The invention relates to a process for the preparation of liquid fuel, gaseous fuel, coke and/or active carbon by a continuous process wherein a) a carbonaceous raw material is fed into a fluidized-bed pyrolyzer, in which it is by means of a hot gas and a fluidized-bed material converted into a pyrolysis product which comprises as components liquid fuel, gaseous fuel and coke, b) the liquid fuel, the gaseous fuel and the coke are separated from each other and are recovered, at least in part for commercial use or for further refining, and electively c) the coke is partially oxidized into active carbon, which is recovered for commercial use. According to the invention the process has been improved so that (i) the fluidized-bed material is separated from one or several products of step a), b) and/or c) and is recycled into the said fluidized-bed pyrolyzer via a fluidized-bed combustion reactor or fluidized-bed combustion vessel which heats it and produces mainly external thermal energy and operates with external fuel. When necessary, (ii) a portion of the pyrolysis product is directed to the said fluidized-bed combustion reactor or vessel for burning. In this manner the pyrolyzer can be integrated into a combustion reactor which operates with external fuel, so as to minimize the losses of heat and material and the operations associated with the process.
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Process for the production of liquid fuel, gaseous fuel, coke and active coal

The invention relates to a method for the production of liquid fuel, gaseous fuel, coke and/or active coal by a continuous process, wherein
a) a carbonaceous raw material is fed into a fluidized-bed pyrolyzer, in which it is, by means of a hot gas and a fluidized-bed material, converted into a pyrolysis product which comprises as components a liquid fuel, a gaseous fuel, and coke,
b) the liquid fuel, the gaseous fuel and the coke are separated from each other and recovered, at least in part for commercial use or further refining, and selectively
c) the coke is subjected to a partial oxidation into active coal, which is recovered for commercial use.

From carbonaceous raw materials which contain volatiles it is possible to prepare, by pyrolysis, liquid fuel, gaseous fuel, and solid fuel, i.e. coke.

From crude fuels, such as liquid or solid fuels and waste materials which contain a large quantity of volatiles, it is possible to prepare by a rapid so-called flash pyrolysis a liquid fuel which can be used in direct combustion or as an engine fuel. The pyrolysis applied constitutes conventional technology in apparatus in which a tarry liquid fuel is produced at a temperature of approx. 400-800 °C and with a retention time of 0.1-100 s. In this case the heat is introduced into the oxygen-free reaction chamber of pyrolysis either directly by means of combustion air or indirectly by using various heat transfer methods.

From FI patent 22282 there is known the pyrolytic production of liquid fuel in connection with a combustion vessel, in which
case the solid residue from the pyrolysis and the waste gas are transferred to the furnace of the combustion vessel and are burned therein. The method is based mainly on the development of exothermal heat of the fuel. This known method has the disadvantage that the drying of the fuel must take place in a separate reactor, and the pyrolysis must be carried out in such a manner that its heat requirement is low, in which case a considerable amount of heat need not be introduced into the pyrolysis reactor from the combustion vessel burning residual carbon and gases. The retention time of the pyrolysis is far too long for the pyrolysis oil yield obtained from the pyrolysis to be sufficient.

In PCT application publication WO 91/11499, a circulating-mass fluidized-bed reactor is used as the pyrolysis reactor, whereby a good control of the retention time for the crude fuel and an efficient transfer of heat are obtained in the pyrolysis reactor. The heat of pyrolysis of the crude fuel is obtained by feeding into its midst a hot, particulate medium, which is heated separately or in connection with the pyrolysis by oxidation. After the pyrolysis reaction the medium is separated from the products of pyrolysis, is heated and fed back into the midst of fresh crude fuel. The process has the disadvantage that the pyrolysis residues are not used for producing heat for the pyrolysis, and that the equipment required for heating the medium is expensive.

GB application publication 1 544 099 discloses the pyrolysis of crude fuel into liquid fuel, solid residue, and residual gas. The solid residue is separated and burned, and the hot inorganic residue from the combustion is fed back into the pyrolysis. This method has the disadvantage that only part of the heating value of the pyrolysis residue is exploited in the pyrolysis.

GB-1 524 345 discloses a process for the gasification of a
solid crude fuel, in which a solid heat transfer medium is fed into the upper section of the reactor, and a solid crude fuel and a fluidization gas are fed into the lower section of the reactor, so that the heat transfer medium will travel downwards and the crude fuel will travel upwards together with the fluidization gas. The heat transfer medium is recovered from the reactor bottom and the gasification product and tarry by-products are recovered from the upper section of the reactor. The tar is preferably fed into a burner which heats the heat transfer medium. The heated heat transfer medium is fed back into the upper section of the reactor. This process, also, has the disadvantage that only part of the heating value of the reaction residue can be exploited in the reaction, and the heating of the heat transfer medium requires an expensive separate apparatus. Furthermore, the publication does not describe the pyrolysis or the solutions to the specific problems associated with it.

The coupling of the pyrolysis stage to a separate combustion vessel has been described in a number of publications, but they do not have a separate preparation of product oil. All of the products obtained from the pyrolysis reactor are directed to the combustion vessel, whereby the feeding in and combustion of the solid crude fuels is facilitated, as they are first pyrolyzed to liquid fuel, solid residue, and residual gas. Publications DE 3 010 336 A1 and DE-3 004 111 C2 describe such systems.

SE patent publication 219 918 discloses a process for the pyrolysis of a solid crude fuel into liquid fuel and solid residue, in which the heat yielded by the high temperature of the solid residue is exploited in the pyrolysis. The solid residue is not burned, and so its heat of combustion remains completely unexploited.

The gas component of the pyrolysis product can be used, for
example as such in gas burners and diesel engines, or it can be pressurized for a gas turbine.

When coke is produced, a carbonaceous fuel is usually heated to a final temperature of approx. 600–1100 °C in an oxygen-free chamber, whereby the volatiles left in the intermediate product in pyrolysis are removed and the coke obtains the desired properties, for example for metallurgical applications. Since the bulk density of the product is in general low and its particle size almost that of dust, it is useful to mix with the intermediate product or the heated product a necessary, generally known binding agent and to granulate the produced mixture by known methods to the desired granule size. Typical such binding agents include pitch, starch and lignosulfonate, and the granulation apparatus used may be a disc granulator, a pelletizer, or a briquetter.

Active carbon is a microcrystalline, non-graphitic form of carbon, and it has been developed in order to produce internal porosity. Thus the specific surface of active carbon may be as high as 300–2500 m²/g, allowing the adsorption to it of gaseous and vaporous components and of dissolved and dispersed substances of liquids. The commercial grades of active carbon are divided roughly into gas-phase and liquid-phase adsorbents. The liquid-phase carbons are usually in the form of a powder or a granulate, whereas the gas-phase carbons are hard granules or tablets. Active carbon is used widely for the removal of impurities from liquids and gases and for the recovery of usable substances from gas flows.

