



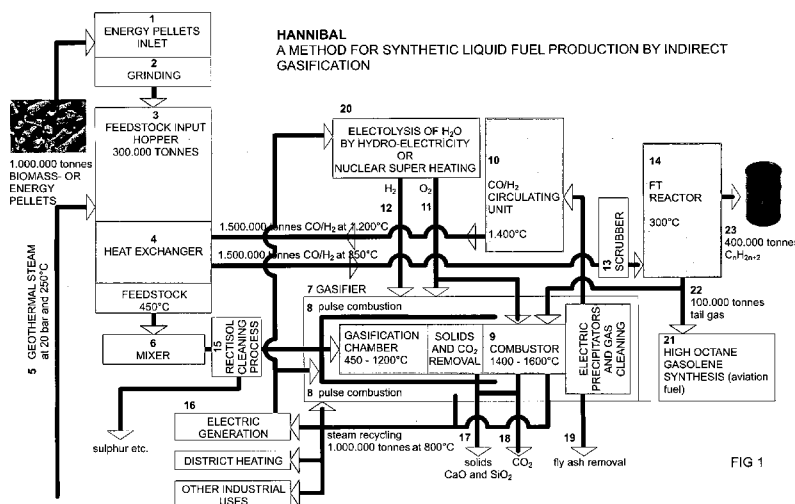
(43) International Publication Date
7 September 2012 (07.09.2012)

- (51) International Patent Classification:
C10G 2/00 (2006.01) C10J 3/00 (2006.01)
- (21) International Application Number:
PCT/IS2011/000002
- (22) International Filing Date:
28 February 2011 (28.02.2011)
- (25) Filing Language: English
- (26) Publication Language: English
- (71) Applicant (for all designated States except US): HANNIBAL [IS/IS]; Gardastræti 17, IS-101 Reykjavik (IS).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): LEIFSSON, Asgeir [IS/IS]; Kumbaravogur, IS-825 Stokkseyri (IS). OLAFSSON, Gestur [IS/IS]; Gardastræti 15, IS-101 Reykjavik (IS). ARMANSSON, Halldor [IS/IS]; Fellsmuli 10, IS-108 Reykjavik (IS). JONSSON, Valdimar, K. [IS/IS]; Kirkjusandur 3, IS-105 Reykjavik (IS).
- (74) Agent: RAGNARSSON, Olafur; Lynghals 4, P.O. Box 10101, IS-130 Reykjavik (IS).

- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— with international search report (Art. 21(3))

(54) Title: A METHOD AND A SYSTEM FOR SYNTHETIC LIQUID FUEL PRODUCTION BY INDIRECT GASIFICATION



(57) Abstract: A novel approach is proposed for applying external renewable energy in the form of high temperature geothermal steam, hydro-electricity, and/or heat derived from nuclear reactors to carbon containing feedstock (for example biomass waste paper or coal) in a large scale well insulated Fischer-Tropsch process to produce liquid fuels of high energy content, and by-products for industrial production of e.g. gypsum or cement and combustion of tail gas in the gasifier to produce additional heat. A nuclear reactor is employed to superheat steam up to temperatures above 2,500°C, at which H₂ and O₂ are separated and then directed to the gasifier in the proportion required for the conversion of said syngas components into liquid fuels by the Fischer-Tropsch synthesis. The heat is recycled wherever possible and thus maximum energy efficiency and maximum material utilization from the feedstock and the geothermal steam are simultaneously achieved. Energy from high temperature steam is recycled in the form of electricity by a generator to electrical heating elements and/or district heating. A system for performing the process is also provided.

WO 2012/117423 A1

A METHOD AND A SYSTEM FOR SYNTHETIC LIQUID FUEL PRODUCTION BY INDIRECT GASIFICATION

Description

5

FIELD OF THE INVENTION

The present invention concerns a process and a system for the production of liquid synthetic fuels with high energy densities, and by-products such as cement, gypsum and glass by allothermal gasification and Fischer-Tropsch process.

10

BACKGROUND TO THE INVENTION.

