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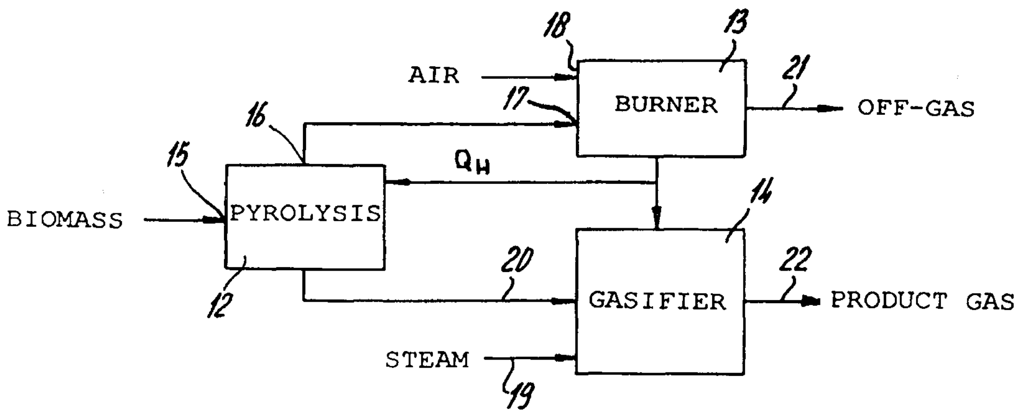

(57) Abstract

The invention relates to a method and device for forming synthesis gas from biomass. In a pyrolysis zone, the biomass is converted into a solid carbonization product (char) and into gaseous pyrolysis products. The gaseous pyrolysis products are burnt in a burner zone and supply the heat for the endothermic pyrolysis process and for an endothermic gasification process for forming synthesis gas. The carbonization products are fed to the gasification zone, in order to be converted, for example by means of steam, into H2 and CO. The fact that the gaseous pyrolysis products and the off-gases from the combustion zone are separate from the gasification zone results in a product gas with a high calorific value which is virtually free of nitrogen. The fact that the solid carbonization products from the pyrolysis process are fed to the gasifier results in a very pure product gas which is free of contaminants which are usually formed when gaseous pyrolysis products are converted into synthesis gas. The device according to the present invention can therefore be operated without using complex purification installations.

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Method and device for forming synthesis gas from biomass and residual materials

The invention relates to a method and a device for forming synthesis gas from non-fossil, carbon-containing biological material (biomass), which device comprises:

- a pyrolysis zone, having a first feed for the carbon-containing material, having a second feed for an inert heat-transfer material, for forming gaseous pyrolysis products and a solid carbonization product (char) virtually in the absence of oxygen, and having a discharge for the heat-transfer material and the carbonization product,
- a combustion zone for heating the heat-transfer material, having a first feed for an oxidizing agent, and having a second feed for the heat-transfer material, and
- a gasification zone, having a first feed for a gasification agent, having a second feed, which is connected to the pyrolysis zone, for feeding the heat-transfer material and the carbonization product formed in the pyrolysis zone, having a first discharge for product gas formed in the gasification zone, and having a second discharge for the heat-transfer material, and also having a first discharge for combustion gases formed in the combustion zone, and having a second discharge for the heat-transfer material, and
- a return path, which is located between the second discharge of the gasification zone and the second feed of the pyrolysis zone, for feeding the heat-transfer material from the gasification zone to the pyrolysis zone.

Currently, mineral oil is the most important raw material for producing organic chemicals and transport fuels. In addition, natural gas is used to produce liquid secondary energy carriers. In view of the expected scarcity of supplies of mineral oil and natural gas in future, alternative raw materials which contain carbon and hydrogen are being sought for the production of liquid secondary energy carriers. Often biomass is used, an additional advantage of which is that virtually no $CO2$ is produced in net terms. When biomass is being converted into liquid energy carriers, the hydrocarbon structures, in particular clusters of cyclic hydrocarbons, have to be partially broken down. The conversion routes which are available for converting biomass into synthesis gas, i.e. the "upstream processes" are gasification, hydro)pyrolysis, direct liquefaction, and biological processes. The ideal product gas as a raw material for producing liquid energy carriers, i.e. "downstream processes" has a high calorific value (without nitrogen), so that a relatively small volumetric flow is required in a compact "downstream" installation, and is clean, without tar-like materials.

In the Battelle process developed in the United States, biomass is gasified to form a product gas with a relatively high calorific value which is suitable for combustion in a gas turbine. This product contains no nitrogen but does contain residual tar-like materials. Without a gas-purification installation, the abovementioned processes are not directly suitable for the production of secondary energy carriers.

