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(54) **METHOD AND EQUIPMENT FOR PYROLYTIC CONVERSION OF COMBUSTIBLE MATERIAL**

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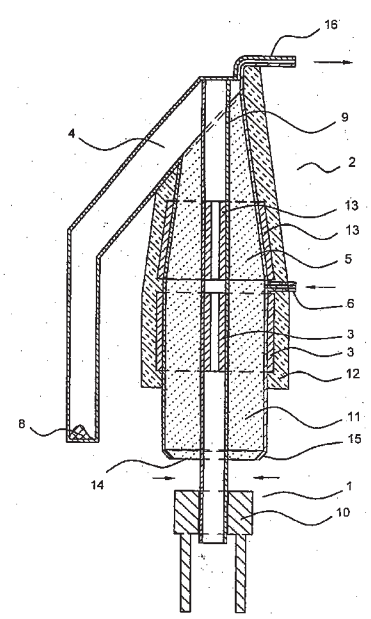
(57) **ABSTRACT**

Combustible material is supplied to the reaction zone, continuously or in pulses, which the reaction zone is separated from the surrounding atmosphere, and combustible material gradually moves through the reaction zone to the reaction zone outlet, in the same direction as released gases leave the combustible material. The reaction zone is heated to the temperature, the value of which is increasing in the direction to the reaction zone outlet, however, to 12000 C as a maximum. Then, released gases are draught off separately from non-gasified residue. As an advantage, steam and/or water is supplied to combustible material and the combustible material previously charged into the reaction zone moves by acting of subsequently supplied combustible material, where the combustible material is being compressed. The equipment for pyrolytic conversion comprises one filling device (**1**), reactor (**2**) comprising the reaction zone (**5**), at least one heater (**3**, **13**), and hopper (**4**) for non-gasified residue (**8**). The reactor (**2**) has an elongated shape and its longitudinal axis is deviated from the vertical direction by 45° as a maximum, where the filling device (**1**) is located in the lowest part of the reactor (**2**) and inlet of hopper (**4**) for non-gasified residue (**8**) is located in the upper part of the reactor (**2**). The reactor (**2**) comprises reaction zone (**5**), which is in contact with at least one heater (**3**, **13**). The hopper (**4**) for non-gasified residue (**8**) is connected to the reactor (**2**) above the reaction zone (**5**). The horizontal cross-section of the reaction zone (**5**) in upwards direction is narrowing in at least one part, and advantageously at least one inlet piping (**6**) is led into the reaction zone (**5**) as a steam and/or water supply. As an advantage, at least one column (**9**) is located inside the reactor (**2**), in its elongated direction. Heaters (**3**, **13**) are electric heating spirals and/or burners. The filling device (**1**) includes at least one piston (**10**) advantageously has a piston (**10**) annular-shaped base, in the centre of which at least one column (**9**) or worm is located. Advantageously the worm is whipped around the column (**9**). The filling hole (**14**) of reactor (**2**) is advantageously provided with a rib (**15**).



