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(54) **Eljárás CO2 csökkentésére egy áramban, energiatermelésre szolgáló szintézisgázzá való átalakítással**

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(54) **METHOD FOR REDUCING CO2 IN A STREAM BY CONVERSION TO A SYNGAS FOR PRODUCTION OF ENERGY**

VERFAHREN ZUR CO2-REDUZIERUNG IN EINEM STROM DURCH UMWANDLUNG IN EIN SYNGAS ZUR STROMPRODUKTION

PROCÉDÉ DE RÉDUCTION DU CO2 DANS UN COURANT PAR CONVERSION EN UN GAZ DE SYNTHÈSE POUR LA PRODUCTION D'ÉNERGIE

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Description

[0001] This application claims the benefit of U.S. Patent Application Serial No. 11/956,107, filed on December 13, 2007, entitled "Method and Apparatus for Reducing CO_2 in a Stream by Conversion to a Syngas for Production of Energy," and continuation-in-part Patent Application Serial No. 12/271,227, filed November 14, 2008, and entitled "Method and Apparatus for Reducing CO_2 in a Stream by Conversion to a Syngas for Production of Energy".

TECHNICAL FIELD

[0002] The present invention relates generally to the field of reducing the presence of carbon dioxide (CO_2), and in specific embodiments, to reducing the carbon dioxide in a gaseous exhaust stream from power plants and other types of industrial plants, and forming a Syngas ($CO + H_2$) that can, in turn, be used in the production of energy such as liquid fuels; for example, Ethanol.

BACKGROUND

[0003] Concern about global warming eventually leads to discussions about the need to reduce the amount of carbon dioxide that pours into the earth's atmosphere on a daily basis from power plants and other industrial factories. At the same time, concerns about dwindling supplies of fossil fuels have encouraged the development of liquid fuels such as Ethanol as future replacement fossil fuels. Unfortunately, most present methods of producing a liquid fuel such as Ethanol result in as much or more carbon dioxide being introduced into the atmosphere as does burning fossil fuels.

[0004] Therefore, a method for producing a Syngas, (easily convertible to Ethanol) from gaseous streams exhausted by industrial plants would offer many advantages in cost, as well as, an overall reduction in the carbon dioxide dumped into the atmosphere.

[0005] WO 2007/022639 A1 discloses a process for the production of a hydrocarbon, which comprises subjecting a feed stream with carbon dioxide and a source of hydrogen to elevated temperatures in an oxygen reduced environment and obtaining a synthesis gas stream comprising carbon monoxide and hydrogen gas; and, utilizing the synthesis gas stream to produce at least one hydrocarbon product.

SUMMARY OF THE INVENTION

[0006] The present invention discloses methods and apparatus for reducing the carbon dioxide that is often present in gaseous streams exhausted or emitted from various power plants and types of industrial plants, such as a cement plant. For example, the typical gaseous exhaust stream of about 181437 kg/h (400,000 lbs/h) total from a cement plant will contain about 30% - 40% (about 72574.7 kg/h or 160,000 lbs/h) of carbon dioxide (CO_2). However, instead of being exhausted to the atmosphere, according to the invention, this gaseous stream is provided to a reaction chamber, such as, for example, a pyrolysis chamber. Reactions take place in the pyrolysis chamber such that the gaseous stream is converted to contain Syngas ($CO + H_2$) and a reduced amount of carbon dioxide (i.e., about 34108 kg/h or 75,195 lbs/h). The reduction in carbon dioxide is about 53%, and the Syngas can then be cleaned and used as a feedstock for the production of Ethanol. For example, a bio-catalytic process such as a Fischer-Tropsch process could be used to produce the Ethanol.

[0007] More specifically, the process for reducing the carbon dioxide and forming the Syngas comprises maintaining a reaction chamber, such as a pyrolysis chamber, at a temperature of between about 400°C and 5000°C (typically between 400°C and 2000°C) and at a pressure of about one atmosphere or greater. Note, when using a Plasma Arc Gasification chamber, temperatures in the plasma arc zone can reach between 3000°C and 7000°C. Heat is added as required since some desired reactions are endothermic. Although a pyrolysis chamber is used in a preferred embodiment, a conventional gasifier reactor, a gasification reactor or a plasma arc reactor is also believed to be suitable. A carbonaceous material being selected from coal, coke and solid waste is also provided to the reactor such that a Boudouard reaction (i.e. $C + CO_2 \leftrightarrow 2CO$) takes place.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawing, in which:

Figure 1 is a block diagram illustrating the processes of the present invention,

Figure 2 is similar to Figure 1 , but includes an available process for converting municipal solid waste to Syngas

that, in turn, uses the Syngas to provide the necessary power (e.g. electricity, steam and/or heat) to the pyrolysis reactor of the present invention,

Figure 3 illustrates the process of Figures 1 or 2 combined with another process for the production of Ethanol; and

Figure 4, which includes Figures 4a and 4b, is a detailed example of Figure 3 illustrating the use of a first and a second bio-catalytic reactor.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0009] The making and using of the presently preferred embodiments are discussed in detail below. It should be appreciated, however, that the present invention provides many applicable inventive concepts as layed down in the appended claims. The specific embodiments discussed are merely illustrative of specific ways to make and use the invention, and do not limit the scope of the invention.

[0010] Referring now to Figure 1, there is illustrated a block diagram of the present inventive process. As shown, a reaction chamber 10 receives a gaseous stream or exhaust gases, as indicated by line 12, from a power plant or industrial plant 14 such as, for example only, a cement plant with a rotary kiln. The gaseous stream from a rotary kiln will typically comprise between about 55% to about 70% Nitrogen (N_2) and about 45% to about 30% carbon dioxide (CO_2) plus minute amounts of oxygen (O_2) and other impurities. The reaction chamber 10 is preferably a pyrolysis reactor, but could also include a conventional gasifier or a plasma arc gasifier. Also provided to reactor 10 is a carbonaceous material as indicated by line 16 such as coke, coal, or another hydrocarbon source 18, such as biomass materials or municipal solid waste. In addition, as will be appreciated by those skilled in the art, since a pyrolysis reaction (i.e. the thermal decomposition of organic material by heating in the absence of oxygen and other reagents, except possibly steam) takes place at a relatively high temperature. A source of heat energy 20, including electricity and/or steam, is provided as indicated at line 22.

[0011] The reaction in the pyrolysis chamber typically will take place at about one atmosphere or one bar and at a temperature of between about 400°C and 2000°C, and preferably at about 1330°C. The primary chemical reaction that takes place in the pyrolysis reactor is the reaction of the carbonaceous material such as carbon (C) with carbon dioxide (CO_2) according to:

$$\text{Equation (1)} \qquad C + CO_2 \leftrightarrow 2CO,$$

which is also sometimes referred to as the Boudouard reaction.

