



## **A gasification unit, a method for producing a product gas and use of such a method**

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*Publication date:*  
2019

*Document Version*  
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

*Citation (APA):*  
Ahrenfeldt, J., Henriksen, U. B., & Østergaard, R. G. (2019). A gasification unit, a method for producing a product gas and use of such a method. (Patent No. WO2019072350).

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- (51) **International Patent Classification:**  
C10J 3/36 (2006.01) C10J 3/66 (2006.01)
- (21) **International Application Number:**  
PCT/DK2018/050256
- (22) **International Filing Date:**  
12 October 2018 (12.10.2018)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**  
PA 2017 70775 12 October 2017 (12.10.2017) DK
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(81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, 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,

(54) **Title:** A GASIFICATION UNIT, A METHOD FOR PRODUCING A PRODUCT GAS AND USE OF SUCH A METHOD

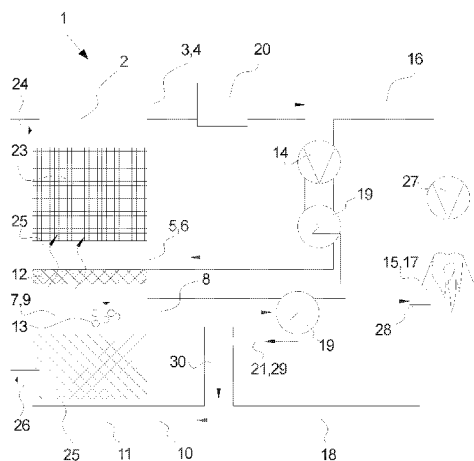


Fig. 1

(57) **Abstract:** Disclosed is a gasification unit (1) for producing a product gas. The gasification unit (1) comprises a co-current or counterflow pyrolysis unit (2) including a pyrolysis gas outlet (3) arranged at an upper part(4)of the pyrolysis unit (2) and a pyrolysis gas inlet (5) arranged at a lower part(6)of the pyrolysis unit (2). The gasification unit (1) further comprises a co-current or counterflow gasifier (7) including a product gas outlet (8) arranged at an upper part(9)of the gasifier (7) and a gasifier inlet (10) arranged at a lower part of the gasifier (7) and coke moving means (12) for allowing pyrolyzed coke (13) to move from the pyrolysis unit (2) to the gasifier (7). The gasification unit (1) also comprises recycling means (14) arranged to guide at least a part of the pyrolysis gas produced in the pyrolysis unit (2) from the pyrolysis gas outlet (3) and back to the pyrolysis gas inlet (5) and heating device (15) comprising an input conduit (16) arranged to guide pyrolysis gas from the pyrolysis gas outlet (3) to a combustion unit (17) in the heating device (15), wherein the combustion unit (17) is arranged to least a partially oxidize the pyrolysis gas from the pyrolysis unit (2), and wherein the heating device (15) comprises an output conduit (18) arranged to guide heating gas generated by the partial oxidization in the combustion unit (17) to the gasifier inlet (10), where in the heating device (15) is arranged external to the pyrolysis unit (2) and the gasifier (7)and wherein said gasification unit (1) further comprises heat exchange means (19) arranged for heating at least a portion of the pyrolysis gas before it enters the pyrolysis unit (2) through said pyrolysis gas inlet (5) by means of at least a part of the product gas exiting said gasifier (7) through said product gas outlet (8). Furthermore, a method for producing a product gas in a gasification unit (1) and use of such a method is disclosed.

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,  
KM, ML, MR, NE, SN, TD, TG).

**Declarations under Rule 4.17:**

— *of inventorship (Rule 4.17(iv))*

**Published:**

— *with international search report (Art. 21(3))*

A GASIFICATION UNIT, A METHOD FOR PRODUCING A PRODUCT GAS AND USE OF SUCH A  
METHOD

**Field of the invention**

- 5 The invention relates to a gasification unit for producing a product gas. The gasification unit comprises a co-current or counterflow pyrolysis unit and a co-current or counterflow gasifier. The invention further relates to a method for producing a product gas in a gasification unit and use of such a method.

10 **Background of the invention**

- Producing product gas from biomass, coal or other is well known in the art e.g. by means of two stage gasification typically based on externally heated pyrolysis and a coke bed in downstream configuration. However, externally heated pyrolysis is problematic – particularly in larger scale because of difficulties in supplying sufficient  
15 heat - and the downstream configuration is problematic in that it can be sensitive to dust and smaller particles.

- Thus, from US 4,069,024 a two-stage gasification system for carbonaceous material is known, wherein the system comprises a pyrolyzing reactor followed by a gasifier and  
20 wherein at least some of the produced product gas is guided back into the gasifier and an ignition zone is formed centrally within the gasifier to increase the temperature inside the gasifier. However, this setup requires substantial subsequent gas cleaning.

- It is therefore an object of the present invention to provide for a cost-efficient technique  
25 for producing a cleaner product gas.