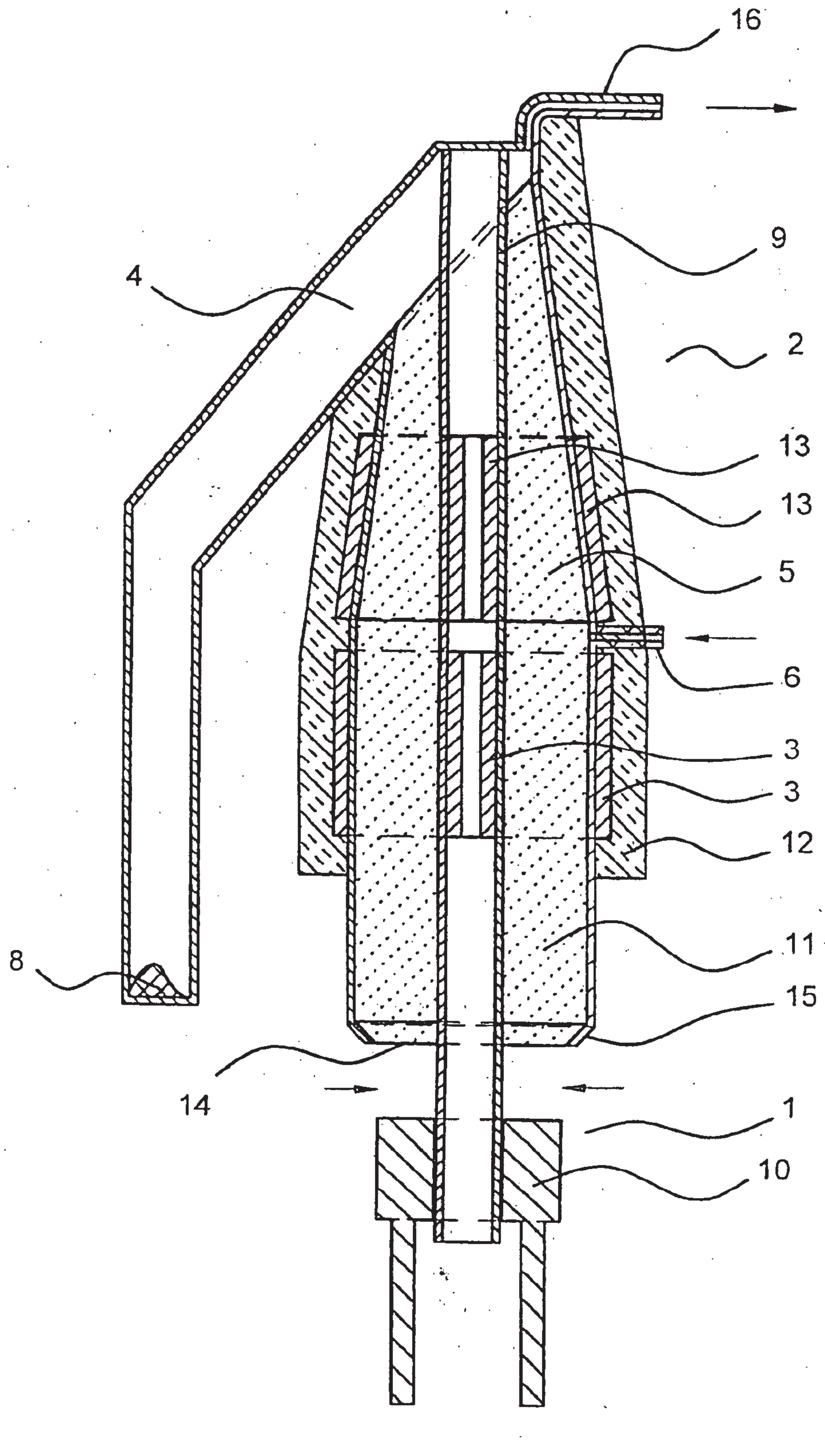


Fig. 1

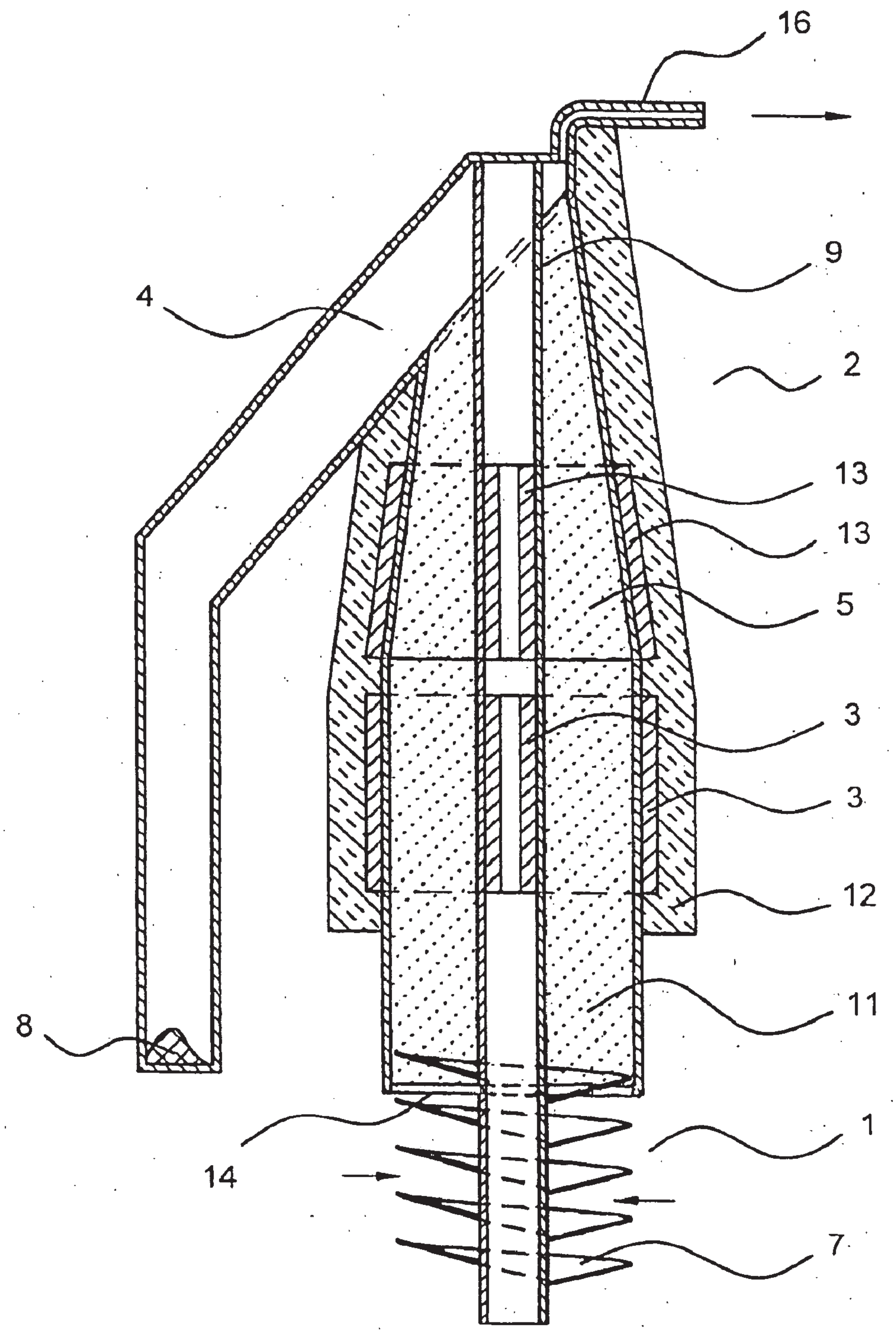


Fig. 2

METHOD AND EQUIPMENT FOR PYROLYTIC CONVERSION OF COMBUSTIBLE MATERIAL

TECHNICAL FIELD

[0001] The invention concerns the method and equipment for pyrolytic conversion of combustible material and relates to the problem of production of energetically and technologically flammable gas, which does not contain tar, and at the same time it relates to effective and ecological utilization of solid substances or mixtures with predominant content of solid substances, such as coal, wooden chips or waste organic residues, namely fermentatively hygienized waste from agricultural or food-industry production or other matters containing free or organically bound carbon.