[0012] Other reactions that may occur in the reaction chamber are:

$$\text{Equation (2)} \qquad C + H_2O \leftrightarrow CO + H_2,$$

often referred to as a gasification with steam;

$$\text{Equation (3)} \qquad CO + H_2O \leftrightarrow H_2 + CO_2,$$

referred to as a water-gas shift reaction; and

$$\text{Equation (4)} \qquad C_nH_m + nH_2O \leftrightarrow nCO + (n + {}^1/_2m)H_2,$$

for steam reforming.

[0013] Importantly, as seen from Equation (1), the carbon (C) provided by the source 18 combines with one of the oxygen (O) atoms of the carbon dioxide (CO_2) molecules to form two molecules of carbon monoxide (2CO) which, of course, reduces the amount of carbon dioxide (CO_2) in the reaction chamber. In addition, as indicated by Equation (2), if water (i.e. steam) is available in the pyrolysis reactor, the carbon (C) will also react with the water (H_2O) to produce carbon monoxide and free hydrogen (H_2). It will also be appreciated that all of the carbon dioxide (CO_2) will not be converted to 2CO (i.e. carbon monoxide). Further, the steam (H_2O) may also react with some of the carbon monoxide (CO) to reform some carbon dioxide (CO_2) and some hydrogen (H_2) as indicated by Equation (3). Consequently, the

pyrolysis reactor discharges Syngas as indicated on line 24 comprised of carbon monoxide (CO), hydrogen (H_2) and a reduced amount of carbon dioxide (CO_2), as indicated by block 26. Also, as shown, there will typically be a vitrified slag or ash product 28 produced by the process depending upon the temperature of the pyrolysis reactor. The chemical content of the vitrified slag or ash will, of course, vary depending upon the carbonaceous source and temperature of the pyrolysis reactor.

[0014] The Syngas may then be provided to an emission control system 30 to remove impurities and clean up the Syngas. The Syngas control and cleanup system will remove impurities in the syngas from the pyrolysis reactor. Depending upon the feed to the pyrolysis reactor, the impurities in the syngas could be about 0.5 wt.% chlorine and 0.8 wt.% sulfur based upon an elemental analysis of the feed, as an example. Most of the sulfur is converted to hydrogen sulfide (H_2S) but some is converted to carbonyl sulfide (COS). Chlorine is converted to hydrogen chloride (HCl). Trace elements of mercury and arsenic can be found in the syngas prior to cleaning. Some particulate carryover occurs with the syngas from the pyrolysis reactor. Selection of the technology for gas cleanup depends upon depends upon the purity requirements of downstream processes using the syngas.

[0015] Particulate control is typically a Metal Candle filter or Water scrubber in combination with a cyclone. Sulfur recovery is typically a Claus plant. The acid gases such as hydrogen chloride are recovered by solvent-based processes such as Selexol or Rectisol.

[0016] Also as shown, the carbon dioxide (CO_2) in the Syngas is removed and may be returned to the pyrolysis reactor, as indicated by dotted line 12a. Thus, Syngas comprised of carbon monoxide (CO) and hydrogen (H_2) is available for further processing, as indicated at block 32.

[0017] An example of the process of reducing the carbon dioxide in a gaseous stream from a power plant or rotary cement kiln is as follows:

> The total output gaseous stream from rotary kiln of 180802 kg/h (398,600 lbs/h) is provided to a pyrolysis reactor. The total gaseous stream output includes about 72574.7 kg/h (160,000 lbs/h) (≈40%) of carbon dioxide (CO_2). A carbonaceous source of about 19805 kg/h (43,663 lbs/h) of coke or coal and a similar amount of steam (H_2O) is provided. The temperature of the reactor is maintained at about 1330°C and at about one atmosphere (one bar) of pressure. The output of the pyrolysis reactor will be a raw or uncleaned Syngas comprised of about 70827.0 kg/h (156,147 lbs/h) of carbon monoxide (CO); 1154 kg/h (2,545 lbs/h) of hydrogen (H_2) and about 34108 kg/h (75,195 lbs/h) of carbon dioxide (CO_2). Thus, it is seen that at this stage of the process the carbon dioxide (CO_2) has been reduced by about 53%. In addition, the carbon monoxide (CO) in the Syngas provides a significant economic advantage, since as will be discussed later; some bio-catalytic processes effectively use carbon monoxide (CO) as feed stock for organisms in bioreactors that produce Ethanol.

[0018] As will be appreciated by those skilled in the art, other known ecologically friendly processes can be combined with the inventive process described above. As an example and referring to Figure 2, there is shown the process of, Figure 1 wherein the source 22 of electricity, steam or heat energy is the product of a plasma arc gasification process that uses various waste products such as municipal solid waste (MSW) as a fuel source. As shown, the MSW 34 is provided to the plasma arc gasifier 36 along with an oxygen source 38 and a carbon material 40 such as coke provide a dirty or raw Syngas as indicated by line 42a. Other byproducts 44 include metals and vitrified slag. The dirty Syngas is then provided to an emission control system 44 to remove various other byproducts 46 from the Syngas such as sulfur and hydrochloric acid, etc. This leaves a clean Syngas provided on line 42b that is then used to provide the required steam and heat energy used by the pyrolysis reactor 10.

[0019] Referring now to Figure 3, there is again shown the process of Figure 1. However, as shown, the produced Syngas is now further processed to provide Ethanol. As shown, the Syngas 32 is provided by line 50 to a water-gas shift reactor 52 and then to a bio-catalytic reactor 54 such as a Fischer-Tropsch synthesis reactor. As known by those skilled in the art, the Fischer-Tropsch reactor may be used to convert the Syngas to Ethanol 56. More specifically, assuming that a flow of Syngas comprised of about 70827.0 kg/h (156,147 lbs/h) of carbon monoxide (CO), 1154 kg/h (2,545 lbs/h) of hydrogen (H_2), 34067 kg/h (75,105 lbs/h) of carbon dioxide (CO_2) is provided to the water-gas shift reactor 52, about 3652 kg/h (8,051 lbs/h) of water (steam) will be required to adjust the carbon monoxide (CO) and hydrogen (H_2) molar ratio to 3.00 moles of carbon monoxide (CO) for 1.00 each mole of hydrogen (H_2). This adjustment is according to the reaction represented by:

$$\text{Equation (5)} \qquad CO + H_2O \rightarrow CO_2 + H_2.$$

[0020] Thus, it will be appreciated that the water-gas shift reactor 52 can be adjusted to produce syngas having a wide range of molar ratios to meet the needs of various downstream processes that convert or use syngas. Various downstream

processes presently in use may successfully operate with carbon monoxide CO to hydrogen H_2 ratios that range between 0.2 to 5.0 moles of carbon monoxide to 5.0 to 0.2 moles of hydrogen.