Gasification is traditionally a process in which either solid or liquid carbonaceous material, containing mostly chemically bound carbon, hydrogen, oxygen, and a variety of inorganic and organic constituents, is reacted with air, oxygen, and/or steam. This reaction provides sufficient exothermic energy to produce a primary gaseous product containing mostly CO, H₂, CO₂, CH₄, H₂O, and light hydrocarbons mixed with volatile and condensable organic and inorganic compounds. The general formula for the production of diesel fuel by the so called Fischer-Tropsch (FT) process is: $n\text{CO} + (2n+1)\text{H}_2 \rightarrow n\text{H}_2\text{O} + \text{C}_n\text{H}_{2n+2}$, whereas when CO₂ is used the formula becomes $n\text{CO}_2 + (3n+1)\text{H}_2 \rightarrow 2n\text{H}_2\text{O} + \text{C}_n\text{H}_{2n+2}$. The latter method thus requires considerably more hydrogen to produce the same quantity of C_nH_{2n}.

15

20

Numerous methods for producing synthesis gas are known. Present commercial techniques for synthesis gas production are based on steam-reforming of natural gas, particularly methane, and industrial gasoline, autothermal-reforming of natural gas or heavier hydrocarbons (with partial oxidation and steam-reforming in a single reactor), oxygen-reforming after steam-reforming (to produce ammonia), partial oxidation of hydrocarbons, coke or coal (with oxygen gasification), and reforming of carbon dioxide (Babu 2005).

30

It is known that energy to provide heat and power in gasification processes has conventionally been produced by combustion. Thus it has not been possible to use a sustainable process with a very high carbon utilization and high energy efficiency resulting in an overall negative

carbon emission and complete conversion of most input materials into valuable products.

Past FT facilities based on the exothermal use of coal have suffered from poor energy efficiency (55%), poor carbon utilization (50%), considerable pollution, mostly CO₂ and H₂S emissions, and have utilized the combustion of locally available carbonaceous feedstock. They have also proved very capital intensive resulting in high unit production costs. Technical obstacles in feeding and gas cleaning have also been encountered (Babu 2005).

In contrast to fossilised materials such as coal, which is currently used in several commercial gasification processes, renewable feedstock containing carbon can be processed into fuel pellets that are more reactive and can thus be effectively gasified at lower temperatures than fossilised matter and can therefore be considered a viable source of renewable energy. Waste processors can classify high content carbonaceous materials, process them into pellets and offer them on the open market. These pellets could then be transported in bulk by ship or train and their procurement costs for a synthetic fuel processor thus lowered. MSW (Municipal Solid Waste) pellets that can be economically transported in large quantities over long distances is probably the cheapest available feedstock.

In at least two countries in the possible future EU, Iceland and Italy, and possibly in Greece and Turkey as well there exist conditions for the utilisation of high temperature geothermal steam. It has been estimated that 60.000.000 tonnes of non-recyclable waste paper will be processed at recycling facilities in the EU within 10 years. Several other possible locations for economical production exist worldwide.

SUMMARY OF THE INVENTION

The present invention provides resolution of the above mentioned problems by employing indirect allothermal gasification technology, renewable carbonaceous feedstock and moreover utilizing renewable energy sources such as hydro-electricity, nuclear energy, high temperature geothermal steam and possibly an inert gas, such as helium, heated by a nuclear reactor and circulated within the gasifier in a closed circuit in tubes for heating the syngas to a temperature exceeding 1200°C. At this temperature no tar components are present in the gas and thus tar does not cause problems in the process. A combustor is employed to increase the temperature of the syngas to about 1600°C.

A novel approach is proposed for applying external renewable energy in the form of high temperature geothermal steam, hydro-electricity, and/or heat derived from nuclear reactors to carbon containing feedstock (for example biomass waste paper or coal) in a large scale well insulated FT process to produce liquid fuels of high energy content, and by-products for industrial production of e.g. gypsum, cement or glass, and combustion of tail gas in the gasifier to produce additional heat.

Heat is recycled wherever possible and thus maximum energy efficiency and maximum material utilization from the feedstock and the geothermal steam are simultaneously achieved.

Energy from high temperature steam is recycled in the form of electricity by a generator to electrical heating elements and/or district heating. Some of the tail gas may be combusted in the gasifier to produce additional heat.

The embodiments of the present invention are described in greater detail in the characterizing parts of the claims.

