gas inlets terminate with the inner wall of the fixed-bed pressure gasification reactor.

8. The method according to claims 3 to 7, **characterized in that** at least two, preferably two to ten flue gas inlets are provided each with the same angular distances from each other.
9. The method according to claim 8, **characterized in that** the flue gas inlets all lie on the same horizontal plane and are connected via a ring gas conduit.
10. The method according to any of the preceding claims, **characterized in that** the flue gas is generated in a combustion chamber which is spatially separate from the fixed-bed pressure gasification reactor, but is in fluid connection with the same.
11. The method according to claim 9, **characterized in that** the combustion chamber is operated at the normal working pressure of the fixed-bed pressure gasification reactor.
12. The method according to any of the preceding claims, **characterized in that** raw synthesis gas from a gas accumulator is supplied to the combustion chamber as fuel.
13. A fixed-bed pressure gasification reactor for carrying out the method according to the preceding claims, comprising a gasification medium inlet, a product gas outlet, a fuel bed arranged on an ash discharge grate, a fuel supply means, and an ash discharge means, **characterized by** a combustion chamber which is spatially separate from the fixed-bed pressure gasification reactor, but in fluid connection with the same, and flue gas inlets.
14. The fixed-bed pressure gasification reactor according to claim 13, **characterized in that** at least two, preferably two to ten flue gas inlets with the same angular distances each are provided.
15. The fixed-bed pressure gasification reactor according to claim 13 or 14, **characterized in that** the flue gas inlets are designed as nozzles or tuyères and are arranged above the ash discharge grate.