**The invention**

- The invention provides for a gasification unit for producing a product gas. The gasification unit comprises a co-current or counterflow pyrolysis unit including a  
30 pyrolysis gas outlet arranged at an upper part of the pyrolysis unit and a pyrolysis gas

inlet arranged at a lower part of the pyrolysis unit. The gasification unit further comprises a co-current or counterflow gasifier including a product gas outlet arranged at an upper part of the gasifier and a gasifier inlet arranged at a lower part of the gasifier and coke moving means for allowing pyrolyzed coke to move from the pyrolysis unit to the gasifier. The gasification unit also comprises recycling means arranged to guide at least a part of the pyrolysis gas produced in the pyrolysis unit from the pyrolysis gas outlet and back to the pyrolysis gas inlet and heating device comprising an input conduit arranged to guide pyrolysis gas from the pyrolysis gas outlet to a combustion unit in the heating device, wherein the combustion unit is arranged to least a partially oxidize the pyrolysis gas from the pyrolysis unit, and wherein the heating device comprises an output conduit arranged to guide heating gas generated by the partial oxidization in the combustion unit to the gasifier inlet, wherein the heating device is arranged external to the pyrolysis unit and the gasifier and wherein the gasification unit further comprises heat exchange means arranged for heating at least a portion of the pyrolysis gas before it enters the pyrolysis unit through the pyrolysis gas inlet by means of at least a part of the product gas exiting the gasifier through the product gas outlet.

Partial oxidization inside the pyrolysis unit or the gasifier is practical because the pyrolysis unit or the gasifier is already cable of handling the high temperatures generated by the combustion. However, arranging the heating device external to the pyrolysis unit and the gasifier is advantageous in that it provides a more controlled environment and thereby a more controlled partial oxidation and thereby better tar decomposition.

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And it is advantageous to heat the pyrolysis gas before it enters the pyrolysis unit by means of the product gas exiting the gasifier in that the temperature of the recirculating pyrolysis gas has to be raised and the temperature of the product gas has to be lowered and both these things hereby can be achieved in a simple and inexpensive manner.

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In this context, the term “pyrolysis unit” should be understood as any kind of unit capable of running a pyrolysis process, which is a thermochemical decomposition of organic material or fossil fuel at elevated temperatures in the absence of oxygen (or any halogen). However, oxygen may be used to run the pyrolysis process, e.g. in the form of at least partial oxidation inside the pyrolysis unit that will raise the temperature to a level suitable for pyrolysis but the oxygen does not form part of the pyrolysis process itself. Pyrolysis involves the simultaneous change of chemical composition and physical phase, and is irreversible. Pyrolysis is a type of thermolyses, and is most commonly observed in organic materials exposed to high temperatures typically starting at 200–300°C and up to 500°C or even higher. In general, pyrolysis of organic substances or fossil fuels produces gas and liquid products and leaves a solid residue richer in carbon content, which in this embodiment is referred to as pyrolysis coke but is also often referred to as pyrolysis char. It should also be noted that in this context the term “pyrolysis” or “pyrolyzed” also covers torrefaction which is a mild form of pyrolysis at temperatures typically between 200 and 320 °C depending on the specific material being pyrolyzed.

Furthermore, it should be emphasised that the term “gasifier” is to be understood as any kind of device suitable for running a gasification process in which organic or based carbonaceous materials is converted into mainly carbon monoxide, hydrogen, carbon dioxide or similar. This is achieved in the gasifier by reacting the material at high temperatures (typically higher than 700°C). The resulting gas mixture is in this embodiment called product gas but could in other embodiments be referred to as syngas, synthesis gas, producer gas or other and is itself a fuel.

It should also be emphasised that the term “coke moving means” is to be understood as any kind of conveyer, auger, slide, valve, register, gate or similar or any combination thereof or any other kind of coke mover suitable for moving or at least allowing pyrolyzed coke to move from the pyrolysis unit to the gasifier.

Further, it should be emphasised that the term “recycling means” is to be understood as any kind of pipe, pump, fan, conduit or similar or any combination thereof or any other kind of recycler suitable for guiding at least a part of the pyrolysis gas produced in the pyrolysis unit from the pyrolysis gas outlet and back to the pyrolysis gas inlet.

It should also be emphasised that the term “counterflow” (pyrolysis unit or gasifier) is to be understood any kind of pyrolysis unit or gasifier where hot gas, air, steam or another gaseous substance is being fed in the bottom of the pyrolysis unit or gasifier to either directly or indirectly drive the respective pyrolysis or gasification and the resulting gas is drawn from the top of the pyrolysis unit or gasifier, while the fuel is fed at the top of the pyrolysis unit or gasifier so that the closer the fuel moves to the bottom of the pyrolysis unit or gasifier the more processed it is. I.e. fuel and gas moves in opposite directions – hence “counterflow”. In this context “counterflow” is also often referred to as “updraft”, “upward draft”, “counter-current” and other.