BRIEF DESCRIPTION OF THE DRAWING

A fuller understanding of the nature and objects of the present invention will become apparent upon consideration of the following detailed description with reference to the accompanying drawing. Figure 1 is a flow diagram of an indirectly heated („allothermal“) gasification process based on the use of renewable carbonaceous feedstock, either biomass or mechanically classified municipal solid waste (MSW) and renewable energy sources, such as geothermal steam fed by a pipe, hydroelectricity or electricity generated by a nuclear reactor.

The gasification system of the present invention is composed of an inlet (1), at least one energy pellet grinding unit (2), feedstock hopper (3), heat exchanger system (4), geothermal steam pipe (5), mixer (6), gasifier (7), electric heaters (8), combustor (9), syngas (CO/H₂) circulating unit (10), O₂ metering device (11), H₂ metering device (12), scrubber (13), FT reactor unit (14), Rectisol® gas cleaning device (15), steam removal unit for electricity generator, other industrial uses or district heating (16), CaO and SiO₂ removal units (17), CO₂ removal unit (18), fly ash and gas cleaning unit (19), electrolysis unit or a nuclear reactor

(20), high octane synthesis unit (21), and bypass for tail gas (22) and storage for final product (23).

DETAILED DESCRIPTION OF THE INVENTION

5

In the process of the present invention solid energy pellets are comminuted in a shredder (2) and ground to a powder prior to introduction to the gasification process.

10

In the gasification a solid or a liquid carbonaceous material is reacted with air, oxygen, and/or steam. This reaction provides sufficient exothermic energy to produce a primary gaseous product containing mostly CO, H₂, CO₂, CH₄, H₂O, and light hydrocarbons mixed with volatile and condensable organic and inorganic compounds. Most of the inorganic constituents in the feedstock are chemically altered and either discharged as bottom ash or entrained with the raw product gas. If heated by a combustor where tailgas is combusted by the infusion of oxygen to reach the high gasifier exit temperature of 1400 - 1600°C everything is "atomized". All molecular impurities, e.g. organics like tars or other polycyclic compounds will be destroyed completely. Same applies for halogeneous compounds. For instance, dioxins do not cause any problems since a clean synthesis gas is produced that can be used in a variety of energy conversion devices, including internal combustion engines, gas turbines, and fuel cells. Biomass and the carbon containing components of the waste paper become volatile at 450°C, at which temperature a synthesis gas ("syngas") rich in CO and H₂, will be produced if gasified with steam and/or oxygen.

15

20

25

Syngas produced from waste paper by utilization of geothermal steam fed by a pipe (5) will contain additional chemical constituents, both from the geothermal steam and the waste paper, which will provide additional H₂, H₂S, CO₂ gas, as well as CaCO₃ and SiO₂ in solid form. CaCO₃ is converted to CaO and CO₂ at 850°C. The gases can in turn be catalytically converted to produce high-value fuels and chemicals in a FT process.

30

Figure 1 shows the process layout of an embodiment of the invention suited for producing good-quality synthesis gas from solid MSW feedstock in an indirectly heated ("allothermal") gasification system based on the use of renewable carbonaceous feedstock, either biomass or technically classified municipal solid waste (MSW). The average chemical content of wood is

51% carbon, 6% hydrogen, 38% oxygen, and 5% ash whereas the chemical content of technically classified waste paper feedstock is approximately: 45% carbon, 30% oxygen, 20% filler material (mainly CaCO_3 and some glass, SiO_2) 4% hydrogen and 1% plastic etc. Employed in the present invention are renewable energy sources, such as geothermal steam (5), hydroelectricity or energy from high temperature steam that will be recycled in the form of electricity by a generator to electrical heating elements, other industrial uses or district heating (16) or heat from a closed circuit filled with an inert gas (8) and generated by a nuclear reactor (20). The gasification system comprises at least one gasification chamber (7) comprising electric heaters and or heated tubes (8) and a combustor (9) where tailgas composed mostly of naphtha and C1 – C4 gases is combusted.

In steam gasification, steam reacts with the raw material and the gaseous components formed during gasification. Some of the gasification reactions can be described by the following reaction formulas: $\text{C} + \text{H}_2\text{O} \rightarrow \text{CO} + \text{H}_2$, $\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2$, $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3\text{H}_2$ and $\text{CH}_4 + 2\text{H}_2\text{O} \rightarrow \text{CO}_2 + 4\text{H}_2$, $\text{C}_n\text{H}_m + 1/4 (4n-m) \text{H}_2\text{O} \rightarrow 1/8 (4n+m) \text{CH}_4 + 1/8 (4n-m)\text{CO}_2$. The amount of reaction steam has a great effect on the degree of carbon conversion and the composition of the product gas.