Active carbon can be prepared from almost any material of animal, vegetable or mineral origin by treating it in a suitable manner. It is prepared from coal, anthracite and brown coal, and also from fuels which contain large quantities of volatiles, such as various biomasses and peat, which are also characterized by a larger pore volume, and thereby greater adsorp-
tion capacity, than is coal.

Active carbon is produced by two principal methods, depending on the raw material and the desired density and coarseness of the active carbon. According to the first method, a carbonaceous material is activated during the production process with inorganic chemical compounds which are either naturally present in the material or are added to it. The chemical compounds decompose or dehydrate the organic molecules during the carbonization or calcination. The second method is based on the activating effect of gases during the production process of active carbon. In this case there occurs partial oxidation of the carbonaceous material, for example under the effect of air at a lower temperature or under the effect of water vapor, carbon dioxide, or combustion gases at higher temperatures. Such activation by means of gases is usually preceded by a preliminary carbonization of the raw material.

Below, by partial oxidation into active carbon of the solid intermediate pyrolysis product or coke is always meant these two methods mentioned above, unless otherwise indicated in the text.

As is evident from the above, active carbon can be prepared both directly from the solid component of the product of pyrolysis and from coke prepared from the pyrolysis product. Both in pyrolysis and in carbonization resulting in coke, the gases and tarry compounds produced as byproducts are often directed for destruction, or their other useful use is not very efficient; this has led to a very high price of both coke and active carbon. Since the processes involved consume a large amount of heat, the costs of heat are also disproportionately high.

In a known coking process, the vaporizing compounds are burned in a waste heat boiler, in which steam is generated for the production of electricity and heat. In the process, a slow
heating rate of the raw material, 2-10 °C/min, is used, by means of which good properties are obtained for coke for typical uses of wood and peat coke. Owing to the low heating rate, the porosity and adsorption properties of the coke are respectively not very high. Efforts have been made to improve this by known methods in which the raw material is partially oxidized directly in the coking drum or in an apparatus located directly thereafter. However, the energy economy of the whole process often remains poor, in which case most of the compounds evaporating from the raw materials cannot be used efficiently for the production of electricity and heat. In general, both an expensive coke and an expensive active carbon result.

In PCT application publication WO-91/11499, a circulating-mass fluidized-bed reactor is used as the pyrolysis reactor, whereby a good control of the retention time for the crude fuel and an efficient transfer of heat in the pyrolysis reactor are obtained. The heat of pyrolysis of the crude fuel is obtained by feeding into its midst a hot particulate medium, which is heated separately or in connection with the pyrolysis by oxidation. After the pyrolysis reaction the medium is separated from the pyrolysis products, is heated, and is fed back into the midst of fresh crude fuel. However, the process has the disadvantage that the pyrolysis residues and the thermal energy obtained by them during the process cannot be exploited. Furthermore, the separate apparatus required for heating the medium of the pyrolysis reactor and the energy required by it make the process unreasonably expensive.

GB-1 524 345 discloses a process for the gasification of a solid crude fuel, in which a solid heat transfer medium is fed into the upper section of the reactor, and a solid crude fuel and a fluidization gas are fed into the lower section of the reactor, so that the heat transfer medium will travel downwards and the crude fuel will travel upwards together with the fluidization gas. The heat transfer medium is recovered from the
reactor bottom, and the gasification product and the tarry by-products are recovered from the upper section of the reactor. The tar is preferably fed into a burner which heats the heat transfer medium. The heated heat transfer medium is fed back into the upper section of the reactor. This process, also, has the disadvantage that only part of the heating value of the reaction residue can be exploited in the reaction, and the heating of the heat transfer medium requires an expensive separate apparatus. Furthermore, the publication does not describe the pyrolysis or a solution to the specific problems associated with it.

The coupling of the pyrolysis stage to a separate combustion vessel has been described in a number of publications, but they do not have a separate preparation of a solid pyrolysis product. All of the products obtained from the pyrolysis reactor are directed to the combustion reactor, whereby the feeding in and combustion of the solid crude fuels are facilitated, as they are first pyrolyzed into solid product, liquid residue, and residual gas. Publications DE 3 010 336 A1 and DE-3 004 111 C2 describe such systems.

Conventional pyrolysis processes have the disadvantage that the heat of the residue produced as a byproduct is wasted and cannot be exploited in the pyrolysis. If the residue is recovered, its separate treatment will require expensive apparatus and space. Also, conventional pyrolysis and carbonization processes often require external energy, thus consuming a great deal of expensive fuel. Those conventional processes in which the combustion heat of the liquid and gaseous pyrolysis residues is used for the pyrolysis have a disadvantage in the highly differing physical properties of the residue to be burned, and the resulting transfer and heating technology difficulties in the combustion process. It can be stated that in conventional processes the thermal value of the pyrolysis residue has not been used advantageously.
The object of the present invention is to eliminate the above-mentioned disadvantages. The object has now been achieved by a new process for the production of liquid fuel, gaseous fuel, coke and, electively, active carbon, the process being primarily characterized in what is stated in the characterizing clause of Claim 1. It has thus been realized that a more economical method for the production of liquid and gaseous fuels and of coke and active carbon by a continuous process can be achieved when the process comprises the following steps:
a) a carbonaceous raw material is fed into a fluidized-bed pyrolyzer, in which it is by means of hot gas and fluidized-bed material converted into a pyrolysis product which comprises as its components liquid fuel, gaseous fuel and coke;
b) the liquid fuel, the gaseous fuel and the coke are separated from each other and are recovered, at least in part for commercial use or further refining and electively
c) the coke is subjected to a partial oxidation into active carbon, which is recovered for commercial use, in which case
(i) the fluidized-bed material is separated from one or several products of step a), b) and/or c) and is recycled to the said fluidized-bed pyrolyzer via a fluidized-bed combustion reactor or fluidized-bed combustion vessel heating it, producing mainly external thermal energy and operating with external fuel. By the fluidized-bed combustion reactor or vessel which produces mainly external energy is meant a fluidized-bed combustion reactor or vessel which produces external energy at least 20 % and preferably 50-80 %.

Thus, in the process according to the invention, there is used a fluidized-bed combustion reactor or vessel which produces mainly external thermal energy and which operates with external fuel, in such a manner that heat is transferred between the fluidized-bed pyrolyzer and the said reactor or vessel by means of the fluidized-bed material. The idea of the invention is
thus based at least in part on the use of a common circulated fluidized-bed material in the pyrolysis of a carbonaceous material into a pyrolysis product which comprises liquid fuel, gaseous fuel, and coke. The invention can thus be utilized in the production of only liquid fuel, only gaseous fuel, or only coke. The invention can also be utilized in the production of both liquid and gaseous fuel, of both liquid fuel and coke, of both gaseous fuel and coke, and of liquid fuel, gaseous fuel and coke.