Likewise, it should also be emphasised that the term “co-current” (pyrolysis unit or gasifier) is to be understood any kind of pyrolysis unit or gasifier where hot gas, air, steam or another gaseous substance is being fed in the top of the pyrolysis unit or gasifier to either directly or indirectly drive the respective pyrolysis or gasification and the resulting gas is drawn from the bottom of the pyrolysis unit or gasifier, while the fuel is fed at the top of the pyrolysis unit or gasifier so that the closer the fuel moves to the bottom of the pyrolysis unit or gasifier the more processed it is. I.e. fuel and gas moves in the same direction – hence “co-current”. In this context “co-current” is also often referred to as “downdraft”, “downward draft”, “downstream” and other.

It should also be emphasised that the term “heat exchange means” is to be understood as any kind of heat exchanger suitable for exchanging heat between pyrolysis gas before it enters the pyrolysis unit and the product gas exiting the gasifier – such as any kind of shell heat exchanger, plate heat exchanger, tube heat exchanger or other.

In an aspect, the pyrolysis gas outlet is connected to filtering means arranged to separate particles from pyrolysis gas flowing out through the pyrolysis gas outlet.

- 5 It is advantageous to filter the pyrolysis gas in that the risk of unwanted particle build-up in the system is hereby reduced.

In this context, the term “filtering means” is to be understood as any kind of filter suitable for separating particles from the pyrolysis gas leaving the pyrolysis unit – i.e.  
10 any kind of cyclone, sieve, strainer or another device for cleaning the pyrolysis gas flow.

In an aspect, the gasification unit comprises cooling means for cooling the heating gas to a temperature between 600°C and 1,200°C, preferably between 700°C and 1,100°C  
15 and most preferred between 800°C and 1,000°C before it enters the gasifier.

If the entrance temperature of the heating gas is too high when it enters the gasifier, the risk of the heat damaging the gasifier and/or equipment in the gasifier is increased. However, if the entrance temperature is too low the gasification process will be  
20 inefficient, and the capacity of the gasifier is reduced. Thus, the present temperature ranges present an advantageous relationship between safety and efficiency.

In an aspect, the cooling means comprises means for adding steam to the heating gas and/or adding product gas to the heating gas to cool the heating gas.

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Cooling the heating gas by means of steam or product is a fast, inert and efficient way of cooling the heating gas.

In an aspect, the co-current or counterflow pyrolysis unit is arranged on top of the co-current or counterflow gasifier.  
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Arranging the co-current or counterflow pyrolysis unit above the co-current or counterflow gasifier is advantageous in that gravity hereby will aid in moving the pyrolyzed coke from the pyrolysis unit and down into the gasifier.

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In an aspect, the coke moving means comprises a screw conveyor.

A screw conveyer is a safe, inexpensive and efficient way of moving coke from a pyrolysis unit to a gasifier.

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The invention further provides for a method for producing a product gas in a gasification unit. The method comprises the steps of:

- feeding fuel to a co-current or counterflow pyrolysis unit,
- circulating at least a part of the pyrolysis gas produced by the fuel in the pyrolysis unit back into the pyrolysis unit to form a flow of pyrolysis gas up through the fuel,
- heating the pyrolysis gas before it re-enters the pyrolysis unit
- pyrolyzing the fuel by means of the re-entering heated pyrolysis gas
- enabling that the pyrolyzed fuel in the pyrolysis unit is moved to a gasifier
- combusting at least a part of the pyrolysis gas outside the pyrolysis unit and the gasifier to form heating gas,
- guiding the heating gas into the gasifier to heat the pyrolyzed fuel to produce a product gas, wherein the pyrolysis gas is heated by means of the product gas before the pyrolysis gas re-enters the pyrolysis unit.

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By partially oxidizing the pyrolysis gas outside the gasifier before it enters the gasifier it is – due to the more controlled environment - possible to better reduce the tar content in the entering heating gas and thereby reduce the tar content in the product gas exiting the gasifier. And heating the pyrolysis gas by means of the produced product gas is advantageous in that this heat source is readily available and it in that it at the same

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time will cool the product gas and thereby save time and energy to perform this operation.

5 In an aspect, the pyrolysis gas is heated by means of the product gas by guiding the pyrolysis gas and the product gas through the same heat exchanger means.

Guiding the pyrolysis gas and the product gas through the same heat exchanger in which pyrolysis gas is heated by means of the product gas directly (i.e. through a metal plate or pipe in the heat exchanger) is advantageous in that this ensures a simple,  
10 efficient, and less complicated heat exchange.

In an aspect, the pyrolysis gas is heated by means of the product gas by guiding the pyrolysis gas through a first heat exchange means and guiding the product gas through second heat exchange means and establish a separate fluid flow between the first and  
15 the second heat exchange means to transfer heat between the first and the second heat exchange means.

Making the pyrolysis gas and the product gas exchange heat indirectly through a separate fluid circulating between at least the two abovementioned separate heat  
20 exchangers is advantageous in that this enables that the heat may be transported over a larger distance and e.g. exchange heat with further processes or other.