The fuel moisture content, the removal of oxygen by adding hydrogen (12) to the gas stream and the amount of additional steam fed to the gasifier (7) determine the amount of steam in the gasifier.

Since the envisaged feedstock (contaminated organic waste paper) contains neither sufficient O_2 , nor H_2 to optimize carbon utilization for fuel production, carefully metered amounts of these gases, produced either by electrolysis or by steam heated to temperatures above 2500°C from a nuclear reactor (20), will be added (11, 12) to the system for reaction purposes, because care must be taken not to cause unwanted combustion.

Some of the tail gas (20 - 30%) cannot be converted into diesel fuel and may be either combusted in the gasifier to produce additional heat (22) or converted into high octane gasoline (21).

CO₂ is produced by combusting the tail gas. It is also a constituent of the geothermal steam and produced in the reaction $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$. The CO₂ may be used as raw material for methanol production.

5 In addition to a partially purified and cooled synthesis gas, the gasifier may be adapted to receive other gas streams, which are obtained from gas purification units situated downstream of the gasifier. Such a gas stream can for instance be carbon dioxide (18) separated from the synthesis gas which, in addition to the above processes, reacts with the raw material as follows: $\text{C} + \text{CO}_2 \rightarrow 2\text{CO}$. Other gas streams may for example include the non-reacted
10 portion of synthesis gas (so-called tail gas) from the synthesis step (22), steam and/or similar side-streams, which may be removed by CO₂ removal units (18).

All heated surfaces of the apparatus are insulated to save energy. Recycling of heat by the circulating loop into either the feedstock or the gasification process is necessary to increase
15 energy efficiency.

The high temperature geothermal steam (5) would be at 20 bar at 250°C, containing H₂, H₂S and H₂O. H₂S must be removed (15) because it would damage the catalysts employed in the FT conversion (14). Therefore it is advantageously eliminated by the Rectisol® process (15)
20 and the CO₂ pollution is also reduced and additionally, ammonia is removed. The Rectisol® process uses refrigerated methanol at high pressure for physical absorption (Koss and Schlichting 2005).

According to an embodiment of the present invention, gasification can be carried out in a
25 gasifier (7) comprising simply a single heat-resistant tube with a refractory liner and a catalyst.

According to a preferred embodiment, the gasifier (7) comprises a tubular vessel, which is either in a horizontal or a vertical position with a refractory liner and a monolith. Oxygen (11)
30 is injected to elevate the reaction temperature to a desired level. From the gasifier (7), synthesis gas is subjected to gas treatment which includes heat treatment, recovery and further purification of the gas (19) from fly ash, whereupon the gas is passed further to a C_nH_{2n+2} circulatory system (10) and GTL (Gas to Liquid) synthesis (FT conversion (14)).

In certain embodiments of the invention, the quality of the synthesis gas can be improved by the use of a suitable catalyst in the gasifier (7) (WO/2004/072207) to bring the reactions therein closer to the chemical equilibrium or, alternatively, oxygen injection (11) can be used to elevate the gas temperature until tar components are practically nonexistent. With the help
5 of the elevated temperature and monolith, the pyrolysis gases produced by the pyrolyser can be refined into feedstock components, i.e. hydrogen and carbon oxides that may be used as further feedstock in FT processes. Since the envisaged feedstock contains neither sufficient O₂, nor H₂ needed to optimize carbon utilization for fuel production, these gases (11, 12) will be carefully dosed by a dosing device built into the system for reaction purposes.

10

There is a further embodiment to the invention whereby the gaseous and liquid product, waste streams of a liquid fuel production plant, and steam produced by the chemical reaction and heating are circulated to bring additional energy to the generation of synthesis gas. Thus, the product and waste streams can be utilised to import additional energy to the gasification stage
15 where the gasifier is provided with a facility for combusting supplementary fuel for start-up and interference situations. The product/waste streams (22) are passed to the combustion cell of the gasifier unit (9). The circulation of non-reacted synthesis gas substantially reduces the need for import of external energy.

20 The invention furthermore includes an embodiment in which gas streams from the process stages situated downstream of the gasifier (9) can be circulated to a combination pyrolyser-gasifier.