US-A-3,853,498 discloses a device with two fluidized-bed reactors which are coupled together. In the first reactor, finely ground biomass is converted by pyrolysis in a fluidized sand bed, in the absence of oxygen, into gaseous pyrolysis products, such as CO, CO_2 and other gaseous pyrolysis products, and into a solid carbonization product (char). The solid carbonization product is fed with the sand from the first reactor to a combustion zone in the second reactor, where the carbonization product is burnt by adding air via a booster. Via a return line, the heat-transfer material (sand), which has been heated in the fluidized-bed combustion zone, is returned to the pyrolysis reactor, in order to provide the energy required for the endothermic pyrolysis reaction. Gaseous pyrolysis products from the pyrolysis reactor are converted into methane in a water gas shift reactor, a CO_2 scrubber and a methanization reactor.

Japanese patent application No. 56038719 discloses a fluidized-bed reactor in accordance with the preamble of Claim 1, for gasification of particulate material, with three annular outer zones, which are separate from one another, and, coaxially with the outer zones, three inner zones, which are separated by partitions. In a first pyrolysis zone, the combustible carbon-containing organic material is converted by pyrolysis into gaseous pyrolysis products and a carbonization product. In a following zone, some of the carbonization product is burnt, with the result that the bed material is heated, and then the bed material, together with the remaining solid carbonization product, is fed to a gasification zone in which steam or CO2 is introduced as the gasification agent. The product gas is discharged from the gasification zone, while the cooled bed material is recirculated to the pyrolysis zone.

European patent application EP-A-0,219,163 discloses a process for cracking hydrocarbons in which the carbonization products, which have been deposited on a solid material, are fed from the pyrolysis zone to a gasification zone for forming hydrogen-containing product gas while steam is being fed in. The process heat which is required is supplied by combustion of at least some of the product gas (synthesis gas), specifically in such a manner that pyrolysis takes place at the highest process temperatures and gasification at the lowest process temperatures.

Drawbacks of the abovementioned systems are that the product gas from the gasification zone comprises relatively large amounts of tar-like materials and that relatively complex gas-purification installations are required in order to purify the product gas, which product gas is not directly suitable as an "upstream" process for the production of liquid energy carriers. Furthermore, the product gas, when air is used as the oxidizing agent, comprises relatively large amounts of nitrogen, with the result that the calorific value is reduced. Owing to the combustion of the product gas to supply the heat required for the gasification, the known processes are relatively inefficient. Moreover, in the process according to EP-A-0,219,163, the yield of pure product gas is relatively low owing to the unfavourable temperature distribution.

Therefore, one object of the present invention is to provide a relatively simple device for efficiently forming synthesis gas from biomass which results in a clean product gas with a high calorific value.

To this end, the device according to the present invention is characterized in that the pyrolysis zone and the combustion zone are connected to the gasification zone in such a manner that at least virtually no gaseous products are able to pass from the combustion zone and the pyrolysis zone to the gasification zone, a gas discharge of the pyrolysis zone being connected to a third feed leading to the combustion zone, in order to feed the solid carbonization product to the combustion zone separately from substantially completely gaseous pyrolysis products.

The invention is based on the insight that the pyrolysis zone and the combustion zone are separated from the gasification zone in such a manner that it is impossible for gaseous pyrolysis products or combustion gases to reach the gasification zone and that at least substantially only the solid carbonization product is converted into product gas in the gasification zone. Since the solid carbonization product is relatively pure and is free from tar-like and/or cyclic hydrocarbon compounds, a pure product gas which comprises CO, CO2 and H2 is obtained at the gas discharge from the gasification zone. Since no off-gases from the combustion zone are fed to the gasification zone, the product gas does not contain any nitrogen, so that it may have a high calorific value. The product gas or synthesis gas can be converted directly into desired hydrocarbon products, without using complex gas-purification and air-separation installations.

The heat-transfer or bed material, in addition to its function in a normal fluidized-bed system, also has the dual function of both heat transfer and mass transfer. The heat produced in the combustion zone is transferred to the bed material and is then transferred to the gasification zone together with the carbonization products, by means of the bed material. In the gasification zone, the bed material is cooled by the endothermic gasification process, after which the cooled bed material is recirculated to the pyrolysis zone ("coke producer"). Together with the hot bed material, the carbonization product formed in the pyrolysis zone is transported from the pyrolysis zone to the gasifier.

The pyrolysis according to the invention takes place at relatively low temperatures, such as between 300°C and 500°C. The gasification takes place at relatively high temperatures, such as for example around 850°C. The device according to the present invention therefore results in optimum separation of product gas and undesirable components, such as tar from the biomass and nitrogen from the air. Since the pyrolysis product comprises a condensable fraction and a non-condensable fraction, and excess heat is produced in the process, it may be useful also to separate the hot pyrolysis gas and to use one of the components for combustion and another for an alternative application.