Since the process according to the invention can be used for preparing a pyrolysis product of the desired type, there may, of course, be produced as byproducts even other pyrolysis products, which are not needed for commercial use or for further refining. According to another and advantageous principal idea of the invention,

(ii) a portion of the pyrolysis product, which comprises as components liquid fuel, gaseous fuel, and/or coke, is directed to the said fluidized-bed combustion reactor or vessel for burning. Thus the thermal losses of the pyrolysis process can be minimized by integrating the pyrolysis into industrial energy production by circulating the fluidized-bed material between the fluidized-bed pyrolyzer and the fluidized-bed combustion reactor or vessel while the excess of the liquid and gaseous fuel and coke is fed into the fluidized-bed combustion reactor or vessel, where it is used for the production of energy and for the heating of the fluidized-bed material to be fed back.

According to one embodiment of the invention, a carbonaceous fuel is used primarily for the production of liquid fuel and/or gaseous fuel. In this case it is preferable that the solid material, i.e. coke, produced as a pyrolysis product is directed, together with the above-mentioned circulating fluidized-bed material, to the said fluidized-bed combustion reactor or vessel for burning and for producing heat. The coke and the fluidized-bed material of the pyrolysis can in this case be
transferred from a separator provided in connection with the pyrolysis reactor, in which separator the liquid and gaseous fuels are separated from the coke and the fluidized-bed material, to a fluidized-bed combustion reactor or vessel for burning.

In step b) of a process according to the invention, the liquid fuel, the gaseous fuel and the coke can be separated from each other in any order, and the components can be partly or entirely, and together or separately, be either recovered for commercial use and for further refining or be fed into the fluidized-bed combustion reactor or vessel for burning. Even though the separation can be carried out in any order whatsoever, it is natural and preferable that in the separation step b) the separation is carried out on the pyrolysis products of step a) in such a manner that the liquid and gaseous fuels are separated from the coke. The separator used may be, for example, a cyclone-type separator. In this case it is typical that the liquid and gaseous fuels are recovered from the upper section of the separator and the coke and the fluidized-bed material are recovered from the lower section of the separator.

As mentioned above, a process according to the invention can be used mainly for the production of liquid fuel and/or gaseous fuel, either for commercial use or for further refining. In this case it is natural that they are separated from each other and at least one of them is recovered for the said use. The solid material from the separation, i.e. the coke and the fluidized-bed material, can, in the manner described above, be fed as such into a fluidized-bed combustion reactor or vessel for burning, in which case the coke will burn and generate heat while the fluidized-bed material is purified and regenerated for being fed back into the fluidized-bed pyrolyzer.

The above description is of that embodiment of the method of the invention in which primarily liquid and/or gaseous fuel is
prepared for commercial use or for further refining. According to another principal embodiment of the invention, the process is used primarily for the production of coke and products possibly further refined from it. In this embodiment, in point (i) of the method according to the invention the fluidized-bed material may be separated from the coke of step b), the coke being recovered for commercial use or for the preparation of the active carbon in step c) of the process according to the invention. According to another alternative variant of this second principal embodiment, the fluidized-bed material is not separated from the coke of step b) but is instead fed together with the coke into the active-carbon reactor, and only after the coke has been converted into active carbon is the separation of fluidized-bed material from the active carbon of step c), mentioned under (i), carried out. The active carbon is thus recovered for commercial use, and the fluidized-bed material is preferably fed into the circulation between the pyrolyzer and the combustion reactor or vessel.

The description above is of the principle of the main embodiments of the process according to the invention. The discussion below will focus on the details of these principal embodiments, enabling maximally good results to be achieved.

Gaseous fuel, liquid fuel, coke, and possibly active carbon can be prepared from almost any carbonaceous material. Coke is usually produced from various types of coal, but also different biomasses and peat have been used as raw materials for coke. Since the production of active carbon is closely associated with the production of coke, a carbonaceous material of animal, vegetable or mineral origin can also be used in it. Active carbon has been prepared mainly from various vegetable materials, such as wood, cobs of field plants, and the peals and shells of fruits, nuts and seeds. Lignin has also been used for the production of active carbon. Active carbon has also been prepared from peat, lignite, soft and hard carbon, tar, pitch,
asphalt, petroleum waste, and soot. Preferred carbonaceous raw materials of active carbon, and in the present context also of coke, include peat, carbon, animal bones, wood and waste wood, lignite, and cellulose process waste (lignin). The most preferred carbonaceous raw material is biomass, such as combustion biomass, wood and waste wood, cellulose process waste, and peat.

In step a) of the process according to the invention, a carbonaceous raw material is fed into a fluidized-bed pyrolyzer, in which it is converted into a pyrolysis product by means of hot gas and fluidized-bed material. The pyrolyzer may be any fluidized-bed pyrolyzer known in the art, such as a pyrolyzer of the bubbling type, the conveyor type, or the circulating-mass type. A typical fluidized-bed pyrolyzer is a so-called circulating-mass reactor. It is particularly preferable to convert in step a) the carbonaceous raw material into a pyrolysis product in a flash-type fluidized-bed pyrolyzer having a retention time of approx. 0.1-100 s, preferably 0.1-10 s, and most preferably 0.1-1 s. The temperature range of the pyrolysis step a) is approx. 400-1000 °C. A preferred temperature range for the pyrolysis is 400-800 °C and the most preferred is 400-500 °C. The fluidized-bed material used may be any material intended for this purpose, known in the art, which promotes pyrolysis without hampering the chemical reactions associated with pyrolysis. Typical fluidized-bed materials include sand, fuel ash, and lime. Sand is a particularly advantageous fluidized-bed material.

When the process according to the invention is used for the production of liquid fuel and/or gaseous fuel, it is advantageous if in step b) the liquid and gaseous fuels are separated from the coke and the fluidized-bed material by using a cyclone-type separator. If it is desired to recover fluid fuel for commercial or other uses, it is advantageous to recycle at least a portion of the gaseous fuel from step b) to the pyro-
ysis step a) to serve as the fluidized-bed gas of the fluidized-bed pyrolyzer. Although it is a fuel, the pyrolysis conditions can be arranged to be so oxygen-free and mild that no combustion will occur; the gaseous fuel will serve merely as a fluidized-bed gas. The recycling of the gaseous fuel to the pyrolysis step may be carried out, for example, by combining the flow of the said gas with the combustion gases of the fluidized-bed combustion reactor or vessel and by directing it together with them to the pyrolyzer as fluidized-bed gas.

In that embodiment of the process according to the invention in which coke and/or a further raffinate of it is prepared, the fluidized-bed material is preferably separated after either step a) or b) from the coke or after step c) from the active carbon. Usually the coke obtained from step a) or step b) is heavier than the fluidized-bed material, or vice versa, in which case they can be separated by using a separator based on flow resistance and/or weight. A typical device of this kind is a sieve which is of the fluidized-bed type or the conveyor type. In such a device the upward flowing gas lifts the lighter material, while the heavier material falls down. The fluidized-bed material is recycled via the said fluidized-bed combustion reactor or vessel to the fluidized-bed pyrolyzer, whereas the coke is either recovered for commercial use or is fed for further refining.