In conventional indirect steam gasification, the bed material and fuel are transported to the
25 upper portion of the gasifier with the help of steam flow. Herein, the minimum mass flow rate of the steam is determined by the transport ability of the steam flow, the bed material and the raw material. Hence, the amount of additional steam cannot be freely used as a control variable.

30 Tar cleaning processes have proven their technical viability. Besides tar, other significant raw gas contaminants include alkalis, ammonia, chlorides, sulphides and particulates. Sulphur, CaO and SiO₂ must, however, be removed from the syngas in order to clean it because sulphur damages the catalysts employed in the FT conversion. Operating procedures with

stepwise gradual gas cooling have proved successful in removing alkalis and chlorides along with particulate matter as they are being separated using for example cyclones, barrier filters and electrostatic precipitators. Both ceramic and sintered metal barrier filters have been developed and successfully demonstrated for removing particulate matter from raw gases in CaO and SiO₂ removal units (17) (WO/2004/072207).

In certain embodiments the solids are effectively and completely separated from the syngas in a separator upstream of the FT conversion (14) by CaO and SiO₂ removal units (17). For some applications flexible ceramic bag filters, which now receive much attention, will offer an attractive alternative to the fragile barrier filters (WO/2004/072207). The solids separator is a cyclone assembly comprising one or more cyclones connected with each other in parallel or in series. It is moreover of advantage to include at least one multi-port cyclone in the cyclone assembly. During the separation of fine materials, some of the particles from an air or gas flow which are really light-weight, are difficult to separate in a single-port cyclone, whereas a multi-port cyclone, or a fly ash removal unit (19) employing e.g. electrostatic precipitators can accomplish this task. Gas clean-up systems may have to be designed to suit site-specific applications.

These methods are capable of effective separation of ash and other solids from the syngas. In an embodiment in which the solids are removed, the gasifier conditions are favourable for the catalyst used at the gasification stage (WO/2004/072207).

The main products of the invention are liquid fuels with high energy densities (i.e. diesel and gasoline fuels and perhaps fuel additives), but the secondary products: S, CaO, SiO₂ and tail gas, have potential industrial applications. Carbon utilization and energy efficiency are thus much higher than can be achieved with existing technology. The synergies with parallel industries can be substantial and result in lower unit production costs.

In an alternative embodiment of the invention, the import of external energy to the gasification stage is effected indirectly by using direct oxygen injection into the gas stream. In an yet another alternative embodiment increased energy efficiency by insulation of all outside heated surfaces will be achieved.

The syngas is heated in an entrained gasifier to a temperature reaching 1200°C and in a combustor where the temperature could reach 1600°C, and cleaned by electrical precipitation. At this stage it is mainly composed of cleaned CO and H₂ delivered from the gasifier to a CO/H₂ circulating unit.

5

The invention also includes an embodiment, in which gas treatment includes heat recovery, filtration, scrubbing (13) and removal of undesired components such as sulphur compounds and carbon dioxide. This embodiment may also involve compression of the synthesis gas, if the pressure levels of the gasification and FT process stages are different.

10

Another important aspect of gas conditioning is the recovery of heat from raw product gases employing heat exchangers and steam recovery. These heat exchangers should be constructed from corrosion resistant materials to prevent fuel gas and air leakage. The heat exchangers should be designed so that the particulate matter entrained within the raw gas passes through and does not lead to blockages. In this regard, it is equally important to select tested and evaluated robust tar decomposition additives or catalysts, which do not contribute to dust entrainment within the product gas. It is also imperative to follow a gas handling procedure that minimises re-absorption of CO₂ by additives and absorbents that may lead to agglomeration of entrained dust and blockage of heat exchanger tubes and gas transfer pipes and the low-ash fusion temperature of certain biomass, particularly under reducing conditions, may require special care in the design and operation of type of gasifier considered (WO/2004/072207).

15

20

One of the main characteristics of FT processes is that the economics of scale apply in such a manner that increases in capacity are very effective up to an input of approximately 400 MW corresponding to 1.000.000 tonnes of feedstock, but is negligible for larger facilities (Tijmensen et al. 2002). The facility cost is by far the largest component of the total processing costs.