In a first embodiment of a device according to the invention, the combustion zone is located in a separate burner, the discharge of the heat-transfer agent and the carbonization product from the pyrolysis zone being connected to the gasifier. The heat for this gasifier is transferred from the burner via the bed material. This cooled bed material is passed on to the pyrolysis reactor. Bed material from the gasifier, from which its carbonization product has been removed, is also returned to the burner. As a result of a separate burner being used, which may, for example, comprise a riser, it is possible, as a result of combustion of part of the pyrolysis product, to generate ample heat for the pyrolysis and for the gasification and to regulate this heat accurately. The heat which is generated in the burner and is not required for pyrolysis and the gasification process is available as a high-grade energy carrier, but may also be used within the process for pretreatment of the biomass and for steam production. The heat can also be used to drive a pneumatic particle conveyor for the heat transfer material, and may furthermore be used to enable the system to operate at pressure (approx. 7 bar) and to compress the product gas to approximately 40 bar. The latter compression step provides a base material which can be converted directly to methanol or another hydrocarbon.

In another embodiment of the device according to the invention, the burner is located within the pyrolysis zone. In this case, partial combustion of the biomass is achieved in the pyrolysis zone as a result of regulating the amount of air and gaseous pyrolysis products fed to the pyrolysis zone.

In a further embodiment of the device according to the invention, a second burner is connected to the gas discharge of the pyrolysis zone for combustion of some of the gaseous pyrolysis products, which second burner is thermally connected to a water feed for the generation of steam, which steam, via a steam line, is connected to the first feed of the gasification zone. By combustion of gaseous pyrolysis products, it is possible to generate steam which can be used in the gasifier as a gasification agent for converting carbon from the solid carbonization products in the gasifier to CO and H2.

An advantageous and compact device according to the present invention is formed by an "interconnected fluid bed" (IFB) reactor as an alternative to reactor systems with pneumatic particle transport. The IFB reactors provide particle transport, and therefore, in this case, mass transfer and heat transfer, by regulating the gas velocities for fluidization, with the result that there is very little damage to the particles of the heat-transfer material, and loss of material remains limited. Furthermore, the IFB reactors are relatively small, so that they take up little floor space. In the IFB reactor, both the pyrolysis zone and the gasification zone form a two-stage reactor, in which the heat-transfer medium can flow from the first, high column, via a common free edge, into the adjoining column of lower height. Via an opening in the lower column of the pyrolysis zone, the heat-transfer material and the carbonization product can pass to the higher column of the gasification zone. From the lower column of the gasification zone, the cooled heat-transfer material can move back into the higher column of the pyrolysis zone through an opening located in the vicinity of the underside. The four columns (or a multiplicity thereof) are connected to one another in a thermally conductive manner via a partition so that, if desired, complete thermal integration takes place. Due to the absence of mechanical transport means, there is little wear to components and particles. The compact, insulated IFB reactor exhibits a minimal heat loss to the environment and is simple to control.

A number of embodiments of the device according to the present invention will now be explained in more detail with reference to the appended drawing, in which:

Fig. 1 shows a diagrammatic depiction of the method and of the operating principle of the device according to the present invention,

Fig. 2 shows a diagrammatic depiction of a device for forming synthesis gas according to the present invention,

Fig. 3 shows a device according to the present invention with an external burner,

Fig. 4 shows an interconnected fluidized-bed reactor [(IFB) reactor] which operates using the principle shown in Fig. 3 or Fig. 5, and

Fig. 5 shows a second embodiment of a device according to the present invention, with a burner integrated in the pyrolysis zone.

Fig. 1 shows an integrated pyrolysis zone and burner, otherwise known as "coke producer" 1, having a first feed 2 for biomass and having a second feed 3 for a bed material, such as for example sand or a catalytically active material for controlling the product quality. In this context, "biomass" is intended to mean a carbon-containing material, other than fossil carbon sources, derived for example from vegetable, fruit and garden waste, cellulose residues, domestic waste containing plastics, and the like. Via a feed 4, an oxidizing agent, such as air or pure oxygen, is fed to the combustion zone of the coke producer 1. In the combustion zone of the coke producer, in which, for example, some of the gaseous pyrolysis products are burnt, the temperature is brought to 1500°C, so that biomass is converted at a temperature of 300°C - 500°C into volatile gases and tar-like materials, and into a solid carbonization product (char). The off-gases from the combustion zone of the coke producer 1, such as CO2, H2O and non-combusted gaseous pyrolysis products, are separated from the solid pyrolysis products, i.e. "coke or char", and are removed from the coke producer via a discharge 5. Via a discharge 6, the solid pyrolysis products, together with the heated bed material, are discharged from the coke producer 1 to a feed 9 of a gasifier 7. Via a feed 8, steam is fed to the gasifier 7 as a gasification agent for converting the coke or char into a product gas which is clean (i.e. free from tar-like materials) and has a high calorific value (i.e. without nitrogen). The heat required for the endothermic gasification reaction is supplied by the bed material, the temperature of which, at the location of the gasifier, is at most 1200°C, for example approx. 850°C. The following endothermic reaction takes place in the gasifier: $C + H2O \rightarrow CO + H2$, the mixture of CO and H2 being referred to as "synthesis gas", which is removed from the gasifier 7 via a discharge 10. The heat which is required to produce the synthesis gas in the gasifier is supplied by the bed material which, after cooling, is removed from the gasifier via a discharge 11 at a temperature of at most 800°C and is recirculated to the coke producer 1. The advantage of the process in accordance with Fig. 1 is that gasification of the solid pyrolysis products or coke results in a very pure product gas and that, as a result of the off-gases from the coke producer 1, including the gaseous pyrolysis products and combustion products, being separated from the gasification zone, the product gas has a high calorific value.