[0021] More specifically, a mass flow rate of 70827.0 kg/h (156,147 lbs/h) of carbon monoxide (CO) represents 702.40 (5,574.7 lbmole/h), and 1154 kg/h (2.545 lbs/h) of hydrogen (H_2) represents 159.06 mol/s (1,262.4 lbmole/hr) of hydrogen (H_2). Therefore, as an example, the water-gas shift reactor may be set to shift or rearrange the amount of carbon monoxide (CO) and hydrogen (H_2) such that the final mixture ratio comprises 646.09 mol/s (5,127.8 lbmole/h) of carbon monoxide (CO) and 215.37 mol/s (1,709.3 lbmole/h) of hydrogen (H_2). This shift is selected to facilitate the reaction that produces Ethanol (C_2HsOH). The reaction is shown below in Equation (6).

Equation (6) $$CO + H_2 + H_2O \rightarrow C_2H_5OH.$$

Therefore, similar to the above discussion, this reaction takes place with a carbon monoxide (CO) to hydrogen (H_2) molar ratio of between 2.0 and 5.0 moles of carbon monoxide to 5.0 to 0.2 moles of hydrogen. For example, with an adjustment of between 3.0 and 0.2 moles of carbon monoxide to 1.0 moles of the production of Ethanol at 100% of its actual experimental yield from a bio-catalytic reactor is 27277 kg/h (60,136 lbs/h) of Ethanol, is about 34618 l/h (80,120,000 gallons/yr) after distillation.

[0022] This reaction does not produce carbon dioxide (CO_2). Therefore, from the start of the industrial gaseous stream 14 containing 72574.7 kg/h (160,000 lbs/hr) of carbon dioxide (CO_2) to the discharge of the pyrolysis reactor 10, the reduction in emitted carbon dioxide (CO_2) is 34067 kg/h (75,105 lbs/h), or a reduction of about 53%. The water-gas shift adds about 8920.8 kg/h (19,667 lbs/h) of carbon dioxide (CO_2) for a total of 43029 kg/h (94,862 lbs/h) of carbon dioxide (CO_2) rather than the original 72574.7 kg/h (160,000 lbs/h) for about a total 40% reduction. Of course, in addition to the reduction in exhausted CO_2, there is a bonus of 27277 kg/h (60,136 lbs/h or 80,120,000 gallons/yr) of Ethanol.

[0023] Referring to Figure 4, there is shown a more detailed block flow diagram for producing Ethanol that uses two bio-catalytic reactors in series and which illustrates the flow rate of gases, steam, and carbonaceous materials, etc. The reference numbers of common elements or systems are the same as in Figure 3. However, as shown, rather than a single bio-catalytic converter 54, there is a first bio-catalytic converter 54a that results in the 34616 l/h (80,114,836 gallons/yr) of Ethanol (block 56) after being distilled as indicated at 58. As is also shown, however, the tail gas from the bio-catalytic converter 54a comprises 43029 kg/h (94,862 lbs/h) of carbon dioxide (CO_2), as well as 9849 kg/h (21,714 lbs/h) of carbon monoxide (CO) and 860.5 kg/h (1,897 lbs/h) of hydrogen (H_2) as indicated in block 60. Therefore, according to this embodiment, the tail gas of block 60 is provided to a second bio-catalytic converter 54b, that is assumed to operate at a 50% yield rather than 100%. Another water-gas shift, as discussed above, is also indicated. The output of the second bio- catalytic converter 54b is another 2616 l/h (6,055,899 gallons/yr) of Ethanol, as indicated at block 64, after passing the gas through a second distillation process 62 for a total of 37232 l/h (86,170,735 gallons/yr). Since the process does not add carbon dioxide (CO_2), the tail gas indicated at block 66 from the second bioreactor 54b still contains the 43001 kg/h (94,802 lbs/h). of carbon dioxide (CO_2) but reduced carbon monoxide (CO). However, if we assume the discharge of the tail gas from the second reactor to the atmosphere is accomplished with a flare burn-off, an additional 8907.6 kg/ h (19,638 lbs/h) of carbon dioxide (CO_2) may be added to the 43029 kg/h (94,862 lbs/h). to give a total of 51936 kg/h (114,500 lbs/h) of carbon dioxide (CO_2). This still represents a 28.4% reduction of carbon dioxide (CO_2) plus the bonus of 37232 l/h (86,170,735 gallons/yr) of Ethanol.

Claims

1. A process for producing syngas that reduces the amount of carbon dioxide in a gaseous stream, wherein said gaseous stream comprises between 55% to 70% nitrogen (N_2) and between 45% to 30% carbon dioxide (CO_2) plus minute amounts of oxygen (O_2) and other impurities;
   the process comprising:

   maintaining a reaction chamber at a temperature of between 400°C and 5000°C and at a pressure of one bar or greater;
   providing a carbonaceous material in said reaction chamber,

   wherein said carbonaceous material is selected from the group consisting of coke, coal and solid waste;

   introducing steam (H_2O) to said reaction chamber;
   introducing said gaseous stream to said reaction chamber;

reacting materials in said reaction chamber, wherein said reacting materials consist essentially of said carbonaceous material, said steam (H_2O) and said carbon dioxide (CO_2) from said gaseous stream to reduce said CO_2 and to form syngas comprising carbon monoxide (CO) and hydrogen (H_2).

2. The process of claim 1, wherein said reaction chamber is selected to be one of a pyrolysis reactor, a conventional gasifier or a plasma arc gasifier.

3. The process of claim 1, wherein said reaction chamber is a pyrolysis reactor.

4. The process of claim 1, wherein said step of reacting comprises a Boudouard reaction as the primary chemical reaction.

5. The process of claim 1, further comprising the step of providing said formed syngas comprising carbon monoxide (CO) and hydrogen (H_2) to an emission control system to clean said syngas by removing impurities.

6. The process of claim 5, wherein said cleaned syngas is provided to a water-gas shift reactor to adjust the carbon monoxide and hydrogen molar ratio between 0.20 to 3.00 molecules of carbon monoxide for 1.00 molecules of hydrogen.

7. The process of claim 6, wherein said molar adjusted carbon monoxide and hydrogen are provided to a bio-catalytic reactor to produce Ethanol.

8. The process of claim 7, wherein said bio-catalytic reactor is a Fischer-Tropsch synthesis reactor.

9. The process of any of claims 1 or 8, wherein said gas comprising carbon monoxide and hydrogen is provided to a bio-catalytic reactor to produce Ethanol.

10. The process of claim 9, wherein an output of said bio-catalytic reactor is provided to another bio-catalytic reactor to provide additional Ethanol.

11. The process of claim 1, wherein said reaction chamber is maintained at a temperature of 1330 °C.

12. The process of claim 1, wherein the amount of CO_2 in said syngas is 53% less than the amount of CO_2 that was provided in said gaseous stream.

13. The process of claim 1, further comprising the step of providing said formed syngas comprising carbon monoxide (CO) and hydrogen (H_2) to a water-gas shift reactor to adjust the carbon monoxide and hydrogen molar ratio between 0.2 to 5.0 molecules of carbon monoxide (CO) and 5.0 to 0.2 molecules of hydrogen (H_2).