25

The second largest cost component is the procurement of suitable feedstock. Therefore the utilization of large installations, cheap energy and the availability of large cheap feedstock quantities (each facility processing 1.000.000 tonnes of energy pellets/year) are necessary prerequisites for an economical operation (Tijmensen et al. 2002).

30

References cited:

Babu, S.P. (2005), "Observations on the current status of biomass gasification", *IEA Bioenergy*.

5

Koss, U. and Schlichting, H. 2005: Lurgi's MPG gasification + Rectisol® gas purification for reliable syngas production. Gasification Technologies 2005, San Francisco, October 9-12, 2005, <http://www.gasification.org/Docs/Conferences/2005/41SCHL.pdf>

- 10 Tijmensen, M.A., Faaij, A.P.C., Hamelinek, C.N. and van Hardeveld, M.R.M. (2002), "Exploration of the possibilities for production of Fischer Tropsch liquids and power via biomass gasification", *Biomass and Bioenergy* 23, 129-152.

WO/2004/072207, "Method for producing synthetic gas."

15

Claims

1. A method for the production of liquid synthetic fuels from carbon containing feedstock, for example biomass, waste paper or coal, which is allothermally gasified in a gasifier (7) to produce syngas components by application of external energy such as:

i) high temperature geothermal steam (5), hydro-electricity, and/or heat derived from nuclear reactors (20),

ii) recycled heat from a syngas product (10),

iii) optionally additional heat produced by combustion of tail gas (22) in a combustor (9) of said gasifier (7), and

iv) optionally recycled energy in the form of electricity (16), generated by high temperature steam generated by the process, applied to electrical heating elements,

characterized in that

a nuclear reactor (20) is employed to superheat steam up to temperatures above 2.500°C, at which H₂ (12) and O₂ (11) are separated and then directed to the gasifier (7) in the proportion required for the conversion of said syngas components into liquid fuels by Fischer-Tropsch synthesis.

2. The method according to claim 1, *characterized by* the use of the excess heat of the heat exchangers and the gasification unit (7) for heating of the feedstock (4) and for production of electricity (16) for the electric heaters.

3. The method according to claims 1 and 2, *characterized in that* the said feedstock is preheated and transported to said gasifier (7) by the said high temperature geothermal steam (5) that is imported through heat exchanger (4) and mixer (6).

4. The method according to claims 1 to 3, *characterized in that* the said high temperature geothermal steam (5) is imported to the said gasifier (7) along with a stream of carbon dioxide and/or tail gas.

5. The method according to any one of the preceding claims, *characterized in that* the said high temperature geothermal steam (5) is imported to an apparatus where refrigerated methanol at high pressure is used for physical absorption and selective separation of H₂S and H₂ from the steam (15) and the latter then utilized for methanol production by reaction with the CO₂ contained in the geothermal steam or produced by combustion in the combustor.
6. The method according to any one of the preceding claims, further *characterized in that* the steam, heated to above 850°C in the gasifier (7), is diverted from the gasifier (7) to an electric generator, other industrial uses or direct heating (16).
7. The method according to any one of the preceding claims, further *characterized in that* a cyclone assembly with barrier filters and electrostatic precipitators is used for removing from the gas stream in the gasification chamber the CaO and SiO₂ that may have entered the stream from the feedstock (3).
8. System for performing the method according to any one claims 1 to 7 in order to produce liquid synthetic fuels of high energy content, other forms of energy and by-products for industrial production of e.g. gypsum or cement or from carbon containing feedstock, for example biomass, waste paper or coal, comprising:
- a) a subsystem for preparation of raw material consisting of an inlet for raw material (1), at least one unit for grinding (2), a hopper (3) for collecting the material, heat exchanger system (4) where geothermal steam (5) is introduced with heat from recirculated syngas (10), a mixer (6) where the said steam (5) and the said raw material is thoroughly blended;
- b) a subsystem for degrading chemically the said raw material, received from the said mixer (6), consisting of a gasifier (7) where the said material is further heated with electric heaters (8) and enriched with O₂ (11) and/or H₂ (12), produced by exposing water to a temperature above 2500°C in a nuclear reactor (20), to produce syngas for further transport to a combustor (9) where tar and other remaining material is combusted/pyrolyzed with the optional aid of heat

generated from combustion of tail gas (22) from a Fischer-Tropsch reactor (14), to produce CO₂ gas that is removed.