DESCRIPTION OF PRIOR ART

[0002] It is known that gasification of biomass itself and its numerous modifications is connected with parallel creation of three products, i.e. pyrolyzed gas, condensable substances, such as tar, and non-gasifiable residue. A disadvantage of pyrolyzed gas produced in such a manner is that it contains both solid particles and condensing substances. Pyrolyzed gas is most frequently processed within electric power generation and its insufficient purity causes corrosion of material, creation of sediment, etc. It is known that such problems are solved by additional treatment of pyrolyzed gas, namely through tar removal or decomposition. The catalytic cracking process is known, including that applied to tar and its components on grain bed. Tar decomposition occurs due to temperature effect and catalytic acting of some phases contained in the grain bed. Efficiency of the process proceeding within the temperature range from 600 up to 900° C. on a decomposition bed containing lime, dolomite and, as catalysts, alumina and silicon carbide, is 60 to 90%. Another known possibility is the use of disc filters filled with alumina mixed with powdered nickel and magnesium oxide. The best temperature for this process is 850° C. Furthermore, grain bed formed by dolomite modified by nickel is known as well. Even this process takes place at elevated temperature. As disadvantages of the processes described above include sensitivity to presence of sulphur compounds, calcium oxide is also added to dolomite usually. It is also known that natural catalysts such as a mixture of limestone, olivine and dolomite or zeolite may also be used for catalytic tar decomposition. Catalytic effect is also featured by substances with increased content of ferric oxide such as siderite or limonite. Insufficient efficiency of catalytic tar decomposition, which is 75% as a maximum, is a disadvantage of the use of these catalysts. A joint disadvantage of all catalytic processes is the necessity of grain bed renewal, availability of all components, problems with environment-friendly disposal or with recycling of decomposition bad material used. Another weakness of catalytic processes is that they take place at elevated temperatures, which increases energy consumption of processing.

DISCLOSURE OF INVENTION

[0003] The mentioned disadvantages are solved by the method and equipment for pyrolytic conversion of combustible material according to the invention.

[0004] The essence of the invention is that combustible material is supplied to the reaction zone, continuously or in pulses, which the reaction zone is separated from the surrounding atmosphere, after which combustible material is gradually shifted through the reaction zone to the reaction zone outlet, in the same direction as released gases leave the combustible material. The reaction zone is heated to the temperature, the value of which is increasing in the direction to the reaction zone outlet, however, to 1200° C. as a maximum. After passage of combustible material through the reaction zone the released gases are draught off separately from non-gasified residue. Alternatively, water steam and/or water are brought to combustible material before entry into the reaction zone and/or upon its passage through the reaction zone. In another alternative, combustible material previously charged into the reaction zone moves through the reaction zone by acting of subsequently supplied combustible material. Alternatively, combustible material is compressed in at least one section while moving through the reaction zone.

[0005] The essence of the equipment comprising at least one filling device, reactor comprising the reaction zone, at least one heater and hopper for non-gasified residue is that the reactor has an elongated shape and its longitudinal axis is deviated from the vertical direction by 45° as a maximum, where the filling device is located in the lowest part of the reactor and non-gasified residue hopper inlet is located in the upper part of the reactor. Furthermore, the reactor comprises the reaction zone which is in contact with at least one heater. The non-gasified residue hopper is connected to the reactor above the reaction zone. Alternatively, the horizontal cross-section of the reaction zone in upwards direction is narrowing in at least one part. In another alternative, at least one supply piping is led into the reaction zone as a steam and/or water supply. Alternatively, at least one column is located inside the reactor, in its elongated directions. In another alternative, heaters are electric heating spirals and/or burners. The filling device alternatively includes at least one piston which advantageously has annular-shaped base, in the centre of which at least one column or worm is located, advantageously the worm is whipped around the column. An advantageous alternative is achieved if the reactor filling hole is provided with a rib which to advantage comprises conical surface, extending in the direction to the reaction zone.

[0006] Advantage of the method and equipment is that generated gas does not contain tar, which contributes to failure-free operation of associated technologies. Generated gas has high heating value as it is enriched with flammable substances generated by tar decomposition. The method is easy controllable by temperature regulation and by supply of combustible material. Advantage of method is also low energy demand. In addition, generated gas can be used in associated technologies. Another advantage is that all organically bounded or free carbon can be converted to gas. It is also advantageous that process runs continuously, generated gas has homogenous composition, quantity of solid residue is minimized and solid residue is also continuously removed from the reaction zone. An advantage of steam blowing or water supply to processes running in the reactor is minimized quantity of free or organically bound carbon in non-gasified residue, as it has been converted to carbon monoxide by reaction with water, with simultaneous generation of hydrogen, which results in improved equipment efficiency.