Patentansprüche

1. Verfahren zum Herstellen von Synthesegas, das die Menge an Kohlendioxid in einem gasförmigen Strom reduziert, wobei der gasförmige Strom zwischen 55% und 70% Stickstoff (N_2) und zwischen 45% und 30% Kohlendioxid (CO_2) plus geringe Mengen an Sauerstoff (O_2) und anderen Verunreinigungen umfasst;
wobei das Verfahren umfasst:

Halten einer Reaktionskammer auf einer Temperatur zwischen 400°C und 5000°C und auf einem Druck von einem Bar oder mehr;
Bereitstellen eines kohlenstoffhaltigen Materials in der Reaktionskammer,

wobei das kohlenstoffhaltige Material aus der Gruppe bestehend aus Koks, Kohle und festem Abfallstoff ausgewählt wird;

Einführen von Dampf (H_2O) in die Reaktionskammer;
Einführen des gasförmigen Stroms in die Reaktionskammer;
Umsetzen der Materialien in der Reaktionskammer, wobei die reagierenden Materialien im Wesentlichen aus dem kohlenstoffhaltigen Material, dem Dampf (H_2O) und dem Kohlendioxid (CO_2) aus dem gasförmigen Strom

bestehen, um das CO_2 zu reduzieren und Synthesegas zu bilden, das Kohlenmonoxid (CO) und Wasserstoff (H_2) umfasst.

2. Verfahren nach Anspruch 1, wobei die Reaktionskammer ausgewählt ist, ein Pyrolysereaktor, ein herkömmlicher Vergaser oder ein Plasmabogenvergaser zu sein.

3. Verfahren nach Anspruch 1, wobei die Reaktionskammer ein Pyrolysereaktor ist.

4. Verfahren nach Anspruch 1, wobei der Schritt des Umsetzens eine Boudouard-Reaktion als primäre chemische Reaktion umfasst.

5. Verfahren nach Anspruch 1, ferner umfassend den Schritt des Bereitstellens des gebildeten Synthesegases, das Kohlenmonoxid (CO) und Wasserstoff (H_2) umfasst, an ein Emissionssteuersystem, um das Synthesegas durch die Entfernung von Verunreinigungen zu reinigen.

6. Verfahren nach Anspruch 5, wobei das gereinigte Synthesegas an einen Wassergas-Shift-Reaktor bereitgestellt wird, um das Molverhältnis von Kohlenmonoxid und Wasserstoff auf 0,20 bis 3,00 Kohlenmonoxidmoleküle zu 1,00 Wasserstoffmolekülen einzustellen.

7. Verfahren nach Anspruch 6, wobei das Kohlemonoxid und der Wasserstoff mit eingestelltem Molverhältnis an einen biokatalytischen Reaktor bereitgestellt werden, um Ethanol zu erzeugen.

8. Verfahren nach Anspruch 7, wobei der biokatalytische Reaktor ein Fischer-Tropsch-Synthesereaktor ist.

9. Verfahren nach einem der Ansprüche 1 oder 8, wobei das Gas, das Kohlenmonoxid und Wasserstoff umfasst, an einen biokatalytischen Reaktor bereitgestellt wird, um Ethanol zu erzeugen.

10. Verfahren nach Anspruch 9, wobei ein Ausstoß des biokatalytischen Reaktors an einen anderen biokatalytischen Reaktor bereitgestellt wird, um zusätzliches Ethanol bereitzustellen.

11. Verfahren nach Anspruch 1, wobei die Reaktionskammer auf einer Temperatur von 1330°C gehalten wird.

12. Verfahren nach Anspruch 1, wobei die Menge an CO_2 in dem Synthesegas um 53% geringer ist als die Menge an CO_2, die in dem gasförmigen Strom bereitgestellt wurde.

13. Verfahren nach Anspruch 1, ferner umfassend den Schritt des Bereitstellens des gebildeten Synthesegases, das Kohlenmonoxid (CO) und Wasserstoff (H_2) umfasst, an einen Wassergas-Shift-Reaktor, um das Molverhältnis von Kohlenmonoxid und Wasserstoff auf 0,2 bis 5,0 Kohlenmonoxidmoleküle (CO) und 5,0 bis 0,2 Wasserstoffinoleküle (H_2) einzustellen.

Revendications

1. Procédé de production de gaz de synthèse réduisant la quantité de dioxyde de carbone dans un flux gazeux, dans lequel ledit flux gazeux comprend entre 55 % et 70 % d'azote (N_2) et entre 45 % et 30 % de dioxyde de carbone (CO_2), plus des quantités infimes d'oxygène (O_2) et d'autres impuretés ;
le procédé comprenant :

le maintien d'une chambre de réaction à une température entre 400 °C et 5000 °C et à une pression de un bar ou plus ;
l'alimentation d'un matériau carboné dans ladite chambre de réaction ;

dans lequel ledit matériau carboné est sélectionné parmi le groupe consistant en du coke, du charbon et des déchets solides ;

l'introduction d'un flux (H_2O) dans ladite chambre de réaction ;
l'introduction dudit flux gazeux dans ladite chambre de réaction ;
la réaction des matériaux dans ladite chambre de réaction, dans lequel lesdits matériaux de réaction consistent

essentiellement en ledit matériau carboné, ledit flux (H_2O) et ledit dioxyde de carbone (CO_2) provenant dudit flux gazeux, afin de réduire ledit CO_2 et de former le gaz de synthèse comprenant du monoxyde de carbone (CO) et de l'hydrogène (H_2).

2. Procédé selon la revendication 1, dans lequel ladite chambre de réaction est sélectionnée pour être un dispositif parmi un réacteur de pyrolyse, un gazéifieur classique, ou un gazéifieur à arc au plasma.

3. Procédé selon la revendication 1, dans lequel ladite chambre de réaction est un réacteur de pyrolyse.

4. Procédé selon la revendication 1, dans lequel ladite étape de réaction comprend une réaction de Boudouard comme réaction chimique primaire.

5. Procédé selon la revendication 1, comprenant en outre l'étape pour alimenter ledit gaz de synthèse formé comprenant du monoxyde de carbone (CO) et de l'hydrogène (H_2) vers un système de contrôle des émissions, afin d'épurer ledit gaz de synthèse en éliminant les impuretés.

6. Procédé selon la revendication 5, dans lequel ledit gaz de synthèse épuré est alimenté vers un réacteur de conversion de gaz à l'eau, afin d'ajuster le rapport molaire du monoxyde de carbone et de l'hydrogène entre 0,20 et 3,00 molécules de monoxyde de carbone pour 1,00 molécules d'hydrogène.

7. Procédé selon la revendication 6, dans lequel le monoxyde de carbone et d'hydrogène dont le rapport molaire a été ajusté sont alimentés vers un réacteur biocatalytique afin de produire de l'éthanol.

8. Procédé selon la revendication 7, dans lequel ledit réacteur biocatalytique est un réacteur de synthèse Fischer-Tropsch.

9. Procédé selon la revendication 1 ou 8, dans lequel ledit gaz comprenant du monoxyde de carbone et de l'hydrogène est alimenté vers un réacteur biocatalytique afin de produire de l'éthanol.