5 c) a subsystem for recirculation of energy consisting of the said circulation of syngas (10), the said burning of tail gas (22), steam received from the said combustor (9) for production of electricity (16) used in heating of said gasifier (7) and/or used in the electrolytic production of O₂ (11) and H₂ (12) used in the gasification and/or the combustion process or distributed to the community and heat optionally obtained from CO₂ (18) and other gases reintroduced to the
10 process;

d) a subsystem for cleaning consisting of a unit for the removal of sulphur (15), a unit for the removal of CO₂ (18), optionally re-introduced to the process or used in the synthesis of methanol, a unit for the removal of fly ash (19), a unit for the removal of CaO and SiO₂ (17) for the optional production of e.g. cement, and a
15 scrubber (13) for the cleanup of the said syngas;

e) a subsystem for steam removal for the production of energy in the form of electricity for use in the process (8, 20) or for outside distribution and/or for
20 district heating and/or other industrial uses (16) or for providing energy to the process from the same (16).

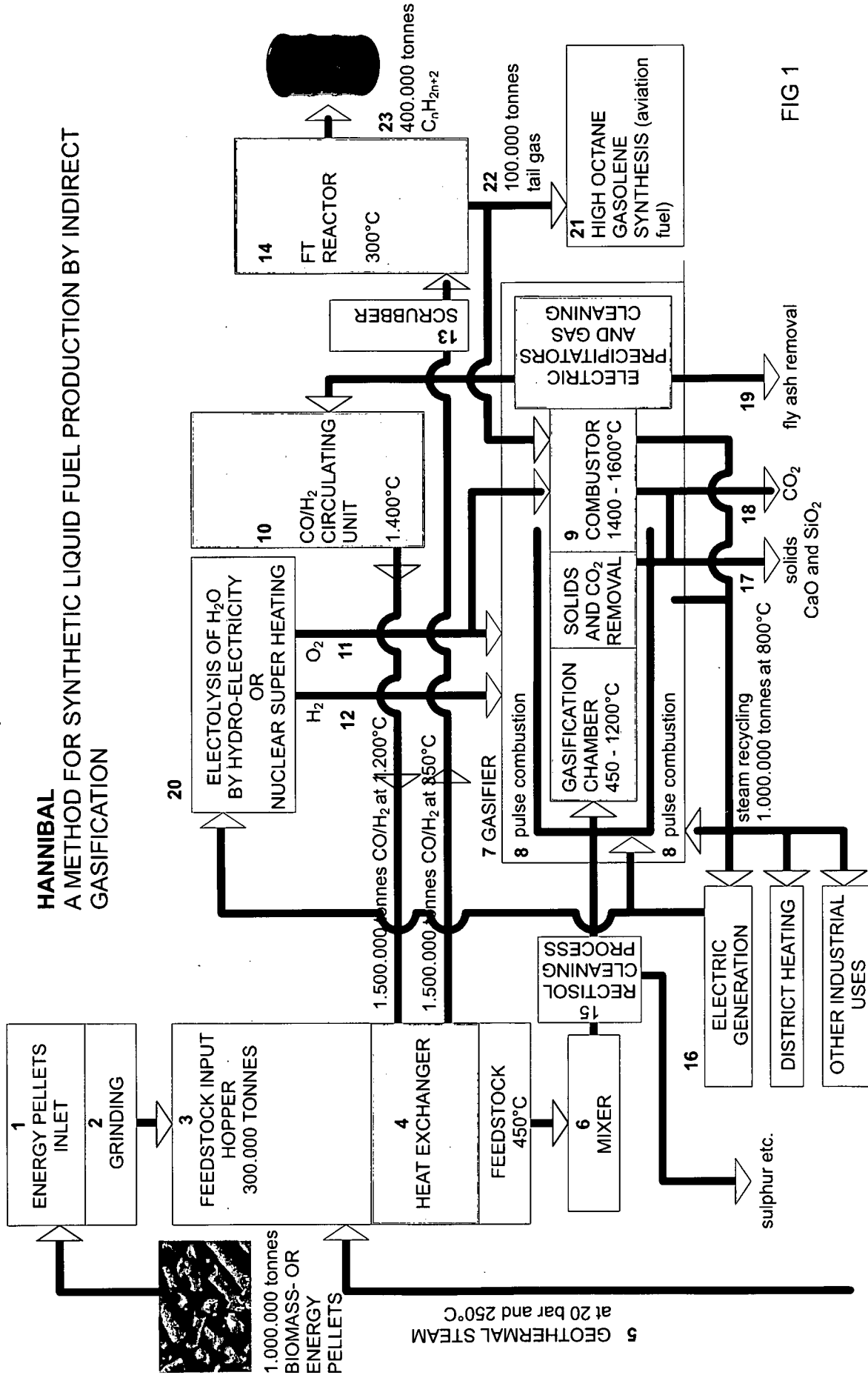


FIG 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IS2011/000002

A. CLASSIFICATION OF SUBJECT MATTER
C10G2/00 (2006.01), C10J3/00 (2006.01)

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/ECLA: C01B, C07C, C10G, C10J, G21C, G21DDocumentation searched other than minimum documentation to the extent that such documents are included in the fields searched
DK, FI, NO, SE: classes as aboveElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPODOC, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|--|-----------------------|
| A | US 2008103220 A1 (CHERRY et al.) 1 May 2008, see the whole document. | 1 and 8 |
| A | WO 2006099573 A1 (FUELCOR LLC) 21 September 2006. | - |
| A | WO 2006022687 A2 (THE REGENTS OF THE UNIVERSITY OF CALIFORNIA) 2 March 2006. | - |
| A | WO 2008033812 A2 (PURDUE RESEARCH FOUNDATION) 20 March 2008. | - |

 Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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