As pointed out above, the basic idea of the invention is to integrate the pyrolyzer into a combustion reactor or vessel participating in external energy production. The integration always takes place by circulating the fluidized-bed material between the pyrolyzer and the reactor or vessel, but preferably also by directing products of the pyrolysis and combustion, such as fuel and/or combustion gases, to the other apparatus and by thereby producing a strong synergic effect between the pyrolysis and the energy combustion. It is advantageous if the fluidized-bed combustion reactor or fluidized-bed combustion
vessel mentioned in points (i) and preferably (ii) is an energy plant combustion reactor or vessel in which the fuel is burned into energy and combustion gas. The control of the emissions into the environment by the plant is easier than if the pyrolyzer were not integrated into the energy plant. It is also preferable to use the fluidized-bed material of point (i) substantially entirely in the fluidized beds of both the said fluidized-bed pyrolyzer and the said fluidized-bed combustion reactor or vessel.

Since the process according to the invention is based on the transfer of solid material between a fluidized-bed pyrolyzer and a fluidized-bed combustion reactor or vessel, the principle of the transfer operation and the selection of its apparatus are important. It is especially preferable to use a powder conveyor and/or fluidization technology for the conveying of coke and fluidized-bed material or mere fluidized-bed material between the fluidized-bed pyrolyzer mentioned in point (i) and the said fluidized-bed combustion reactor or vessel. In a typical process, the solid material is preferably conveyed between the bottom of the fluidized-bed pyrolyzer and the middle section or bottom of the fluidized-bed combustion reactor or vessel by means of the said apparatus.

According to one preferred embodiment, the combustion gases from the fluidized-bed combustion reactor or vessel are directed hot either directly into the fluidized-bed pyrolyzer of step a) to serve as fluidization gas and/or into a heat exchanger which produces heat for the fluidized-bed pyrolyzer. Since preferably dry carbonaceous material should be fed into the pyrolyzer, the hot flue gases from a fluidized-bed combustion reactor or vessel arranged in connection with the pyrolyzer may also be used for drying it, when necessary. A heat exchanger system may also be used for the drying. There is even a third advantageous use for the flue gases of the fluidized-bed combustion reactor or vessel. They can be directed as separation
gas into the sieve for the fluidized-bed material and coke of step b) and/or the fluidized-bed material and active carbon of step c).

If the desired product distribution of the pyrolysis is such that gaseous fuel is produced in excess of the commercial need, a portion of it may be fed from the fluidized-bed pyrolyzer or from the subsequent separator into the fluidized-bed combustion reactor or vessel, preferably in such a manner that gaseous fuel is directed from the upper section of the fluidized-bed pyrolyzer to the middle or upper section of the combustion reactor or vessel. In this manner the excess gaseous fuel can be used for the production of thermal energy both for commercial use and for the pyrolysis of a carbonaceous material. Also excess liquid fuel may be directed to the fluidized-bed combustion reactor or vessel for burning. Thus a gapless interaction is produced between the pyrolyzer used in the process according to the invention and a combustion reactor operating with external fuel; this interaction is manifested in improved efficiency of both the pyrolysis and the combustion. It should be pointed out that the carbonaceous raw material fed into the fluidized-bed pyrolyzer in step a) can also be dried by using the hot combustion gases of a fluidized-bed combustion reactor or vessel arranged in connection with the pyrolyzer. A heat exchange system, for example, can be used for this purpose.

When the process according to the invention is used for the production of coke and/or active carbon, the bulk density of the coke product of step a) or b) or the active carbon product of step c) may be too low and the particle size may be almost dust-like. Therefore, according to one embodiment it is preferable to mix a binder with the material to be carbonized, and to granulate it to the desired granule size. Preferred binders include pitch, starch and lignosulfonate. Preferred granulation devices include disc granulators, pelletizers, and briquetters. Thus different grades of coke can be prepared with considerable
economy, since otherwise the value of coke in the process disclosed consists only of its heating value, which is in general 20-60 % of the price of commercial cokes.

The process according to the invention also includes an elective step, which comprises a partial oxidation of the coke to active carbon. This step is carried out on coke after it has been separated from the liquid and gaseous fuels. It should be pointed out that, in the present patent application, by partial oxidation is always meant the chemical conversion of coke into activated carbon. The word oxidation comes from the fact that carbon which contains electrons capable of bonding (active carbon) has a higher degree of oxidation than carbon which is bound to, for example hydrogen (organic hydrocarbon). Partial oxidation, for its part, means that the carbonaceous raw material or coke is not converted entirely into carbon monoxide and carbon dioxide; the carbon has a lower degree of oxidation than these.

The partial oxidation in step c) of coke into active carbon can be carried out, for example, by separating the fluidized-bed material and the coke from each other, and by thereafter subjecting the coke to the said partial oxidation, or preferably by carrying out the partial oxidation of coke in a fluidized-bed reactor in the presence of the said fluidized-bed material. According to one preferred embodiment, the partial oxidation in step c) according to the invention into active carbon is performed by reacting the coke with oxidizing gases. The partially oxidizing gases typically include water vapor, carbon dioxide, combustion gas and/or air. When air is used for the partial oxidation of coke, the temperature need not be elevated, a factor which is advantageous in terms of the heat balance of the process of the invention. The partial oxidation of coke into active carbon in step c) is preferably carried out at a temperature of approx. 800-1000 °C, most preferably at a temperature of 850-950 °C.
The synergy of the process according to the invention can further be increased by using the byproducts of the partial oxidation of coke in the other units of the process according to the invention, and/or by using the fluidized-bed material, combustion residues and combustion gases from the other units of the invention in the step c) partial oxidation of coke into active carbon. According to one embodiment, the partial oxidation coke into active carbon in step c) is carried out by reacting the coke with the combustion gases and/or water vapor from the fluidized-bed combustion reactor or vessel, the fluidized-bed pyrolyzer, and/or an elective coking reactor. Synergy is thus produced by taking the combustion gas, carbon dioxide and/or water vapor, and of course the reaction heat, needed for the partial oxidation, from the fluidized-bed combustion reactor or vessel, the fluidized-bed pyrolyzer and/or a possible separate coking reactor. The coking can be carried out in the same reactor as the pyrolysis, but it is preferable to use a separate coking reactor.

The partial oxidation of coke into active carbon in step c) is carried out preferably by using a mixture of water vapor and combustion gas. The reactor used is preferably a fluidized-bed, drum or multiple-layer furnace. In case the fluidized-bed material is present in the partial oxidation in step c) and is not separated until from the active carbon, the separation is preferably carried out by cooling the active carbon and the fluidized-bed material and by separating the fluidized-bed material from the active carbon by using one of the separation methods mentioned above, such as air-stream or corresponding classification, and subsequently possibly also water classification. If the active carbon is in the form of dust, it will form the higher fraction in a fluidized-bed sieve, the fluidized-bed material falling to the bottom of the separator. The separated bed material is fed back into the combustion vessel together with the byproducts possibly produced in the
preparation of active carbon, and for combustion with waste and recycling in the system.