10. Procédé selon la revendication 9, dans lequel une sortie dudit réacteur biocatalytique est alimentée vers un autre réacteur biocatalytique afin de produire de l'éthanol supplémentaire.

11. Procédé selon la revendication 1, dans lequel ladite chambre de réaction est maintenue à une température de 1330 °C.

12. Procédé selon la revendication 1, dans lequel la quantité de CO_2 dans ledit gaz de synthèse est de 53 % inférieure à la quantité de CO_2 alimentée dans ledit flux gazeux.

13. Procédé selon la revendication 1, comprenant en outre l'étape pour alimenter ledit gaz de synthèse formé comprenant du monoxyde de carbone (CO) et de l'hydrogène (H_2) vers un réacteur de conversion de gaz à l'eau, afin d'ajuster le rapport molaire du monoxyde de carbone et de l'hydrogène entre 0,2 et 5,0 molécules de monoxyde de carbone (CO) et entre 5,0 et 0,2 molécules d'hydrogène (H_2).

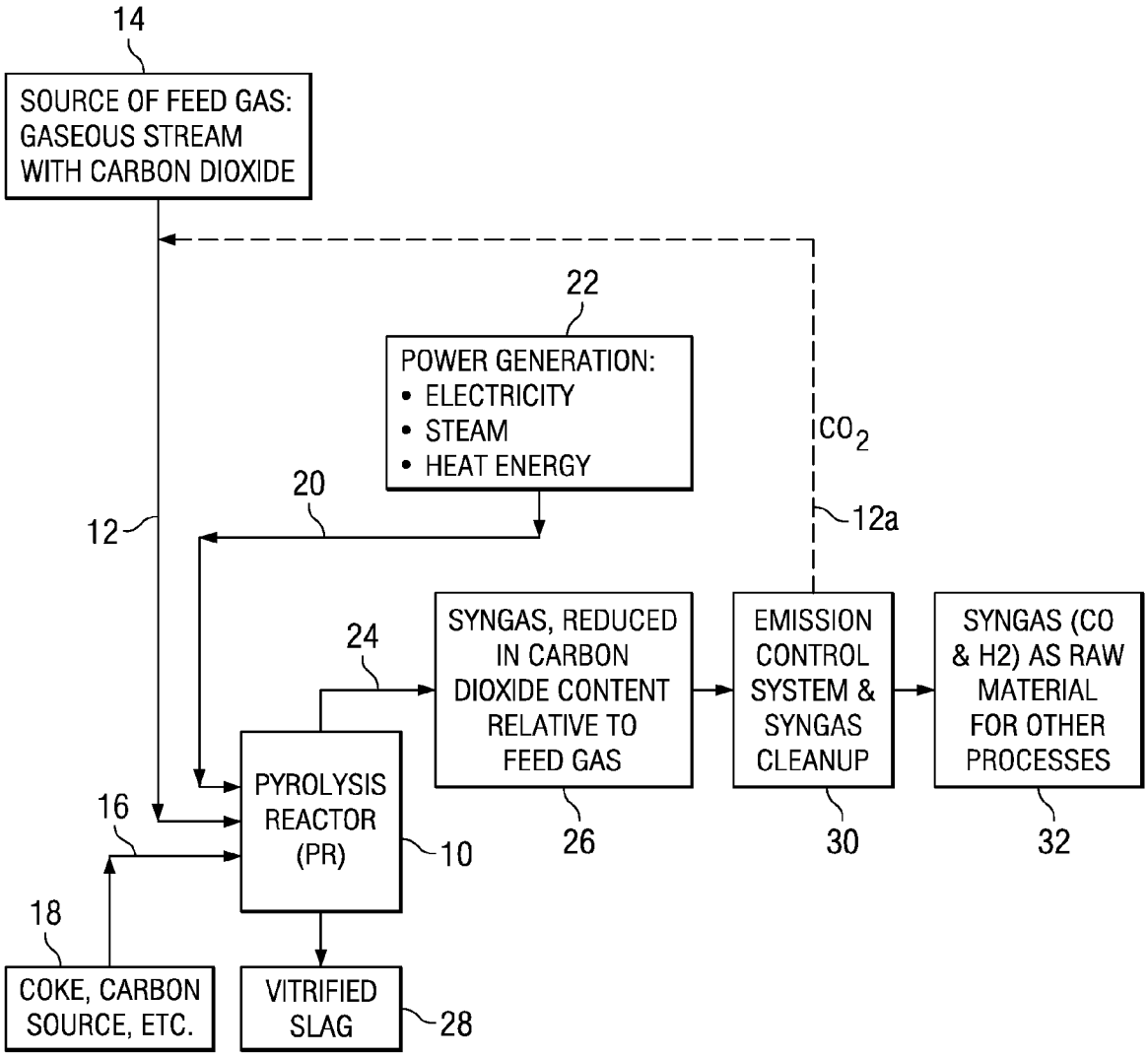
14
SOURCE OF FEED GAS: GASEOUS STREAM WITH CARBON DIOXIDE
22
POWER GENERATION:
• ELECTRICITY
• STEAM
• HEAT ENERGY
CO_2
20
12
12a
24
SYNGAS, REDUCED IN CARBON DIOXIDE CONTENT RELATIVE TO FEED GAS
EMISSION CONTROL SYSTEM & SYNGAS CLEANUP
SYNGAS (CO & H2) AS RAW MATERIAL FOR OTHER PROCESSES
16
PYROLYSIS REACTOR (PR)
10
26
30
32
18
COKE, CARBON SOURCE, ETC.
VITRIFIED SLAG
28