Fig. 2 shows a diagrammatic embodiment of a device according to the present invention, having a pyrolysis reactor 12, a burner 13 and a gasifier 14. The biomass which is fed to the pyrolysis zone 12 via a feed 15 is converted into gaseous pyrolysis products, including tar-like materials, which, via a discharge 16, are guided to a feed 17 of the burner 13. In the burner 13, the gaseous pyrolysis products are burnt with air. The heat QH produced is transferred to the gasifier 14, in which the steam and solid carbonization products introduced via feeds 19 and 20 are converted into product gas. Some of the heat QH generated in the burner 13 is transferred to the pyrolysis reactor 12. The combustion gases are discharged from the burner 13 via a discharge 21, while the product gas is discharged from the gasifier via a discharge 22, to a downstream process stage, such as in order to supply liquid product. The pyrolysis reactor 12 and the gasifier 14 may be designed as circulating fluidized beds which are known per se, while the burner 13 may be designed as a riser. The pyrolysis reactor 12 may be connected to the gasifier 14 and the burner 13 via cyclones.

Fig. 3 shows a first embodiment of a device according to the present invention having a pyrolysis reactor 23, a gasifier 24 and a separate burner 25. The pyrolysis reactor 23 comprises a first feed 26 for biomass, a second feed 27 for feeding bed material, and a third feed 28, along which some of the gaseous pyrolysis products are recirculated to the pyrolysis reactor 23. Recirculation of the gaseous pyrolysis products is used where the pyrolysis reactor is of the fluidized-bed type, in order to obtain fluidization. The gaseous pyrolysis products may be condensed out, in which case, if desired, the gaseous or condensed fraction may be used for some other purpose. That fraction of the pyrolysis products which is used within the process is fed to the burner 25 via a feed 29. The bed material and air are introduced into the burner 25 via feeds 30 and 31, for combustion of the gaseous pyrolysis products. The off-gases are discharged from the burner 25 via discharge 32. From the burner 25, heated bed material is fed to the gasifier 24 via feed 33.

If the burner 25 is formed by a riser, the hot outlet of the riser is also the highest point, so that it is possible to transport particles under the influence of the force of gravity. The cold inlet is the lowest point, with the result that here too the particles flow from the gasifier to the riser under the influence of gravity. Via a feed 35, steam is fed to the gasifier 24, and via a feed 36 bed material, containing the solid carbonization products, enters the gasifier 24. The product gases leave the gasifier 24 via a product-gas discharge 37, while the cooled bed material is guided to the burner 25 via discharge 34. Via a discharge 38, hot bed material is guided from the burner 25 to the gasifier

24 and, after it has released heat in the gasifier, is guided to the pyrolysis reactor 23. It is also possible to guide sub-streams from the burner direct to the gasifier and the pyrolysis reactor, which may provide advantages in terms of control engineering. As a result of fluidization, the bed material is mixed with the solid carbonization products in the pyrolysis reactor 23, which are transferred from the pyrolysis reactor to the gasifier 24 via discharge 39.

An excess of gaseous pyrolysis products formed in the process may be discharged via a blow-off pipe 40.

An alternative embodiment is that in which the pyrolysis and combustion are integrated in a single system. Fig. 4 shows this with a diagrammatic, perspective illustration of an IFB reactor, which integrates the gasification and pyrolysis. An IFB reactor in accordance with Fig. 4 comprises the compartments 40 and 41 of the pyrolysis reactor, as well as the compartments 42 and 43 of the gasifier, which are separated from one another, and a single, common heat-transferring wall. A common partition 58 separates the compartments 40, 41 from the compartments 42 and 43. All the compartments 40-43 are surrounded by a common outer wall 57. Consequently, the total height of all the compartments is in principle equal. The compartments 40, 41 are in communication with one another via a common free edge 59. The compartments 42 and 43 are connected via a free edge 60. The compartment 41 of the pyrolysis zone is in communication with the compartment 42 of the gasification zone via one or more openings in the partition 58, slightly above the gas-distribution plate of the fluid bed. The same applies for the connection between the compartment 43 and the compartment 40, which is formed by an opening 54, 55 in the partition 58.

The action of the reactor shown in Fig. 4 may be presented as a system of four communicating vessels. In gas-fluidized solids systems, it is possible to create density differences between two adjoining compartments by fluidizing each of the compartments with a different gas velocity. As a result of the compartments 40 and 42 being fluidized at a relatively high velocity and the compartments 41 and 43 being fluidized at a relatively low velocity, particle transport takes place through the system of the four compartments, from the compartment 40 via the free edge 59, to the compartment 41, and, via the opening located on the underside, to the underside of the compartment 42. From the compartment 42, particle transport takes place via the free edge 60 and, from the underside of the compartment 43, via the openings 54 and 55, back to the compartment 40.