As was already pointed out, the fluidized-bed pyrolyzer used is preferably a fluidized-bed reactor of the bubbling type, the conveyor type, or the circulating-mass type. A preferred fluidized-bed combustion reactor or vessel is preferably a fluidized-bed vessel of the bubbling or the circulating-mass type.

According to one of the above-mentioned embodiments of the invention, gaseous fuel is prepared in the process. The gaseous fuel can be recovered for commercial use or be further refined into various products. The gas mixture leaving the pyrolyzer, having a high heating value but containing tarry and dust-like impurities, is directed preferably to a purification apparatus before being recovered or being fed into a drive apparatus. Typically the gas with its impurities is directed to a cyclone reactor together with air, whereafter it is cooled in order to separate the impurities from the gaseous fuel. A portion of the gaseous fuel can be returned to the pyrolyzer to serve as fluidization gas. The gaseous fuel may also be filtered, preferably so that the solid material filtered out is returned to the fluidized-bed combustion reactor or vessel for burning. After filtration, the gas may be cooled further before being fed into the drive apparatus, which is preferably a gas turbine.

Below, five figures are presented to illustrate the invention, in which

Figure 1 depicts the process and apparatus according to one embodiment of the invention, for the production of liquid fuel,

Figure 2 depicts the process and apparatus according to another embodiment of the invention, for the
production of liquid fuel,

Figure 3 depicts the process and apparatus according to a third embodiment of the invention, for the production of liquid fuel,

Figure 4 depicts the process and apparatus according to a fourth embodiment of the invention, and

Figure 5 depicts the process and apparatus according to a fifth embodiment of the invention.

In a rapid pyrolysis of crude fuel, there is released, for example from wood, typically at a temperature of 500 °C approximately 50-70 % by weight of a condensable liquid fuel, 5-20 % by weight of a solid carbonization residue, the balance consisting of gaseous compounds.

Figures 1 and 2 illustrate the principles of the process disclosed. The carbonization residue is directed from the pyrolysis reactor 21, operating according to the fluidized-bed principle, together with the other fluidized-bed material back 8 or 35 to the fluidized-bed combustion vessel 1, in which the carbon is burned and the fluidized-bed material 2 is reheated. Thereafter it can be refed 3 into the pyrolysis reactor. The water vapor and gases 31 leaving the pyrolysis reactor 21 are also directed to the gas chamber of the combustion vessel 1 for burning 9 after the separation of the liquid fuel. Through control of the condensation temperature 30 it is possible to regulate the chemical composition, and thus the physical properties, of the liquid fuel 25. When necessary, also a reforming catalytic unit can be installed in the product line 25 in order to improve the quality of the liquid fuel.

The possible filtration residue of the liquid fuel and any byproducts produced in the further refining of the liquid fuel can also be directed to the combustion vessel. The difference between the processes depicted in Figures 1 and 2 is the feeding of the fluidized-bed material 3 into the pyrolysis reactor,
which in Figure 1 is carried out by using a powder conveyor, for example a cooled screw. In Figure 2 the feeding is carried out by fluidizing the discharge line 32, in which case the fluidized-bed material falls by gravity into the pyrolysis reactor 21, which is positioned at a level lower than the fluidized-bed vessel. In Figure 1, the cooled bed material and the solid residual carbon produced in the pyrolysis are separated out by means of a cyclone 22 or other separator into an intermediate silo 23, from where the material is fed by means of a conveyor 8 back into the vessel 1. In Figure 2, no intermediate silo is needed; the material is fed, for example via an elbow pipe 34 used in circulating-mass reactors, directly back 35 into the fluidized-bed vessel 1, which may in each case be of the so-called bubbling type or of the circulating-mass type. In Figure 3 the material 37 of the pyrolysis reactor 21 is ruffled with air 39, is mixed with fuel fed in by a conveyor 4, and is fed via a grate and conveyor 36 into the vessel 1.

The combustion vessel may be either a bubbling or circulating-mass fluidized-bed vessel, in which the bed material used is sand, fuel ash, lime or other chemically active material by means of which, for example, the properties of the produced oil or the melting and softening properties of the fuel ash can be affected. If the heat required by the pyrolysis reactor is introduced in hot combustion gases directly 11, 13, 17, 20 or indirectly via a heat exchanger, the vessel may be of some type even other than a fluidized-bed vessel. From the pyrolysis reactor the carbon and the bed material are in this case fed to the after-burning grate of the vessel or to a separate burner device, depending on the melting behavior of the ash. Also in the case that there is fed into the combustion vessel a solid material which is, after being heated, recovered either together with the fuel ash or separately, for being fed further into the pyrolysis reactor, the vessel may be of some type other than the fluidized-bed type. A chain grate vessel is in this case the most suitable combustion vessel.
If the combustion vessel and the pyrolyzer operate at a pressure higher than atmospheric pressure, no separate gas blowers from the combustion vessel to the pyrolysis reactor are needed. In a pressurized alternative, the combustion vessel may also be replaced by a gasifier.

In general, the point of departure is that the pyrolysis reactor 21 is of the circulating-mass type. This need not always be the case; the pyrolysis reactor may also be a so-called conventional fluidized-bed reactor or a conveyor reactor. The solid material rising from the fluidized bed is in a conventional case separated in the fluidized-bed reactor, as shown in Figures 1 and 2, and is returned to the combustion reactor. The hot material from the combustion reactor, serving to introduce heat, can be returned from the pyrolysis reactor to the combustion reactor by means of, for example, a conveyor or most preferably in such a manner that the pyrolysis reactor and the combustion reactor communicate with each other either continuously or intermittently via conduits in the fluidization chamber, Figure 3. In the case of a conveyor reactor, the bed material circulates as in a circulating-mass reactor.

Figure 4 depicts the process and apparatus according to one embodiment of the invention, for the production of coke and electively active carbon.

The apparatus shown in Figure 4 is made up of a fluidized-bed pyrolyzer 21, a fluidized-bed combustion reactor 1, a fluidized-material conveying route 3 between the lower sections of the fluidized-bed reactor 1 and the fluidized-bed pyrolyzer 21, a separator 22 coupled to the upper left-hand corner of the fluidized-bed pyrolyzer 21, and a solids separator 40 coupled between the lower end of the separator 22 and the lower end of the fluidized-bed combustion reactor 1. In addition, between the separator 22 and the fluidized-bed combustion reactor 1
there is coupled a liquid and/or gas pipe 29-31 with liquid and gas separators 24-26 and a blower 19. Furthermore, from the upper section of the fluidized-bed reactor 1 there leads a combustion-gas pipe 12 to the flue 14 of the plant and to the lower section of the fluidized-bed pyrolyzer 21. The combustion-gas pipe 12 is equipped with a combustion-gas blower 18 and with a fluidization-gas blower 17 in connection with the fluidized-bed pyrolyzer 21.