"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

"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

"Z" document member of the same patent family

Date of the actual completion of the international search

09/09/2011

Date of mailing of the international search report

15/09/2011

Name and mailing address of the ISA/
Nordic Patent Institute
Helgeshøj Allé 81, 2630 Taastrup, Denmark

Facsimile No. +45 43 50 80 08

Authorized officer

Verner Holm

Telephone No. +45 43 50 83 54 (direct number)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/IS2011/000002

| Patent document Cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---------------------|----------------------------|---------------------|
| US 2008103220 A1 | 2008-05-01 | US 2008098654 A1 | 2008-05-01 |
| ----- | | | |
| WO 2006099573 A1 | 2006-09-21 | US 2011054047 A1 | 2011-03-03 |
| | | US 2011054044 A1 | 2011-03-03 |
| | | US 2011044860 A1 | 2011-02-24 |
| | | US 2010111783 A1 | 2010-05-06 |
| | | US 2010113623 A1 | 2010-05-06 |
| | | US 7863340 B2 | 2011-01-04 |
| | | KR 20070122215 A | 2007-12-28 |
| | | US 2006211777 A1 | 2006-09-21 |
| | | US 7642292 B2 | 2010-01-05 |
| | | SG 160406 A1 | 2010-04-29 |
| | | RU 2007138221 A | 2009-04-27 |
| | | RU 2394871 C2 | 2010-07-20 |
| | | JP 2008533287 A | 2008-08-21 |
| | | EP 1861478 A1 | 2007-12-05 |
| | | CN 101160375 A | 2008-04-09 |
| | | CA 2601445 A1 | 2006-09-21 |
| ----- | | | |
| WO 2006022687 A2 | 2006-03-02 | US 2011126458 A1 | 2011-06-02 |
| | | US 2010285576 A1 | 2010-11-11 |
| | | US 2009221721 A1 | 2009-09-03 |
| | | KR 20070042571 A | 2007-04-23 |
| | | MX 2007001565 A | 2007-04-18 |
| | | WO 2006022687 A3 | 2008-01-03 |
| | | RU 2007108085 A | 2008-09-10 |
| | | JP 2008525532 A | 2008-07-17 |
| | | EP 1792134 A2 | 2007-06-06 |
| | | CN 101218018 A | 2008-07-09 |
| | | CA 2575963 A1 | 2006-03-02 |
| | | BRPI 0418977 A | 2008-01-29 |
| | | AU 2004322730 A1 | 2006-03-02 |
| | | AU 2004322730B B2 | 2010-09-16 |
| | | US 2005032920 A1 | 2005-02-10 |
| | | US 7500997 B2 | 2009-03-10 |
| ----- | | | |
| WO 2008033812 A2 | 2008-03-20 | WO 2008033812 A3 | 2008-09-12 |
| | | US 2008115415 A1 | 2008-05-22 |