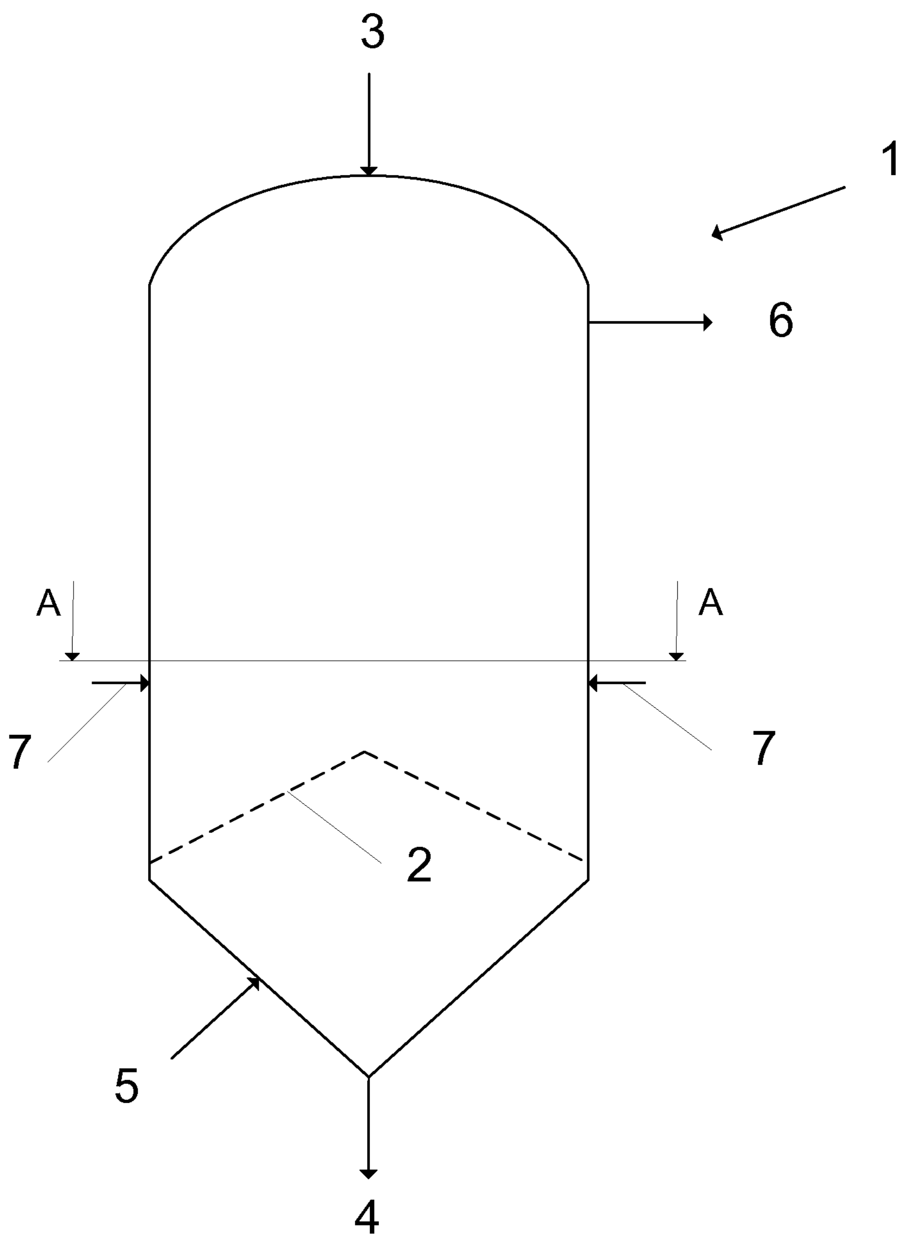

Fig. 1

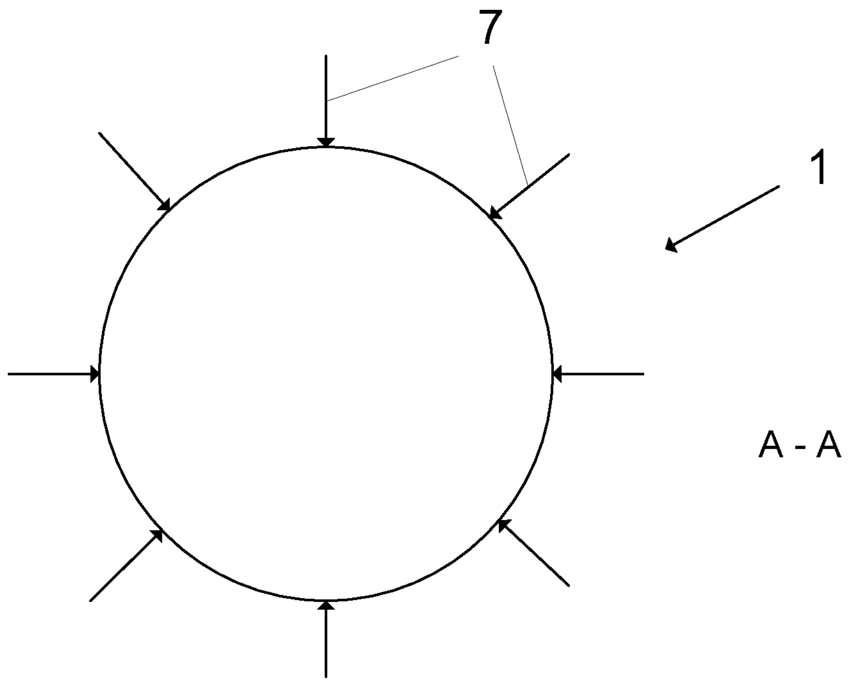

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/073927

A. CLASSIFICATION OF SUBJECT MATTER
INV. C10J3/02 C10J3/72 C10J3/36
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	DD 214 385 A1 (INST ENERGETIK ZRE BEREICH DRE [DD]) 10 October 1984 (1984-10-10) page 4, paragraph 1 - page 4, paragraph 2 -----	1,13
X	EP 2 077 311 A1 (NAGASAKI INST OF APPLIED SCIEN [JP] NAGASAKI INST OF APPLIED SCIENCE [) 8 July 2009 (2009-07-08) paragraph [0009] - paragraph [0036]; figure 1 -----	1-12,14, 15
A	US 5 484 465 A (HILLIARD WESLEY P [US] ET AL) 16 January 1996 (1996-01-16) the whole document -----	1-15
A	WO 95/25151 A1 (AMERICAN HIGH TEMP INC [US]) 21 September 1995 (1995-09-21) the whole document -----	1-15

☐ 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

"E" earlier application or patent but published on or after the international filing date

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 January 2015	19/01/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Iyer-Baldew, A

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2014/073927

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