In an aspect, the pyrolysis gas is heated by means of the product gas before the pyrolysis gas re-enters the pyrolysis unit.

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The product gas will typically be between 600°C and 1,000°C and most often between 700°C and 800°C when leaving the gasifier and will therefore have to be cooled. It is therefore advantageous to heat the recycled pyrolysis gas by means of this readily available heat source – particularly since the pyrolysis gas re-entering the pyrolysis  
30 unit only has to be heated to around or a little over 500°C.

In an aspect, between 1% and 95%, preferably between 5% and 70% and most preferred between 10% and 50% - such as between 20% to 30% - of the pyrolysis gas produced by the fuel in the pyrolysis unit is circulated back into the pyrolysis unit to form a flow of pyrolysis gas up through the fuel.

If too much or too little of the pyrolysis gas is circulated back into the pyrolysis unit, the gasification unit will run more inefficiently. Thus, the present amount ranges will ensure higher efficiency.

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Even further, the invention provides for use of a method according to any of the previously mentioned methods for producing a product gas from biomass in a gasification unit according to any of the previously discussed gasification units.

15 Pyrolyzing and/or gasification of biomass is problematic in relation to tar content in the resulting gas and it is therefore particularly advantageous to use the present invention in relation to pyrolyzing and/or gasification of biomass.

### Figures

20 The invention will be described in the following with reference to the figures in which

fig. 1. illustrates a gasification unit with a pyrolysis unit arranged on top of a gasifier, as seen from the front, and

25 fig. 2 illustrates a gasification unit with a pyrolysis unit arranged beside a gasifier, as seen from the front.

### Detailed description

Fig. 1 illustrates a gasification unit 1 with a counterflow pyrolysis unit 2 arranged on top of a counterflow gasifier 7, as seen from the front and fig. 2 illustrates a

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gasification unit 1 with a counterflow pyrolysis unit 2 arranged beside a counterflow gasifier 7, as seen from the front.

The units 1 illustrated in fig. 1 and 2 have many features in common and in principle only the displacement of the pyrolyzed coke 13 from the pyrolysis unit 2 to the gasifier differs and except for this issue both drawings will be discussed simultaneously in the following.

In this embodiment fuel 23 is guided into pyrolysis unit 2 through a fuel inlet 24 at an upper part 4 of the pyrolysis unit 2.

In this embodiment, the fuel 23 is wood chips but in another embodiment the fuel could be (raw or pre-dried) animal slurry, (raw or pre-dried) sewage, surplus material from biochemical production or food production, another natural plant material or any other form of organic material or fossil fuel.

At the top 4 of the pyrolysis unit 2 the operation temperature will typically be around 250-300°C but as the fuel 23 moves downwards inside the pyrolysis unit 2 the temperature rises to 500°C or more at the bottom 6 of the pyrolysis unit 2. At the lower part 6 of the pyrolysis unit 2 the fuel is transformed into pyrolyzed coke 13 and it will fall through the grate device 25 on which the fuel 23 rests in the pyrolysis unit 2.

In the embodiment disclosed in fig. 1 the pyrolyzed coke 13 continues down through the coke moving means 12 arranged to allow the coke 13 to move downwards to the gasifier 7, while at the same time ensuring that gas can only travel upwards – i.e. ensuring that pyrolysis gas cannot travel downwards into the upper part 9 of the gasifier 7. In this embodiment, the coke moving means 12 could comprise a register, a gate, a lock, a sluice or other e.g. comprising some sort of gas lock.

In the embodiment disclosed in fig. 2 the coke moving means 12 comprises a screw conveyer 22 arranged to move the pyrolyzed coke 13 from the bottom 6 of the pyrolysis unit 2 to the top 9 of the gasifier 7. However, in another embodiment the coke moving means 12 could comprise conveyers, slides, tubes or other or any  
5 combination thereof.

In this embodiment, the pressure inside the gasifier 7 is at least slightly higher than the pressure inside the pyrolysis unit 2 - or at least slightly higher than the pressure just above the coke moving means 12 - that the risk of pyrolysis gas traveling into  
10 the gasifier 7 via coke moving means 12 or other is substantially eliminated.

In the upper part 9 of the gasifier 7 the temperature is in this embodiment 700-750°C but it will rise as the pyrolyzed coke 13 travels down through the gasifier 7 to around 950°C before the gasified material is removed as ash material or gasifier coke  
15 through an ash outlet 26 at the bottom 11 of the gasifier 7.

It should be underlined that the temperature examples mentioned above and below are specific examples relating to a specific type of wood chip being used as fuel 23 in this embodiment. However, if different fuel 23 was used some of the temperatures  
20 might be higher or lower.