FIG. 1

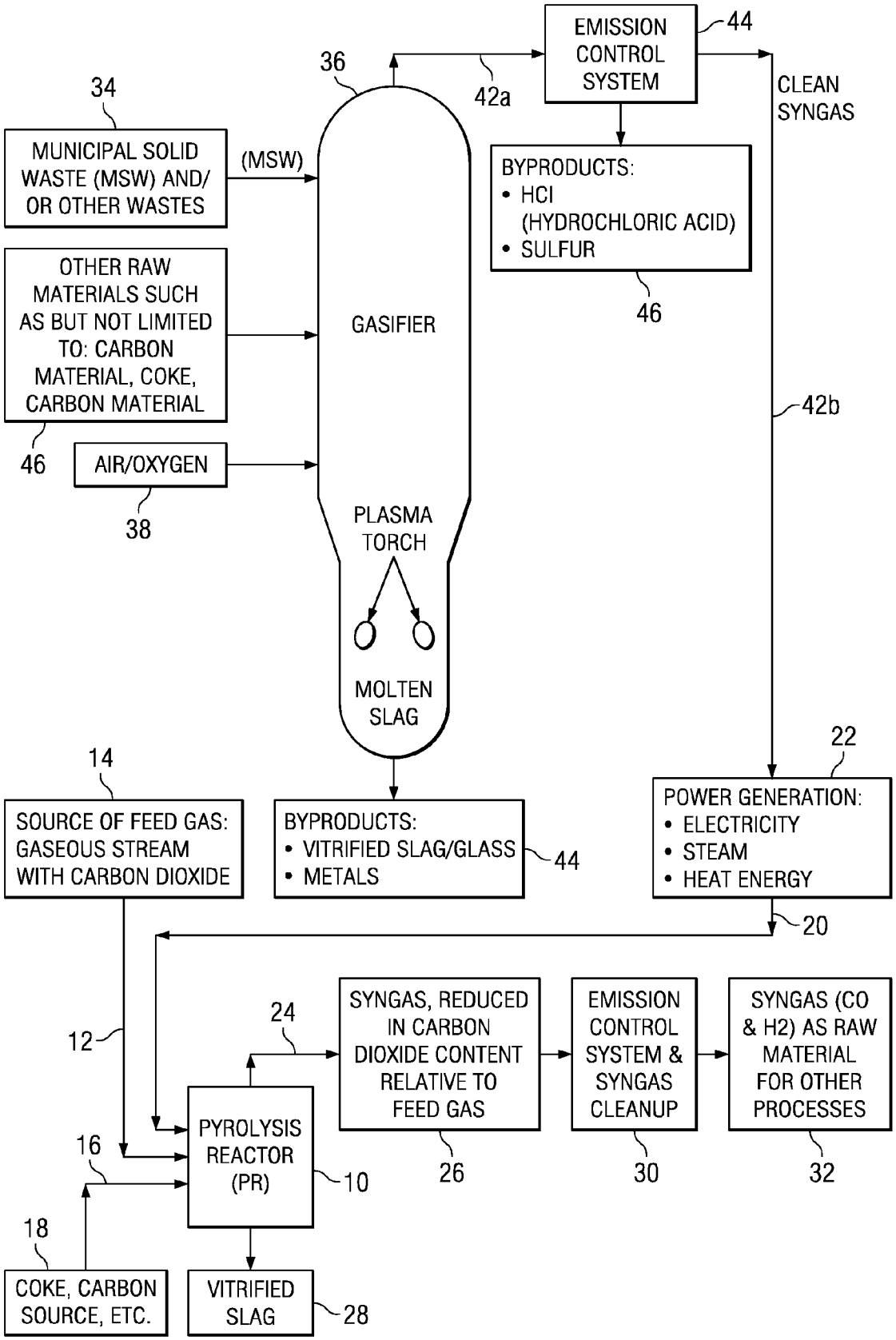
EMISSION CONTROL SYSTEM
44
CLEAN SYNGAS
36
42a
34
MUNICIPAL SOLID WASTE (MSW) AND/ OR OTHER WASTES
(MSW)
BYPRODUCTS:
• HCl (HYDROCHLORIC ACID)
• SULFUR
46
OTHER RAW MATERIALS SUCH AS BUT NOT LIMITED TO: CARBON MATERIAL, COKE, CARBON MATERIAL
GASIFIER
42b
46
AIR/OXYGEN
38
PLASMA TORCH
MOLTEN SLAG
22
14
SOURCE OF FEED GAS: GASEOUS STREAM WITH CARBON DIOXIDE
BYPRODUCTS:
• VITRIFIED SLAG/GLASS
• METALS
44
POWER GENERATION:
• ELECTRICITY
• STEAM
• HEAT ENERGY
20
24
SYNGAS, REDUCED IN CARBON DIOXIDE CONTENT RELATIVE TO FEED GAS
EMISSION CONTROL SYSTEM & SYNGAS CLEANUP
SYNGAS (CO & H2) AS RAW MATERIAL FOR OTHER PROCESSES
12
16
PYROLYSIS REACTOR (PR)
10
26
30
32
18
COKE, CARBON SOURCE, ETC.
VITRIFIED SLAG
28

FIG. 2

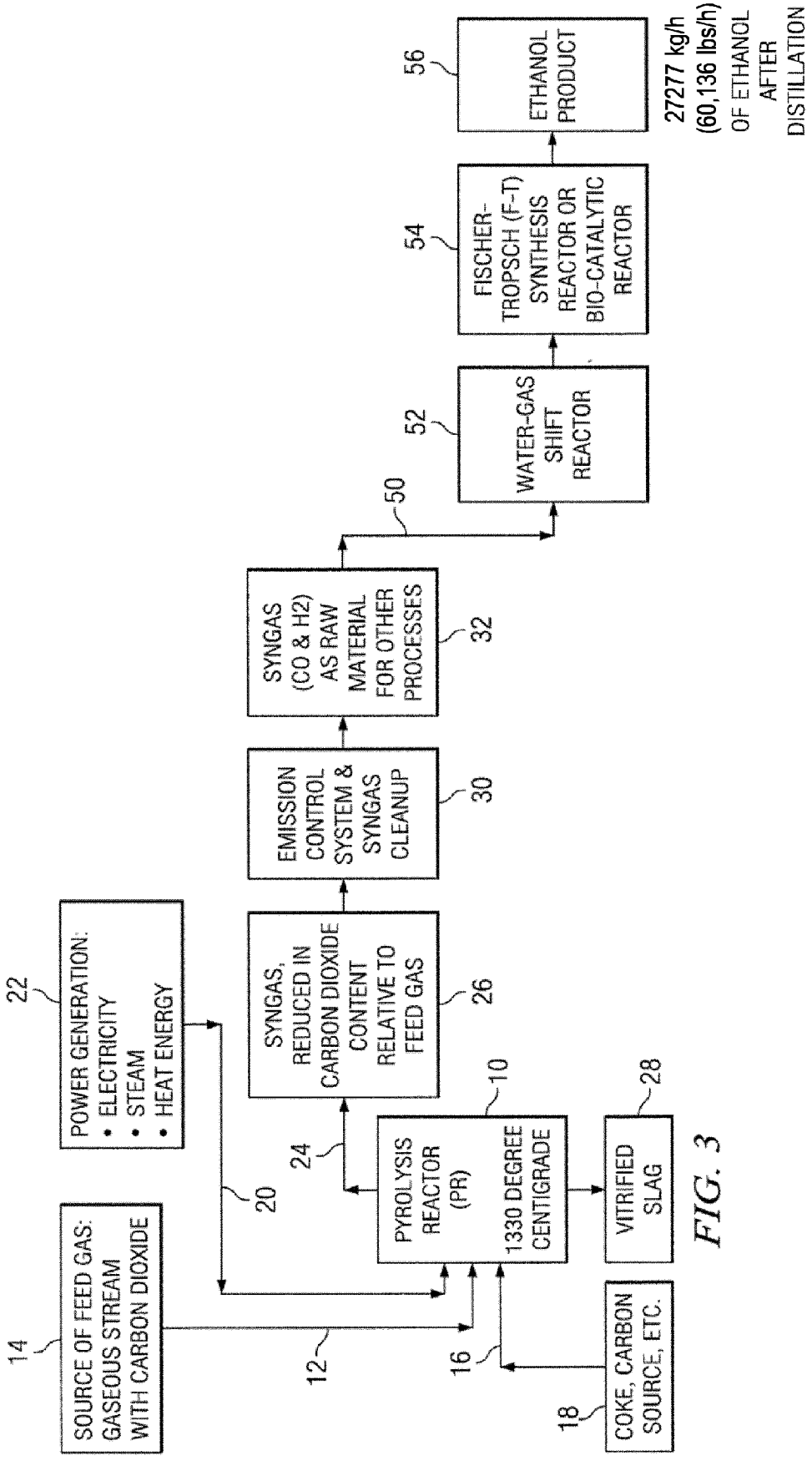
SOURCE OF FEED GAS: GASEOUS STREAM WITH CARBON DIOXIDE
14
POWER GENERATION:
• ELECTRICITY
• STEAM
• HEAT ENERGY
22
20
12
16
PYROLYSIS REACTOR (PR)
1330 DEGREE CENTIGRADE
10
24
COKE, CARBON SOURCE, ETC.
18
VITRIFIED SLAG
28
SYNGAS, REDUCED IN CARBON DIOXIDE CONTENT RELATIVE TO FEED GAS
26
EMISSION CONTROL SYSTEM & SYNGAS CLEANUP
30
SYNGAS (CO & H2) AS RAW MATERIAL FOR OTHER PROCESSES
32
50
WATER-GAS SHIFT REACTOR
52
FISCHER-TROPSCH (F-T) SYNTHESIS REACTOR OR BIO-CATALYTIC REACTOR
54
ETHANOL PRODUCT
56
27277 kg/h (60,136 lbs/h) OF ETHANOL AFTER DISTILLATION