[0007] An advantage of the equipment is that it has simple and compact design, as all processes take place in one reaction zone, i.e. heating, gasification, reduction reaction and, alternatively, water gas generation. Other advantages include variability of capacity, variability of physical properties of combustible material, e.g. different granulometry or different content of liquid portion. It is also of an advantage that the equipment may be designed as mobile. Another advantage is that no output analysis of pyrolyzed gas is necessary and that the equipment is not dependant on other technologies, such as gas treatment equipment.

DESCRIPTION OF DRAWINGS

[0008] FIG. **1** shows a scheme of equipment as per example 4, while FIG. **2** shows equipment as per example 5.

EXAMPLE OF INVENTION EMBODIMENT

Example 1

[0009] In Example 1, combustible material is fermentatively hygienized waste from agricultural and food production. Combustible material is continuously supplied to the reaction zone, which is heated by gas burners and separated from surrounding atmosphere. When passing through the system, combustible material is exposed to gradually increasing temperature, generating gases which pass through the combustible material, exposed to higher temperature than the combustible material from which gas has generated. While gas passes through the combustible material, chemical reactions proceed resulting in gasification of additional portions of combustible material and change in gas chemical composition. During heating to 150° C., water evaporates and absorbed gases, such as CO_2 and CH_4 primarily release. Temperature around 250° C. represents the beginning of organic compound splitting accompanied with generation of CO_2 a CO. At temperature above 300° C., fission reactions continue, generating CO_2 and CO and starting other decomposition reactions resulting in generation of CH_4 and H_2. At temperatures above 350° C., tar substances start releasing and combustible material losses residues of bound hydrogen and oxygen. At temperatures above 550° C. the original organic material is virtually decomposed to carbon, released gas and tar substances. If temperature increasing continues, above temperature of 700° C., decomposition of tar substances, with generation of hydrogen, take place. At temperatures above 800° C., the Boudouard reaction starts to show up, resulting in CO content increasing gradually and, at the same time, decreasing of CO_2 and O_2 content in gas. At the same time, additional hydrogen portions are generated due to both fission of tar substances and decomposition of steam which formed when combustible materials were passing through previous heating phases under lower temperatures. This decomposition takes place on full-hot carbon field and it results in reduced carbon content in combustible material and, simultaneously, in increased carbon content in gas.

[0010] Once the combustible material passes through the reaction zone, incombustible residues having temperature not greater than 1200° C. is thrown off the reaction zone to a shaft, where it is collected and from which is removed periodically.

Example 2

[0011] Example 2 differs from Example 1 in that, the reaction zone is heated electrically, combustible material forming a charge is dosed into the equipment periodically in predetermined volumes and, moreover, steam content in the reaction zone increases by supplying it from an external source. In this case, production of H_2 and CO is much more intensive and amount of non-gasified residue is lower, as there is nearly no free carbon contained therein, nor any other organic carbon compounds.

Example 3

[0012] Example 3 differs from Example 1 in that combustible material contains 30% of tires as a minimum.

Example 4

[0013] Equipment for pyrolytic conversion of combustible material to pyrolyzed gas and non-gasified residue **8** as per Example 4 consists of the filling device **1** reactor **2**, comprising reaction zone **5**, low-temperature heater **3** and high-temperature heater **13**, and hopper **4** for non-gasified residue **8**. Reactor **2**, covered by lagging **12**, has an elongated shape, its longitudinal axis is vertical. Filling device **1** is located in the lowest part of reactor **2** and inlet of hopper **4** for non-gasified residue **8** is located in the upper part of the reactor **2**. The reactor **2** includes reaction zone **5**, which is in contact with both heaters **3**, **13**. Gas outlet **16** is led to the reactor **2** in its highest point. Horizontal cross-section of the reaction zone **5** in the part which is in contact with the high-temperature heater **13** is reducing in the upwards direction. The inlet piping **6** for supplying of steam and/or water is led into the reaction zone **5**. The column **9** is also located inside the reactor **2** in its longitudinal axis.

[0014] Both the low-temperature heater **3** and high-temperature heater **13** represent electric heating spirals. The filling device **1** comprises a piston **10** with annular-shaped base, to in the centre of which column **9** is located. The filling hole **14** of reactor **2** is provided with a rib **15**. The rib **15** has a conical frustum shape, its greater base is located on the side of reaction zone **5**. Equipment according to this example works in the manner described in Example 2.