In the pyrolysis units 2 the produced pyrolysis gas will travel upwards and leave the pyrolysis units 2 through the pyrolysis gas outlet 3. From there the pyrolysis gas travels through filtering means 20 in which dust and minor particles are removed from the  
25 gas. After the filtering means 20 the pyrolysis gas is divided into two different flow directions with one guiding the some of the pyrolysis gas back to the pyrolysis units 2 and with the other guiding the remaining pyrolysis gas towards the gasifier 7. Recycling means 14 comprising a fan (or another type of flow generator) arranged to generate a pyrolysis gas flow and pipes arranged to guide the pyrolysis gas will thereby  
30 guide a part of the pyrolysis gas produced in the pyrolysis unit 2 from the pyrolysis

gas outlet 3 and back to the pyrolysis gas inlet 5. However, before the recycled pyrolysis gas enters the pyrolysis units 2 the pyrolysis gas is heated so that when it enters the pyrolysis gas it has a temperature of around – or preferably above – 500°C.

- 5 In this embodiment, the recycled pyrolysis gas is heated by means of a heat exchanger 19 enabling that the pyrolysis gas is being heated by the product gas leaving the gasifier 7. In fig. 1 a heat exchanger 19 is arranged in relation to both the pyrolysis gas and the product gas and these two heat exchangers are then arranged to exchange heat through a separate fluid flowing in pipes connecting the first heat exchanger 19 with the second
- 10 heat exchanger 19. However, in a preferred embodiment the two illustrated heat exchangers 19 are in fact the one and the same heat exchanger 19 and in such an embodiment the product gas leaving the gasifier 7 will exchange heat directly with the pyrolysis gas in the same heat exchanger means 19. Or in another embodiment the gasification unit 1 could comprise means enabling that the recycled pyrolysis gas could
- 15 be heated by means of another internal heat source – such as e.g. partial oxidation - or by means of an external heat source and likewise the product gas could be cooled by means of another internal source or an external source.

- In this embodiment the heat exchanger means 19 are plate heat exchangers but in
- 20 another embodiment one or more of the heat exchangers 19 could also or instead be a shell heat exchange, a tube heat exchanger, a coil heat exchanger or other.

- The other part of the pyrolysis gas will simultaneously travel towards the gasifier 7 through an input conduit 16 arranged to guide the pyrolysis gas from the pyrolysis gas
- 25 outlet 3 to a combustion unit 17 in a heating device 15.

In the embodiment disclosed in fig. 1 the pyrolysis gas will also pass a flow generator 27 – arranged to generate or at least aid the gas flow during this travel - before it enters the heating device 15. However, in the embodiment disclosed in fig. 2 the flow of

pyrolysis gas towards the gasifier 7 is generated by the recycling means 14 and/or the pressure generated by the pyrolysis process in the pyrolysis units 2.

In the combustion unit 17 the pyrolysis gas is partially oxidized in that air, oxygen  
5 enriched air or pure oxygen is added to the pyrolysis gas through an oxidation inlet 28 so that a part of the pyrolysis gas is combusted, which in turn will raise the temperature of the resulting heating gas to around 1,150°C (or at least typically in the 900-1300°C range) before the heating gas leaves the heating device 15 through an output conduit 18 arranged to guide the heating gas to a gasifier inlet 10 of the gasifier 7. Heating the  
10 gas to this relative high temperature level ensures a more efficient tar decomposition.

However, heating gas that is this hot might damage the gasifier 7 and particularly the grate device 25 on which the pyrolyzed coke 13 rests in the gasifier 7 and in this embodiment the heating gas is therefore cooled to around 900-1,000°C (preferably  
15 around 950°C) before it enters the gasifier 7. In this embodiment, the heating gas is cooled by means of cooling means 21 including means for blowing steam into the heating gas through a cooling inlet 29. However, in another embodiment the cooling means 21 could also or instead be enabled otherwise – such as by blowing CO<sub>2</sub>, H<sub>2</sub>, CH<sub>4</sub>, biogas or other into the heating gas or by means of cooling tubes, a cooling  
20 shawl, a heat exchanger or other.

The cooled heating gas now enters the gasifier through the gasifier inlet 10 at the bottom 11 of the gasifier 7 from where it will flow upwards and thereby gasify the pyrolyzed coke to form a gas mixture named product gas which leaves the gasifier  
25 through the product gas outlet 8 arranged at the top 9 of the gasifier 7.

In this embodiment, some of the produced product is returned by means of a return conduit 30 so that it re-enters the gasifier 7 through the gasifier inlet 10 to help cooling the heating gas before it enters the gasifier 7.

It should be noted that the term “partial oxidation” in this embodiment means that some oxygen is added to the pyrolysis gas but not enough to fully combust the pyrolysis gas completely. I.e. in this specific embodiment enough oxygen is added that all the pyrolysis gas is approximately 35% combusted (which is a more correct way to put it than saying that 35% of the pyrolysis gas is combusted). However, in another embodiment the partial oxidation involves adding enough oxygen to combust all the pyrolysis gas between 10% and 60%, preferably between 25% and 50%. Furthermore, it should be noted that the oxygen may be added in the form of pure liquid or gaseous oxygen, an oxygen containing compound – such as air, methanol or other, a mixture of oxygen and water vapor, a mixture of oxygen and CO<sub>2</sub> and/or in another form and/or mixed with another gas or vapor.