The fluidized-bed material route 3 leading from the lower end of the fluidized-bed combustion reactor 1 to the lower end of the fluidized-bed pyrolyzer 21 is equipped with a fluidization system 33. The apparatus used in the invention is, of course, also equipped with a silo 5 for the carbonaceous raw material and with a conveyor 4 leading therefrom to the fluidized-bed pyrolyzer 21. The fluidized-bed combustion reactor 1 is respectively equipped with a fuel silo 7 and with a conveyor 6 leading therefrom to the fluidized-bed combustion reactor.

The apparatus operates so that the carbonaceous raw material is fed from the silo 5 by the conveyor 4 into the fluidized-bed pyrolyzer 21, in which it is by means of a hot fluidized bed converted into a pyrolysis product which comprises liquid and gaseous fuel, coke, and fluidized-bed material. Gas is blown by means of the fluidization-gas blower 17 into the lower section of the fluidized-bed pyrolyzer 21, and during the pyrolysis this gas lifts the pyrolysis products into the upper section of the fluidized-bed pyrolyzer 21, from where is travels to the cyclone separator 22, where the liquid and gaseous fuels are separated from the solid coke and fluidized-bed material. The liquid and gaseous fuels emerge from the upper end of the cyclone separator 22 and travel via the condenser 24-26, which separates at least a portion of the liquid fuel for commercial use, for example for energy production. The pyrolysis gas continues its travel via pipe 31 and is blown by the blower 19 into the fluidized-bed combustion reactor 1, where it burns and
increases the production of heat. Pyrolysis gas may also be recovered for commercial use.

Coke and fluidized-bed material are withdrawn from the lower end of the cyclone separator into the solids separator 40, which separates the coke from the fluidized-bed material. The fluidized-bed material continues its travel to the lower end of the fluidized-bed combustion reactor 1, where it participates in the combustion, being thereby purified.

From the solids separator 40, the coke is recovered for commercial use or is fed into a partial oxidation reactor, where it is partially oxidized into active carbon. The reactor for the production of active carbon is not shown in the figure, but it is a conventional reactor for the production of active carbon. The active-carbon reactor may, in the same manner as the fluidized-bed pyrolyzer 1, be coupled to the fluidized-bed burner. According to the idea of the invention, conduits for fluidized-bed material, liquid or gas may be coupled also between the fluidized-bed pyrolyzer and the active-carbon reactor.

As was pointed out, in the fluidized-bed combustion reactor 1 the fluidized-bed material participates in the combustion, whereby it is purified and heated. The hot and clean fluidized-bed material is fed via conduit 3 back into the fluidized-bed pyrolyzer 21. The conduit 3 is equipped with fluidization 33, the gas for which is preferably taken from the hot gases of the fluidized-bed combustion reactor 1 or the fluidized-bed pyrolyzer 21. The fluidized-bed combustion reactor 1 produces energy so that waste from a wood or cellulose process is collected into the fuel silo 7, from where it is fed into the fluidized-bed combustion reactor 1 by means of the conveyor 6. Combustion gas leaves the upper end of the combustion reactor 1 via pipe 12 and the combustion-gas blower 18, one portion of it being directed into the atmosphere via the flue 14 and another por-
tion being directed via the fluidized-bed blower 17 to the lower end, i.e. the grate end, of the fluidized-bed pyrolyzer 21. The invention can be varied widely, and also other apparatus are suitable for use, for example, the apparatus described in FI application 931785; the content of that application is appended hereto as reference.

Figure 5 illustrates the process according to one embodiment of the invention, in which mainly gaseous fuel is produced. The apparatus is similar to that in Figure 4, except that it lacks coke recovery 40, and the liquid separation system 24-28 and the gas circulation system 19 are replaced by a purification system 41-45 for gaseous fuel and a gas utilization system 47.

At a point after the fluidized-bed pyrolyzer 21 and the cyclone separator 22, the gaseous fuel is fed via pipe 29 into the cyclone reactor 42, into which air is also fed via the blower 41. In the cyclone reactor 42, tarry impurities are decomposed thermally, possibly in the presence of a catalyst.

Any dust-like compounds and also any alkali compounds condensing after the cooling are removed from the gas flow in a particle filter 43, for which a number of known filters can be used.

Finally the purified gaseous fuel is cooled 45 and is pressurized into the gas utilization system 47, into which air 46 is also fed, when necessary.

According to one variant, the product obtained from the pyrolyzer 21 and the cyclone 22 is condensed 43, in which case the uncondensed portion, i.e. the gaseous fuel, is directed via the pump 17 back to the pyrolyzer or via the pump 19 to the combustion vessel. In order to avoid problems associated with pressurized feed, the condensed portion may be fed in liquid or paste-like form, as such or mixed with additional fuel, into a
pressurized gasification reactor, and thus gas for the utilization 47 can be produced.

Reference numerals in Figures 1-5:
1 = fluidized-bed vessel or reactor
2 = bed material
3 = hot bed material to be directed to the pyrolysis reactor
4 = crude fuel to be pyrolyzed
5 = silo for material to be pyrolyzed
6 = feeding of fuel into the fluidized-bed reactor
7 = fuel silo or container of the fluidized-bed vessel
8 = return to the fluidized-bed reactor (vessel) of the bed material and residual coke which have circulated via the pyrolysis reactor
9 = burner for the gas formed in the pyrolysis, including the pyrolysis-reactor fluidization gas
10 = thermal surface (e.g. superheater) of the fluidized-bed reactor (vessel)
11 = hot fluidization gas after the thermal surface 10
12 = cold fluidization gas after the combustion-gas blower 18
13 = fluidization gas mixed from flows 11 and 12 into the pyrolysis reactor
14 = flue
15 = control baffle
16 = control baffle
17 = fluidization-gas blower of the pyrolysis reactor
18 = combustion-gas blower
19 = residual-gas blower
20 = pyrolysis reactor grate and grate box into which the fluidization gas is blown and to which hot (combustion) gases generated in an external furnace may also be directed
21 = pyrolysis reactor
22 = separator for pyrolysis reactor solids
23 = intermediate storage container
24 = cooler for the pyrolysis product and gases
25 = product oil
26 = cooling, by the control of which the products of the product oil, e.g. its water content, are affected
27 = after-heater
28 = medium (steam or the like) used for heating
29 = gas and oil flow after the pyrolyzer
30 = gas flow, temperature 50-300 °C, typically approx. 80-120 °C, after the cooling
31 = after-heated gas flow for combustion; the temperature is selected so that residual tars will not sediment in the conduits, the blower 19, or the burner 9
32 = connecting conduit, equipped with a fluidization bottom, from the fluidized-bed vessel to the pyrolysis reactor, which is located at a lower level
33 = fluidization-gas flow to the connecting conduit 32
34 = fluidization-gas flow to the so-called elbow pipe (gas lock)
35 = conduit from 34 to the reactor (vessel)
36 = conduit from the pyrolysis reactor to the vessel
37 = fluidized bed
38 = outlet conduit from the pyrolysis reactor (fluidized-bed material)
39 = conveying and fluidization gas required for conveying the cold fluidized-bed material
40 = separator for coke and fluidized-bed material
41 = air blower
42 = thermal cyclone reactor
43 = cooler
44 = filter
45 = cooler
46 = air feed
47 = gas utilizing apparatus