FIG. 3

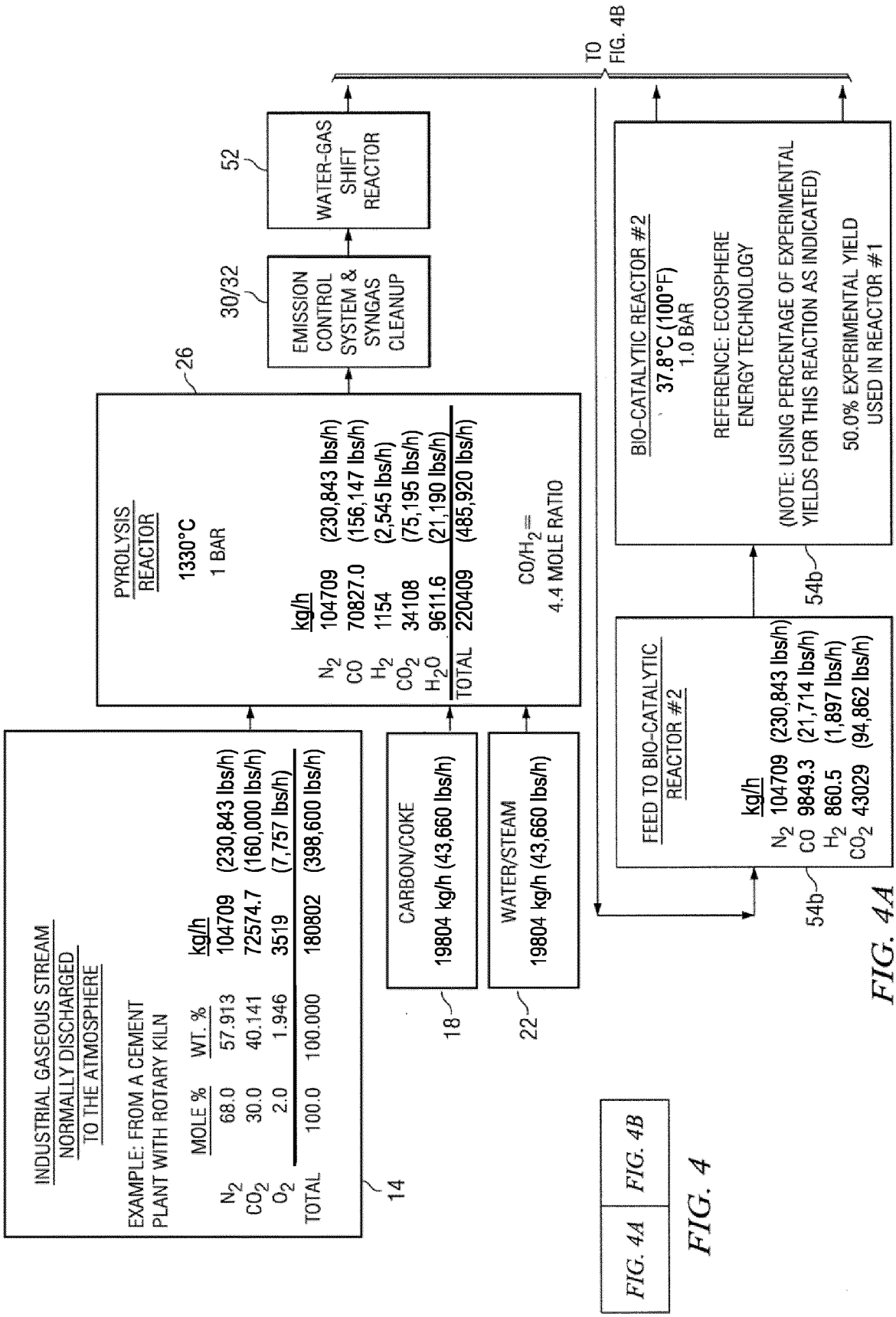

FIG. 4A

FIG. 4

FIG. 4A	FIG. 4B

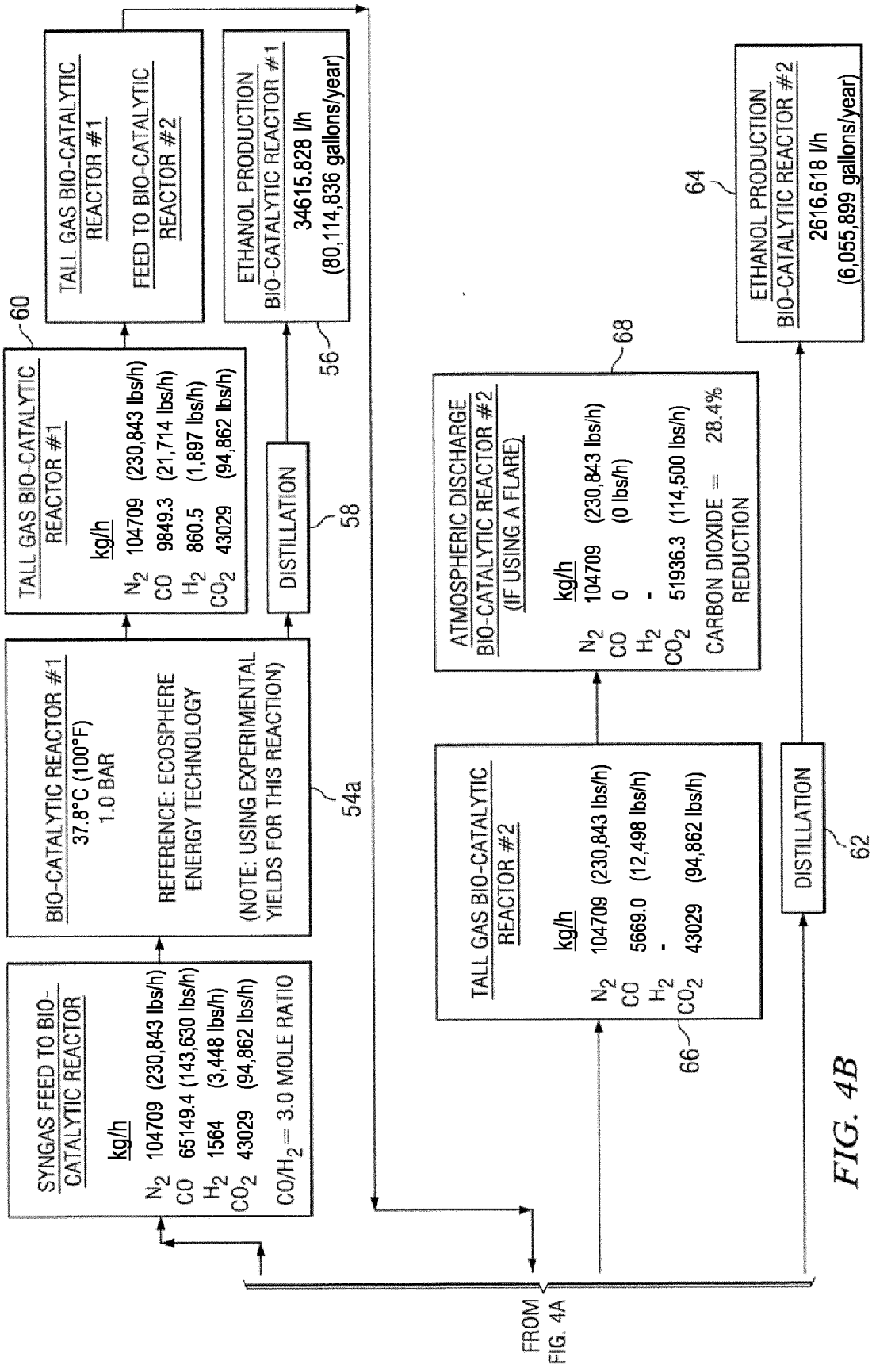
SYNGAS FEED TO BIO-CATALYTIC REACTOR
kg/h
N2 104709 (230,843 lbs/h)
CO 65149.4 (143,630 lbs/h)
H2 1564 (3,448 lbs/h)
CO2 43029 (94,862 lbs/h)
CO/H2 = 3.0 MOLE RATIO
BIO-CATALYTIC REACTOR #1
37.8°C (100°F)
1.0 BAR
REFERENCE: ECOSPHERE ENERGY TECHNOLOGY
(NOTE: USING EXPERIMENTAL YIELDS FOR THIS REACTION)
54a
TALL GAS BIO-CATALYTIC REACTOR #1
kg/h
N2 104709 (230,843 lbs/h)
CO 9849.3 (21,714 lbs/h)
H2 860.5 (1,897 lbs/h)
CO2 43029 (94,862 lbs/h)
60
DISTILLATION
58
TALL GAS BIO-CATALYTIC REACTOR #1
FEED TO BIO-CATALYTIC REACTOR #2
ETHANOL PRODUCTION
BIO-CATALYTIC REACTOR #1
34615.828 l/h
(80,114,836 gallons/year)
56
FROM FIG. 4A
TALL GAS BIO-CATALYTIC REACTOR #2
kg/h
N2 104709 (230,843 lbs/h)
CO 5669.0 (12,498 lbs/h)
H2 -
CO2 43029 (94,862 lbs/h)
66
ATMOSPHERIC DISCHARGE BIO-CATALYTIC REACTOR #2
(IF USING A FLARE)
kg/h
N2 104709 (230,843 lbs/h)
CO 0 (0 lbs/h)
H2 -
CO2 51936.3 (114,500 lbs/h)
CARBON DIOXIDE REDUCTION = 28.4%
68
DISTILLATION
62
ETHANOL PRODUCTION
BIO-CATALYTIC REACTOR #2
2616.618 l/h
(6,055,899 gallons/year)
64

FIG. 4B

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 95610707 A **[0001]**
- US 12271227 B **[0001]**
- WO 2007022639 A1 **[0005]**

Eljárás CO_2 csökkentésére egy áramban, energiatermelésre szolgáló szintézisgázzá való átalakítással

SZABADALMI IGÉNYPONTOK