The invention has been exemplified above with reference to specific examples of pyrolysis units 2, gasifiers 7, coke moving means 12 and other. However, it should be understood that the invention is not limited to the particular examples described above but may be designed and altered in a multitude of varieties within the scope of the invention as specified in the claims.

#### List

1. Gasification unit
2. Counterflow pyrolysis unit
3. Pyrolysis gas outlet
4. Upper part of pyrolysis unit
5. Pyrolysis gas inlet
6. Lower part of pyrolysis unit
7. Gasifier
8. Product gas outlet
9. Upper part of gasifier
10. Gasifier inlet
11. Lower part of gasifier
12. Coke moving means



- 13. Pyrolyzed coke
- 14. Recycling means
- 15. Heating device
- 16. Input conduit
- 5 17. Combustion unit
- 18. Output conduit
- 19. Heat exchange means
- 20. Filtering means
- 21. Cooling means
- 10 22. Screw conveyor
- 23. Fuel
- 24. Fuel inlet
- 25. Grate device
- 26. Ash outlet
- 15 27. Flow generator
- 28. Oxidation inlet
- 29. Cooling inlet
- 30. Return conduit

**Claims**

1. A gasification unit (1) for producing a product gas, said gasification unit (1) comprising,
- 5 a co-current or counterflow pyrolysis unit (2) comprising a pyrolysis gas outlet (3) arranged at an upper part (4) of said pyrolysis unit (2) and a pyrolysis gas inlet (5) arranged at a lower part (6) of said pyrolysis unit (2),
- a co-current or counterflow gasifier (7) comprising a product gas outlet (8) arranged
- 10 at an upper part (9) of said gasifier (7) and a gasifier inlet (10) arranged at a lower part (11) of said gasifier (7),
- coke moving means (12) for allowing pyrolyzed coke (13) to move from said pyrolysis unit (2) to said gasifier (7),
- 15 recycling means (14) arranged to guide at least a part of the pyrolysis gas produced in said pyrolysis unit (2) from said pyrolysis gas outlet (3) and back to said pyrolysis gas inlet (5),
- 20 a heating device (15) comprising an input conduit (16) arranged to guide pyrolysis gas from said pyrolysis gas outlet (3) to a combustion unit (17) in said heating device (15), wherein said combustion unit (17) is arranged to least a partially oxidize said pyrolysis gas from said pyrolysis unit (2), and wherein said heating device (15) comprises an output conduit (18) arranged to guide heating gas generated by said partial oxidization
- 25 in said combustion unit (17) to said gasifier inlet (10),
- wherein said heating device (15) is arranged external to said pyrolysis unit (2) and said gasifier (7) and wherein said gasification unit (1) further comprises heat exchange means (19) arranged for heating at least a portion of said pyrolysis gas before it enters

said pyrolysis unit (2) through said pyrolysis gas inlet (5) by means of at least a part of the product gas exiting said gasifier (7) through said product gas outlet (8).

2. A gasification unit (1) according to claim 1, wherein said pyrolysis gas is heated by said product gas directly in the same heat exchange means (19).

3. A gasification unit (1) according to claim 1, wherein said pyrolysis gas is heated in a first heat exchange means (19) and said product gas delivers heat in a second heat exchange means (19) and wherein a separate fluid flow ensures heat transfer between said first and said second heat exchange means (19).

4. A gasification unit (1) according to any of the preceding claims, wherein said heat exchange means (19) comprises at least one plate heat exchanger.

5. A gasification unit (1) according to any of the preceding claims, wherein said gasification unit (1) comprises cooling means (21) for cooling said heating gas to a temperature between 600°C and 1,200°C, preferably between 700°C and 1,100°C and most preferred between 800°C and 1,000°C before it enters said gasifier (7).

6. A gasification unit (1) according to claim 5, wherein said cooling means (21) comprises means for adding steam to said heating gas and/or adding product gas to said heating gas to cool said heating gas.

7. A gasification unit (1) according to any of the preceding claims, wherein said co-current or counterflow pyrolysis unit (2) is arranged on top of said co-current or counterflow gasifier (7).

8. A gasification unit (1) according to any of the preceding claims, wherein said coke moving means (12) comprises a screw conveyor (22).

9. A method for producing a product gas in a gasification unit (1), said method comprising the steps of:

- feeding fuel (23) to a co-current or counterflow pyrolysis unit (2),
- circulating at least a part of the pyrolysis gas produced by said fuel (23) in said  
5 pyrolysis unit (2) back into said pyrolysis unit (2) to form a flow of pyrolysis  
gas up through said fuel (23),
- heating said pyrolysis gas before it re-enters said pyrolysis unit (2)
- pyrolyzing said fuel (23) by means of said re-entering heated pyrolysis gas
- enabling that said pyrolyzed fuel (23) in said pyrolysis unit (2) is moved to a  
10 gasifier (7)
- combusting at least a part of said pyrolysis gas outside said pyrolysis unit (2)  
and said gasifier (7) to form heating gas,
- guiding said heating gas into said gasifier (7) to heat said pyrolyzed fuel to  
produce a product gas, wherein said pyrolysis gas is heated by means of said  
15 product gas before said pyrolysis gas re-enters said pyrolysis unit (2).