At the top, the IFB reactor is closed off by a cap 60 with a first compartment 61 which adjoins compartments 40, 41 and is separate from a second compartment 62 which adjoins the compartments 42, 43 of the gasification zone. The cap 60 is provided with an intermediate wall 63 which adjoins the partition 58.

In the structure shown in Fig. 4, the burner, in order to supply the heat for the endothermic reactions (pyrolysis and gasification), may be located either outside the reactor, in a separate riser, as shown by the diagrammatic representation of Fig. 3, or inside the compartment 41 of the pyrolysis zone, as shown by the diagrammatic representation in Fig. 5.

The fact that the pyrolysis zone 41 and the gasification zone 43 are fluidized at a relatively low velocity, while the pyrolysis zone 40 and the gasification zone 42 are fluidized at a relatively high velocity, results in particle transport through the system in the direction of the first pyrolysis zone 40, towards the second gasification zone 43. In this case, the primary function of the pyrolysis zone 41 and the gasification zone 43 is to transport particles, but they also form an additional reactor stage in the two-stage conversion, and considerable heat exchange takes place between the bed material and the solid pyrolysis products. Since the average residence time of the particles in the pyrolysis reactor 41 and in the gasifier 43 is generally short, the dimensions (i.e. the bed surface) are relatively small, so that only small quantities of gas are required for fluidization. Furthermore, one of the compartments 41, 43 which are fluidized at a low velocity may be used for controlling the particle transport through the reactor.

Fluidization of the pyrolysis reactor and/or gasification reactor can be increased by recirculation of the pyrolysis gases or the gasification product. The latter takes place together with the steam which has to be supplied in any case.

Fig. 5 shows an interconnected fluid bed system (IFB) with two pyrolysis zones 40, 41 and two gasification zones 42, 43. The biomass is introduced into the first pyrolysis zone 1 via a first feed 44. The gaseous pyrolysis products are guided out of the pyrolysis zones 40, 41 to an external burner 46 via a discharge 45, and are partially recirculated to feeds 47 and 48. In the second pyrolysis zone 41, the recirculated pyrolysis gas is burnt in an internal combustion zone 41 with the addition of air via feed 50. Via a feed 51, which is located in the vicinity of the underside of the gasifier 42, hot bed material and solid carbonization products enter the first gasifier 42, inside which they are partially converted into product gas. The remaining carbonization products enter the second gasification zone 43 at the top of the first gasification zone. The product gas is discharged from the gasification zones 42 and 43 via a discharge 53. The cooled bed material is returned to a feed 55 of the first pyrolysis zone 40 via a discharge 54. Steam is generated using the external burner 46 which, via a steam line 56, is connected to the first and second gasifiers 42, 43.

CLAIMS

1. Device for forming synthesis gas from non-fossil, carbon-containing biological material (biomass), comprising
- a pyrolysis zone (23; 40, 41), having a first feed (26; 44) for the carbon-containing material, having a second feed (27; 55) for an inert heat-transfer material, for forming gaseous pyrolysis products and a solid carbonization product (char) virtually in the absence of oxygen, and having a discharge (39; 52) for the heat-transfer material and the carbonization product,
- a combustion zone (25; 49) for heating the heat-transfer material, having a first feed (30; 50) for an oxidizing agent, and having a second feed (31; 51) for the heat-transfer material, and also having a first discharge (32; 45) for combustion gases formed in the combustion zone, and having a second discharge (38; 52) for the heat-transfer material, and
- a gasification zone (24; 42, 43), having a first feed (35; 56) for a gasification agent, having a second feed (36; 51), which is connected to the pyrolysis zone, for feeding the heat-transfer material and the carbonization product formed in the pyrolysis zone, having a first discharge (37; 53) for product gas formed in the gasification zone, and having a second discharge (34; 54) for the heat-transfer material, and
- a return path, which is located between the second discharge (34; 54) of the gasification zone and the second feed (27; 55) of the pyrolysis zone, for feeding the heat-transfer material from the gasification zone (24; 42, 43) to the pyrolysis zone (23; 40, 41), characterized in that the pyrolysis zone (23; 40, 41) and the combustion zone (25; 49) are connected to the gasification zone (24; 42, 43) in such a manner that at least substantially no gaseous products are able to pass from the combustion zone and the pyrolysis zone to the gasification zone, a gas discharge (28; 45) of the pyrolysis zone being connected to a third feed (29; 48) leading to the combustion zone (25; 49), in order to feed the solid carbonization product to the combustion zone separately from substantially completely gaseous pyrolysis products.

2. Device according to Claim 1, characterized in that the combustion zone is located in a separate burner (25), the discharge from the pyrolysis zone (39) for discharging the heat-transfer agent and the carbonization product, via the second feed (36) and the second discharge (34) of the gasification zone (24), being connected to the second feed (31) of the combustion zone (25), and a discharge (38) of the combustion zone (25), via a third feed (33) of the gasification zone (24), being connected to the second feed (27) of the pyrolysis zone.