Example (preparation of liquid fuel)

A circulating-mass pyrolysis reactor is coupled to a typical
fluidized-bed combustion vessel. When peat or wood is fed into the flash pyrolysis, the products obtained from air-dry fuel are pyrolysis oil approx. 60-75 % by weight, carbonization residue 5-15 % by weight, and uncondensed gases 10-20 % by weight, depending on the conditions. The pyrolysis oil is separated from the solid material in cyclones subsequent to the circulating-mass reactor and are condensed in a condenser. The chemical energy contained in the solid carbonization residue and the residual gas can be exploited in the heat recovery system of a separate combustion vessel. By varying the condenser temperature and the degree of aerosol recovery, a portion of the water content present in the fuel, the water vapor, and the gaseous compounds condensing at a low temperature, leaving the pyrolyzer, are also directed to the gas flow traveling to the combustion vessel. The thermal power of the fluidized-bed reactor in the example is assumed to be 100 MW and the fuel power of the fuel, for example sawdust, fed into the pyrolyzer is assumed to be 20 MW, in which case the thermal power required by the pyrolysis is 1-5 MW, depending on, for example, the moisture content of the sawdust. The shield gas flow of the example vessel is 40 m³/s (160 m³/s), the amount of bed material in the vessel is 20-50 t, and the solid material flow in the cycle in the circulating-mass system is 100-200 kg/s. The bed temperature is typically approx. 850 °C. If the temperature of the bed material drops from 800 °C to 500 °C, the requirement of heat transfer material (= bed material) is approx. 5-20 kg/s. This would have only slight effect on the bed temperature. The example shows that the fuel powers of the combustion vessel and the pyrolysis reactor may be, for example, equal. The smaller the pyrolysis reactor relative to the power of the combustion vessel, the smaller the temperature drop caused in the combustion vessel by the feeding point of the combustion/sand bed and on the other hand of the pyrolyzer product gas.
Example (preparation of coke and/or active carbon)

The product distribution prepared from saw dust by rapid flash pyrolysis was pyrolysis oil 60-75 % of the dry weight, gaseous compounds 10-20 %, the balance being solid carbonization residue. The temperature was in this case typically 400-600 °C and the retention time 200-1000 ms. When typical conditions of fluidized-bed gasification were used, i.e. a temperature of 650-1000 °C, the carbonization residue obtained was from wood 25-35 %, from peat 25-40 %, and from brown coal or from coal 40-70 %.

The ash content of the pyrolysis coke was 3 % by weight and its BET surface area 8 m²/g. When coke was carbonized in an oxygen-free chamber at a temperature of 800 °C for 20 min, BET rose to a level of 20 m²/g. A partial gasification was carried out at 820 °C by using a mixture of water vapor and combustion gas, in which case the BET surface area in the product was 800 m²/g.

When, in accordance with the invention, a pyrolysis reactor is coupled in connection with a power plant, the following advantages can be gained:
- As compared with the approx. 50-70 % efficiency of a separate pyrolysis process, also the released gaseous and solid fuels can be exploited in the vessel, whereby the total efficiency rises significantly, to approx. 80-90 %.
- The existing feeding and auxiliary devices can be exploited in the operation of the pyrolysis reactor, and thereby the investment costs can be lowered. If the combustion vessel does not operate at full capacity throughout the year, the capacity difference between full capacity and instantaneous capacity can be exploited in the production of liquid fuel.
- The produced liquid fuel can be used in direct combustion in some vessel or in engines, for example for the
production of electricity and heat. Since, for example, with diesel engines, even of a small size category, a higher build-up and higher efficiency in electricity production are achieved than in conventional solid-fuel power plant processes, electricity can be produced efficiently from peat, various biomasses and wastes. It is also possible to use other alternatives for the power engine, for example a Stirling engine. The storage and easy transportation of liquid fuel enable flexible, decentralized production of energy to be implemented if economical fuel is available in a quantity higher than that made possible by the local heat load of combined electricity and heat production.

When conventional combustion or temperatures lower than gasification, typically 400-700 °C, are used in the pyrolysis reactor, a significant proportion of the harmful compounds present in the solid fuel are concentrated in either the solid residue or the product gas, thus enabling a higher-grade fuel oil raffinate to be produced. The purification devices of the original vessel can be used for the purification or treatment of the harmful components.

The most important uses of the invention are:

a) Peat and biomass power plants
Compared with a conventional power plant, the above-mentioned plant concept can take in 20-100 % more fuel and produce therefrom a liquid fuel which is so-called bio-oil resembling fuel oil. The oil is used either in an engine process of a higher build-up in the same power plant or is transported to separate power plants based on small engines (diesel or the like) producing electricity and heat or to oil vessels.

b) Power plant of a pulp mill
Waste fuels, such as bark or wood chips, are often available in
higher quantities than the thermal loads of the mill enable to be used for combined electricity and heat production in a power plant based on a steam turbine plant. In connection with the bark vessel it is possible to produce pyrolysis oil from biofuels and to use the oil in separate oil burners or a plant for the production of electricity.

c) Waste recycling plant
Since pyrolysis technology can be used for refining, from various waste materials, a liquid oil fraction in which impurities passing into a solid carbonization residue or residual gases are not concentrated, a higher-grade product can thus be prepared for energy production. For example, waste plastics or plastic-coated papers can be refined either into fuel oil or the obtained pyrolysis product can be reused for the preparation of plastics products.
Claims

1. A process for the production of liquid fuel, gaseous fuel, coke and/or active carbon by a continuous process, wherein
   a) a carbonaceous material is fed into a fluidized-bed pyrolyzer, in which it is converted by means of a hot gas and a fluidized-bed material into a pyrolysis product, which comprises as components liquid fuel, gaseous fuel and coke,
   b) the liquid fuel, the gaseous fuel and the coke are separated from each other and are recovered, at least in part for commercial use or further refining, and optionally
   c) the coke is subjected to partial oxidation into active carbon, which is recovered for commercial use, characterized in that
      (i) the fluidized-bed material is separated from one or several products of step a), b) and/or c) and is recycled to the said fluidized-bed pyrolyzer via a fluidized-bed combustion reactor or fluidized-bed combustion vessel which heats it and in the main produces external thermal energy and operates with external fuel.

2. A process according to Claim 1, characterized in that
   (ii) a portion of the pyrolysis product which comprises as components liquid fuel, gaseous fuel and/or coke is directed to the said fluidized-bed combustion reactor or fluidized-bed combustion vessel for burning.

3. A process according to Claim 2, characterized in that
   the coke, together with the circulating fluidized-bed material, is directed to the said fluidized-bed combustion reactor or fluidized-bed combustion vessel for burning and for producing heat.