10. A method according to claim 9, wherein said pyrolysis gas is heated by means of  
said product gas by guiding said pyrolysis gas and said product gas through the same  
heat exchanger means (19).

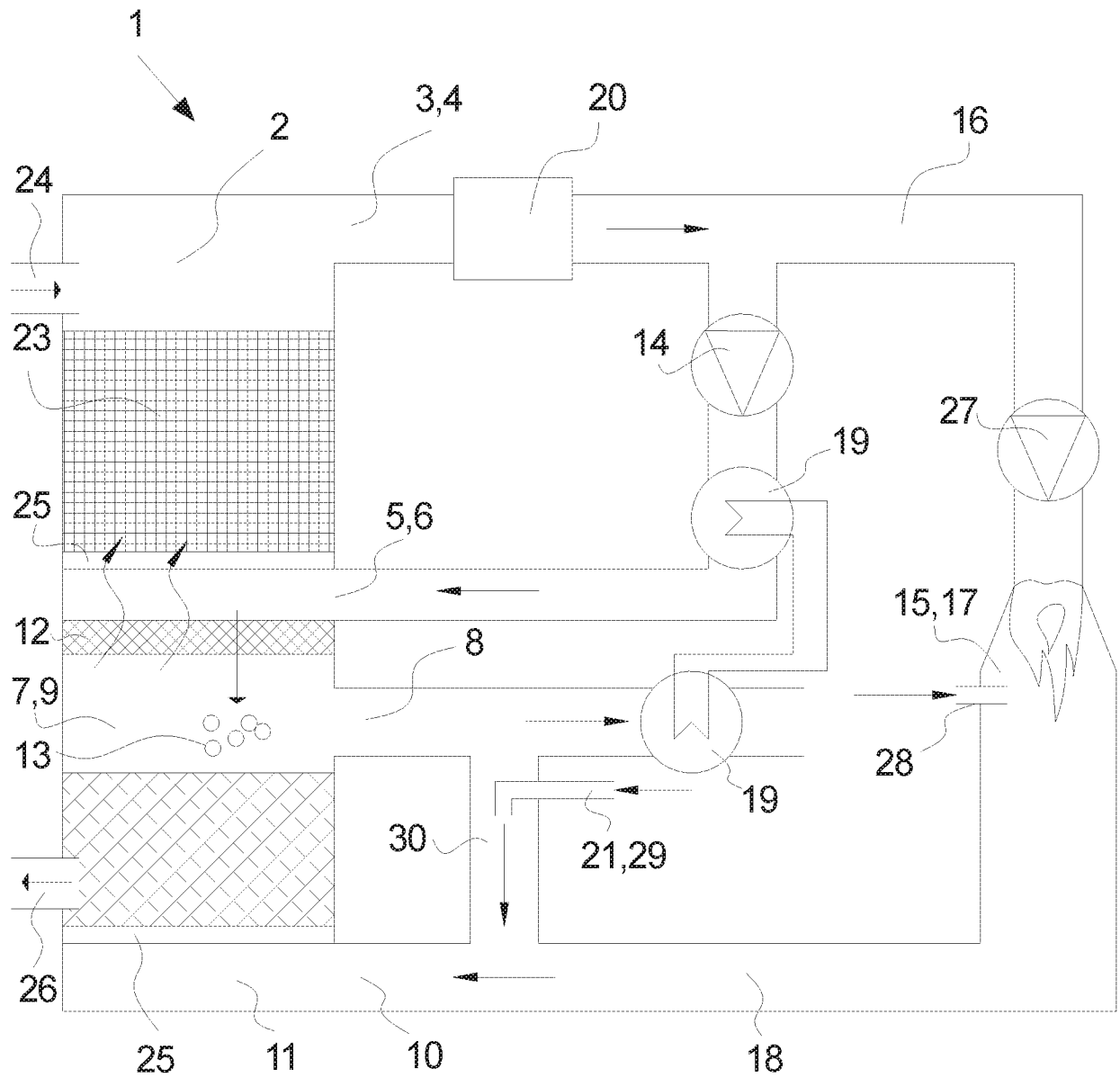
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11. A method according to claim 9, wherein said pyrolysis gas is heated by means of  
said product gas by guiding said pyrolysis gas through a first heat exchange means  
(19) and guiding said product gas through second heat exchange means (19) and  
establish a separate fluid flow between said first and said second heat exchange means  
25 (19) to transfer heat between said first and said second heat exchange means.

12. A method according to claims 9 to 11, wherein between 1% and 95%, preferably  
between 5% and 70% and most preferred between 10% and 50% of the pyrolysis gas  
produced by said fuel (23) in said pyrolysis unit (2) is circulated back into said  
30 pyrolysis unit (2) to form a flow of pyrolysis gas up through said fuel (23).