Example 5

[0015] Equipment for pyrolytic conversion of combustible material as per Example 5 differs from the equipment described in Example 4 in that any inlet piping **6** is led into the reaction zone **5**, for supplying stream and/or water and both low-temperature heater **3** and high-temperature heater **13** represent gas burners, filling hole **14** of reactor **2** is not provided with rib **15** and filling device **1** comprises worm **7** which whips around the column **9**. Equipment according to per this example works in the manner described in Example 1.

INDUSTRIAL APPLICATION

[0016] The invention can be used for processing of all solid matters or mixtures with the majority of solid matters, containing free or organically bound carbon, either for solid matter gasification or for concentration of substances forming non-combustible residue.

1. Method of pyrolytic conversion of combustible material characterized in that the invention is that combustible material is supplied to the reaction zone, continuously or in pulses, which the reaction zone is separated from the surrounding atmosphere, after which combustible material is gradually shifted through the reaction zone to the reaction zone outlet, in the same direction as released gases leave the combustible material, and the reaction zone is heated to the temperature, the value of which is increasing in the to direction to the reaction zone outlet, however, to 1200° C. as a maximum and, after passage of combustible material through the reaction zone the released gases are draught off separately from non-gasified residue.

2. Method claimed in claim **1** characterized in that water steam and/or water are brought to combustible material before entry into the reaction zone and/or upon its passage through the reaction zone.

3. Method claimed in claim **1** characterized in that combustible material previously charged into the reaction zone moves through the reaction zone by acting of subsequently supplied combustible material.

4. Method claimed in claim **1** characterized in that combustible material is compressed in at least one section while moving through the reaction zone.

5. Equipment for pyrolytic conversion of combustible material (**11**) to pyrolyzed gas and non-gasified residue (**8**), comprising filling device (**1**), reactor (**2**) comprising the reaction zone (**5**) and at least one heater (**3**, **13**) and hopper (**4**) for non-gasified residue (**8**), characterized in that the reactor (**2**) has an elongated shape and its longitudinal axis is deviated from the vertical direction by 45° as a maximum, where the filling device (**1**) is located in the lowest part of the reactor (**2**) and in let of hopper (**4**) for non-gasified residue (**8**) is located in the upper part of the reactor (**2**), and the reactor (**2**) also comprises a reaction zone (**5**) which is in contact with at least one heater (**3**,**13**), where the hopper (**4**) for non-gasified residue (**8**) is connected to the reactor (**2**) above the reaction zone (**5**).

6. Equipment for pyrolytic conversion of combustible material claimed in claim **5**, characterized in that the horizontal cross-section of the reaction zone (**5**) in upwards direction is narrowing in at least one part.

7. Equipment for pyrolytic conversion of combustible material claimed in claim **5** characterized in that at least one inlet piping (**6**) is led into the reaction zone (**5**) as a steam and/or water supply.

8. Equipment for pyrolytic conversion of combustible material claimed in claim **5**, characterized in that at least one column (**9**) is located inside the reactor (**2**), in its elongated direction.

9. Equipment for pyrolytic conversion of combustible material claimed in claim **5**, characterized in that the heaters (**3**, **13**) are electric heating spirals and/or burners.

10. Equipment for pyrolytic conversion of combustible material claimed in claim **5**, characterized in that the filling device (**1**) comprises at least one piston (**10**) which advantageously has an annular-shaped base, in the centre of which at least one column (**9**) is located.

11. Equipment for pyrolytic conversion of combustible material claimed in claim **5**, characterized in that the filling device (**1**) comprises at least one worm (**7**), advantageously at least one worm (**7**) is whipped around the column (**9**).

12. Equipment for pyrolytic conversion of combustible material claimed in claim **5**, characterized in that the (**2**) filling hole (**14**) of reactor (**2**) is provided with a rib (**15**) advantageously has a rib (**15**) conical surface extending in the direction to the reaction zone.

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