3. Device according to Claim 1, characterized in that the combustion zone (29) is located within the pyrolysis zone (41).

4. Device according to Claim 1, 2 or 3, characterized in that a second burner (46) is connected to the gas discharge (45) of the pyrolysis zone (40, 41) for combustion of some of the gaseous pyrolysis products, which second burner (46) is thermally connected to a water feed for the generation of steam, which steam, via a steam line (56), is connected to the first feed of the gasification zone.

5. Device according to one of the preceding claims, characterized in that the device comprises at least four sub-reactors, in the form of at least four columns, the pyrolysis zone and the gasification zone each comprising a first column (40, 42) of a predetermined height and a second column (41, 43) of a lower height, which is positioned against the first column (40, 42), a free edge (59, 60) of which first column (40, 42) projects above the lower column (41, 43), the first feed (44) of the pyrolysis zone (40, 41) being located in the vicinity of the underside of the first column (40) of the pyrolysis zone, and the second feed (51) of the gasification zone being formed by an opening in the vicinity of the underside of the first, higher column (42) of the gasification zone, which opening opens out in the vicinity of the underside of the second, lower column (41) of the pyrolysis zone (40, 41), the heat-transfer material being able to pass, via the free edge (59, 60) of the respective first, higher column (40, 42) of the pyrolysis zone and of the gasification zone, to the respective second column (41,

43) of the pyrolysis zone and the gasification zone, the second discharge (54) of the gasification zone (42, 43) being formed by an opening (54, 55) in the vicinity of the underside of the second column (43) of the gasification zone, which opens out in the vicinity of the underside of the first column (40) of the pyrolysis zone (40, 41), the columns (40, 41) of the pyrolysis zone opening out, on the topside, in a first cap (61) containing the gas discharge, the columns of the gasification zone (42, 43) opening out in a second cap (62), which is separate from the first cap, containing the first discharge for the product gas, and with a gas-feed opening, in the vicinity of the underside of each of the columns (40, 41, 42, 43), for feeding a fluidizing gas in order to fluidize the heat-transfer material.

6. Device according to Claim 5, characterized in that some of the gaseous pyrolysis product is fed from the gas discharge to the undersides of the first and second columns (40, 41) of the pyrolysis zone, and gaseous gasification agent being fed to the undersides of the two columns (42, 43) of the gasification zone.

7. Assembly of a device according to one of the preceding claims and a compressor which is thermally connected to the device for compressing the product gas, a generator for generating electricity, or a condenser for condensing a condensable fraction of the pyrolysis product, or combinations thereof.

8. Method for forming synthesis gas from non-fossil, carbon-containing material, comprising the following steps:

- feeding the carbon-containing material to a pyrolysis zone and converting the material into gaseous pyrolysis products and into a solid carbonization product,
- separating the solid pyrolysis products and the gaseous pyrolysis products,
- feeding the solid carbonization products to a gasification zone,
- burning at least some of the gaseous pyrolysis products in a combustion zone, and feeding heat from the combustion zone to the gasification zone, and

- feeding a gasification agent to the gasification zone and converting the solid carbonization product into CO and H2.

9. Method according to Claim 8, characterized in that the temperature in the pyrolysis zone is no lower than 600°C, preferably between 300°C and 500°C, and in that the temperature in the gasification zone is between 600°C and 1200°C, preferably between 700°C and 900°C.