13. Use of a method according to any of claims 9 to 12 for producing a product gas from biomass in a gasification unit (1) according to any of claims 1-8.

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*Fig. 1*

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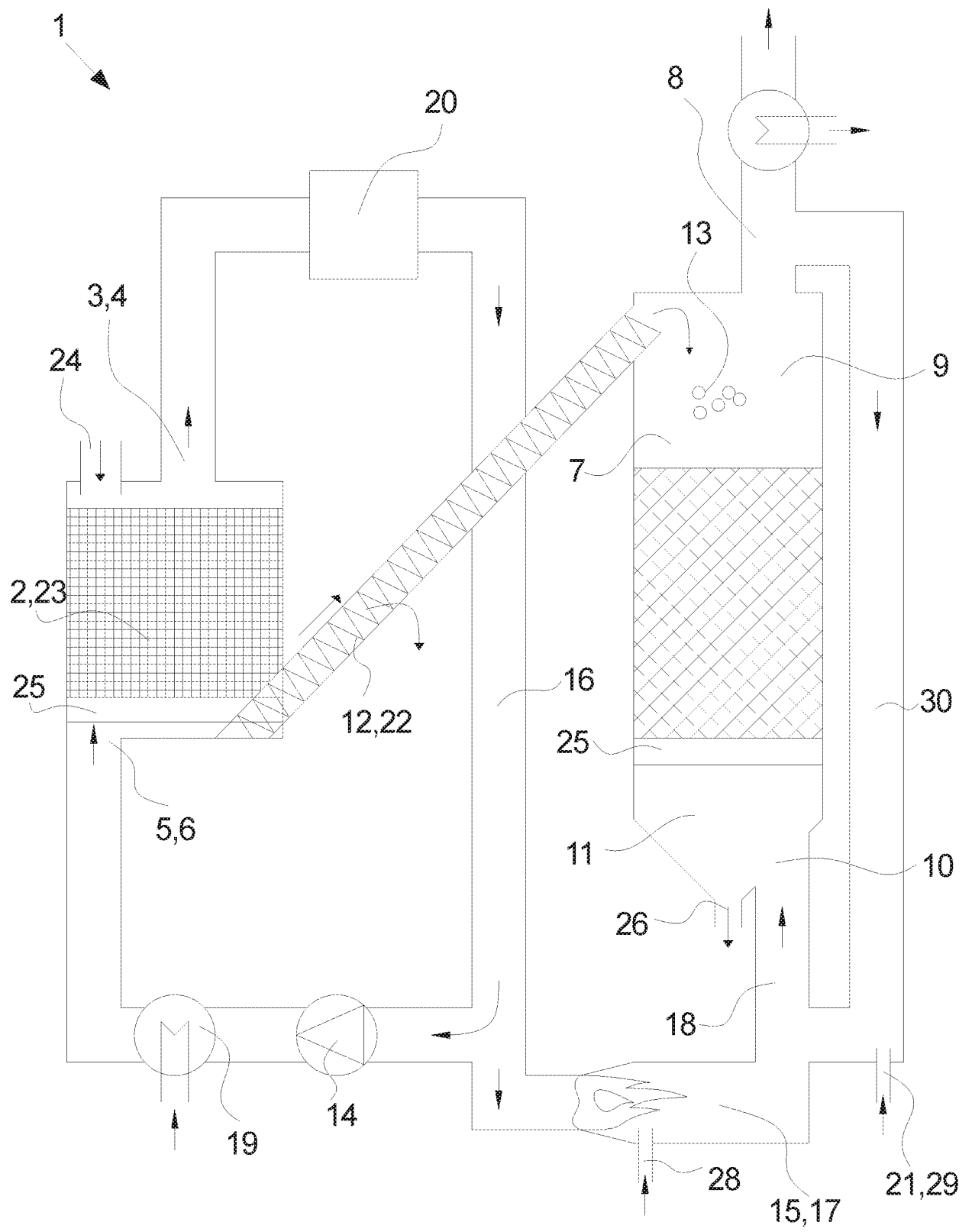


Fig. 2

## INTERNATIONAL SEARCH REPORT

International application No

PCT/DK2018/050256

A. CLASSIFICATION OF SUBJECT MATTER  
 INV. C10J3/36 C10J3/66  
 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.
Y	US 2013/000569 A1 (SCHNEIDER ARNO [DE] ET AL) 3 January 2013 (2013-01-03) paragraph [0071]; figure 1 paragraph [0150] - paragraph [0159] -----	1-13
Y	US 2013/026419 A1 (SONG KAN [CN] ET AL) 31 January 2013 (2013-01-31) paragraph [0059]; figure 1 -----	1-13
A	WO 2008/107727 A2 (ELEFSINIOTIS LAMPROS [GR]) 12 September 2008 (2008-09-12) the whole document -----	1-13



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

6 December 2018

Date of mailing of the international search report

02/01/2019

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/DK2018/050256

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