4. A process according to Claim 1, 2 or 3, characterized in that in step b) the pyrolysis product of step a) is subjected to separation so that the liquid fuel and the gaseous fuel are
separated from the coke.

5. A process according to Claim 4, characterized in that the liquid fuel and the gaseous fuel are separated from each other, preferably by means of a condenser, and at least one of them is recovered for commercial use.

6. A process according to any of the above claims, characterized in that in point (i) the fluidized-bed material is separated from the coke of step b), the coke being recovered for commercial use or for the preparation of the active carbon of step c).

7. A process according to any of the above claims, characterized in that in point (i) the fluidized-bed material is separated from the step c) active carbon, which is recovered for commercial use.

8. A process according to any of the above claims, characterized in that the carbonaceous raw material of step a) is biomass, for example field biomass, wood, waste wood, waste from a paper or pulp process, or peat.

9. A process according to any of the above claims, characterized in that in step a) the carbonaceous raw material is converted into a pyrolysis product in a flash-type fluidized-bed pyrolyzer, in which the retention time is approx. 0.1-10 s, preferably 0.1-1 s.

10. A process according to any of the above claims, characterized in that in step a) the carbonaceous raw material is converted into a pyrolysis product at a temperature of 400-800 °C, preferably 400-500 °C.

11. A process according to any of the above claims, characterized in that the fluidized-bed material used is sand, fuel
ash and/or lime, preferably sand.

12. A process according to any of the above claims, characterized in that in step b) the liquid fuel and the gaseous fuel are separated from the coke by using a cyclone-type separator.

13. A process according to any of the above claims, characterized in that a portion of the gaseous fuel of step b) is recycled to step a) as fluidized-bed gas for the fluidized-bed pyrolyzer.

14. A process according to any of the above claims, characterized in that in point (i) the fluidized-bed material is separated from the coke of step a) or b) or from the active carbon of step c) by means of a sieve, which is of the fluidized-bed type or the conveyor type, in which an upwards-flowing gas, such as combustion gas from the fluidized-bed burner, lifts the lighter material, while the heavier material falls down.

15. A process according to any of the above claims, characterized in that the said fluidized-bed combustion reactor or fluidized-bed combustion vessel of points (i) and preferably (ii) is an energy plant combustion reactor or combustion vessel, in which the fuel is burned into energy and combustion gas.

16. A process according to any of the above claims, characterized in that the fluidized-bed material of point (i) is used substantially entirely in the fluidized bed of both the said fluidized-bed pyrolyzer and the said fluidized-bed combustion reactor or fluidized-bed combustion vessel.

17. A process according to any of the above claims, characterized in that a powder conveyor and/or fluidization technology is used for the conveying of the coke and fluidized-bed
material or of the fluidized-bed material between the fluidized-bed pyrolyzer mentioned in point (i) and the said fluidized-bed combustion reactor or fluidized-bed combustion vessel, preferably between the bottom of the said fluidized-bed pyrolyzer and the middle section or bottom of the said fluidized-bed combustion reactor or fluidized-bed combustion vessel.

18. A process according to any of the above claims, characterized in that the combustion gases from the said fluidized-bed combustion reactor or fluidized-bed combustion vessel are directed, hot, either directly as fluidization gases to the fluidized-bed pyrolyzer of step a) or to a heat exchanger which produces heat for the fluidized-bed pyrolyzer.

19. A process according to any of the above claims, characterized in that the combustion gases from the said fluidized-bed combustion reactor or fluidized-bed combustion vessel are directed as separation gas to the sieve for the fluidized-bed material and coke of step b) and/or the fluidized-bed material and active coke of step c).

20. A process according to any of the above claims, characterized in that at least a portion of the gaseous fuel is fed from the fluidized-bed pyrolyzer into the fluidized-bed combustion reactor or fluidized-bed combustion vessel, preferably from the upper section of the fluidized-bed pyrolyzer into the middle and/or upper section of the fluidized-bed combustion reactor or vessel, for burning.

21. A process according to any of the above claims, characterized in that the coke obtained from step b) and/or the active carbon obtained from step c) is granulated, preferably by using a binding agent.

22. A process according to any of the above claims, charac-
terized in that the partial oxidation of the coke into active carbon in step c) is carried out by oxidizing the coke partially in a fluidized-bed reactor in the presence of the fluidized-bed material.

23. A process according to any of Claims 1-22, characterized in that the partial oxidation of the coke into active carbon in step c) is carried out by reacting the coke with oxidizing gases, preferably water vapor, carbon dioxide and/or combustion gas.

24. A process according to Claim 23, characterized in that the partial oxidation into active carbon in step c) is carried out by reacting the coke of step b) with air.

25. A process according to Claim 23 or 24, characterized in that the partial oxidation into active carbon in step c) is carried out at a temperature of approx. 800-1000 °C, preferably at a temperature of 850-950 °C.

26. A process according to Claim 23, 24 or 25, characterized in that the partial oxidation into active carbon in step c) is carried out by reacting the coke of step b) with combustion gases and/or water vapor from the said fluidized-bed combustion reactor/fluidized-bed combustion vessel and/or the said fluidized-bed pyrolyzer.

27. A process according to any of the above claims, characterized in that the fluidized-bed pyrolyzer is a fluidized-bed reactor which is of the bubbling type, of the conveyor type or of the circulating-mass type.

28. A process according to any of the above claims, characterized in that the fluidized-bed combustion reactor or fluidized-bed combustion vessel used is a fluidized-bed vessel which is of the bubbling type or of the circulating-mass type.
29. A process according to any of the above claims, characterized in that the gaseous fuel separated and purified in step (b) is fed, together with air and/or oxygen, into a gas-utilizing plant, where it burns and produces energy.

30. A process according to Claim 29, characterized in that the gaseous fuel separated in step (b) is purified in a thermal after-reactor and a filter before being fed into a gas-utilizing plant.
# INTERNATIONAL SEARCH REPORT

## Classifications of Subject Matter

**IPC5:** C10B 49/22 // C01B 31/08, C01B 31/14  
According to International Patent Classification (IPC) or to both national classification and IPC

## Fields Searched

Minimum documentation searched (classification system followed by classification symbols)

**IPC5:** C10B

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

**SE, DK, FI, NO classes as above**

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## EPDOC

### Documents Considered to Be Relevant

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<td>EP, A1, 0028021 (ISHIZAKA, SEICHI PRESIDENT OF AGENCY OF INDUSTRIAL SCIENCE AND TECHNOLOGY), 6 May 1981 (06.05.81), page 5, line 1 - page 7, line 31</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

### Special Categories of Cited Documents

- **A** document defining the general state of the art which is not considered to be of particular relevance
- **E** earlier document but published on or after the international filing date
- **L** document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- **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

### Date of the actual completion of the international search

1 July 1994

### Date of mailing of the international search report

26 -07- 1994

Name and mailing address of the ISA/Swedish Patent Office

Box 5055, S-102 42 STOCKHOLM  
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Authorized officer

Jan Carlérud  
Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)
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