Fig-1

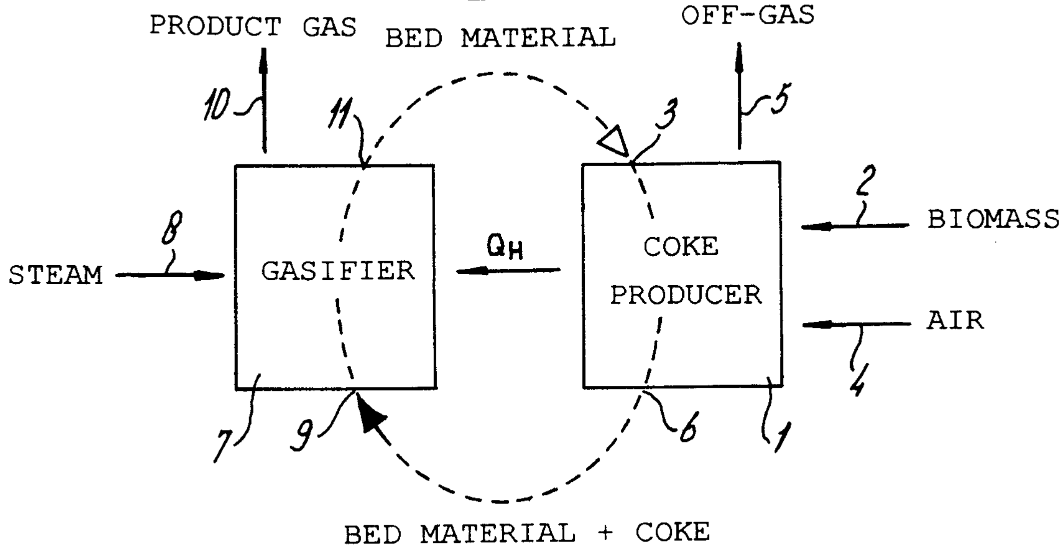


Fig-2

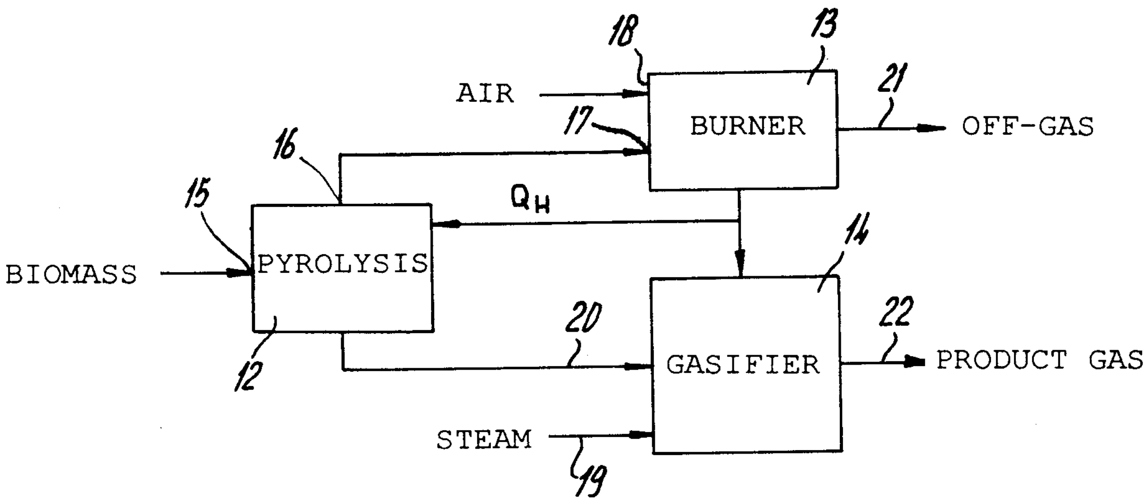


Fig-3

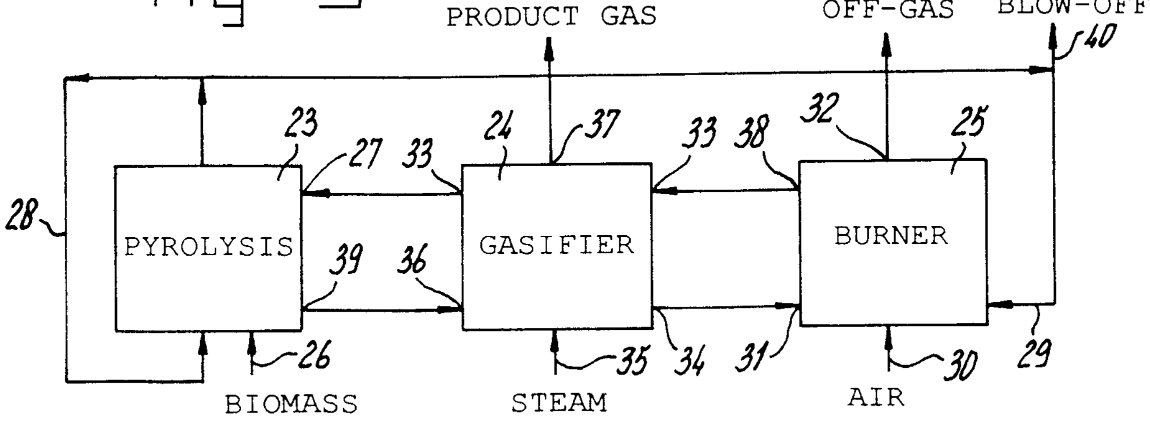


fig-4

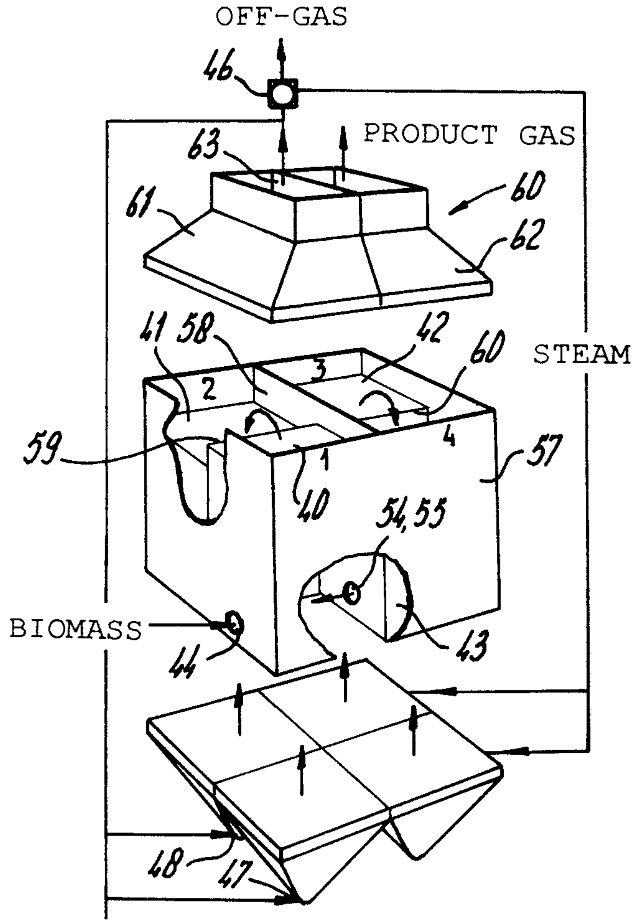
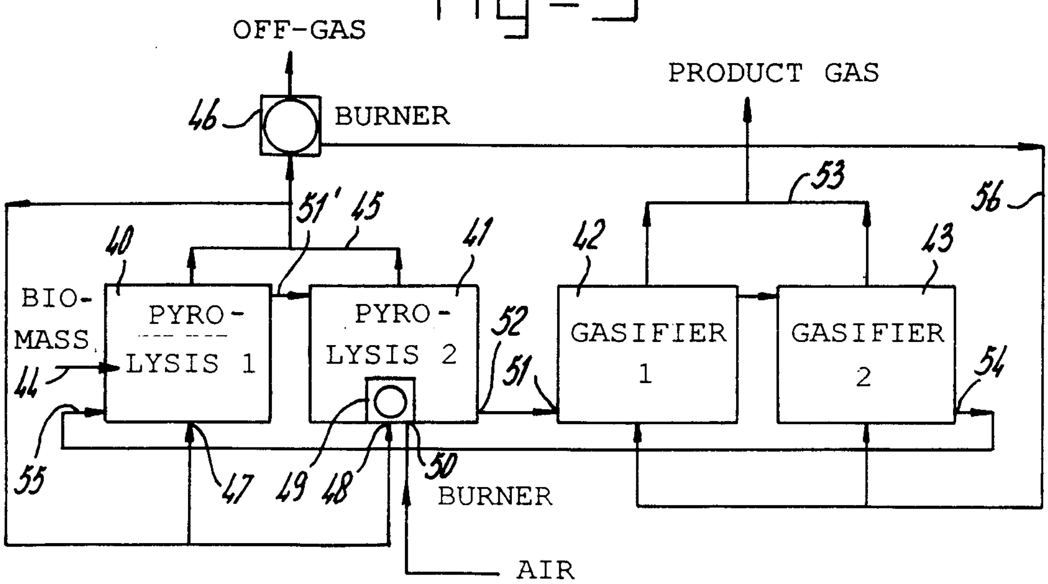

OFF-GAS
46
PRODUCT GAS
63
60
61
62
41 58
42
60
STEAM
3
2
4
1
59
57
40
54,55
BIOMASS
44
43
48
47

fig-5


OFF-GAS
PRODUCT GAS
46
BURNER
53
56
51' 45
40
41
42
43
BIO-
MASS
PYRO-
LYSIS 1
PYRO-
LYSIS 2
52
GASIFIER
1
GASIFIER
2
44
51
54
55
47
49
48
50
BURNER
AIR

Key to figures:

Fig. 1:

1. BED MATERIAL
2. OFF-GAS
3. STEAM
4. GASIFIER
5. COKE PRODUCER
6. BIOMASS
7. AIR
8. BED MATERIAL + COKE

Fig. 2:

1. AIR
2. BURNER
3. OFF-GAS
4. BIOMASS
5. PYROLYSIS
6. GASIFIER
7. PRODUCT GAS
8. STEAM

Fig. 3:

1. PRODUCT GAS
2. OFF-GAS
3. BLOW-OFF
4. PYROLYSIS
5. GASIFIER
6. BURNER
7. BIOMASS
8. STEAM
9. AIR

Fig. 4:

1. OFF-GAS
2. PRODUCT GAS
3. STEAM
4. BIOMASS

Fig. 5:

1. OFF-GAS
2. BURNER
3. PRODUCT GAS
4. BIOMASS
5. PYROLYSIS 1
6. PYROLYSIS 2
7. GASIFIER 1
8. GASIFIER 2
9. BURNER
10. AIR

INTERNATIONAL SEARCH REPORT

International Application No
PCT/NL 99/00481

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C10J3/12 C10J3/66 C10J3/58 C10J3/54 C10J3/56

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)
IPC 7 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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	page 5-7; claims 1-14	1,7

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in 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.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 October 1999	10/11/1999

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, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Meertens, J

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Internatic Application No
PCT/NL 99/00481

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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