1. Eljárás szintézisgáz előállítására, amely eljárás csökkenti a szén-dioxid mennyiségét egy gázáramban, ahol a gázáram 55-70 % nitrogént (N_2) és 45-30 % szén-dioxidot (CO_2) tartalmaz, ezenkívül kis mennyiségű oxigént (O_2) és más szennyeződéseket; amely eljárás magában foglalja:

egy reakciókamrának 400°C és 5000°C közötti hőmérsékleten és 1 bar vagy ennél magasabb nyomáson való tartása;

egy szenes vegyületnek a reakciókamrába való biztosítása,

ahol a szenes vegyületet a koksz, kőszén és a szilárd hulladék által alkotott csoportból választjuk ki;

gőznek (H_2O) a reakciókamrába való bevezetése;

a gázállapotú áramnak a reakciókamrába való bevezetése;

az anyagoknak a reakciókamrában való reagáltatása, ahol a reagáló anyagok lényegileg a szenes anyagból, a gőzből (H_2O) és a gázállapotú árambeli szén-dioxidból (CO_2) állnak, amellyel csökkentjük a CO_2-ot, és szén-monoxidot (CO) valamint hidrogént (H_2) tartalmazó szintézisgázt képezünk.

2. Az 1. igénypont szerinti eljárás, amelyben a reakciókamrát úgy választjuk, hogy egy pirolízis reaktor, egy hagyományos elgázosító vagy egy plazmaív elgázosító közül az egyik legyen.

3. Az 1. igénypont szerinti eljárás, amelyben a reaktor egy pirolízis reaktor.

4. Az 1. igénypont szerinti eljárás, amelyben a reakciólépés elsődleges kémia reakcióként egy Boudouard-reakciót foglal magába.

5. Az 1. igénypont szerinti eljárás, amely továbbá magában foglalja a képződött, szén-monoxidot (CO) és hidrogént (H_2) magában foglaló szintézisgáznak egy emissziót szabályozó rendszerhez való hozzáadását, amellyel a szintézisgázt, a szennyeződések eltávolításával, tisztítjuk.

6. Az 5. igénypont szerinti eljárás, amelyben a tisztított szintézisgázt egy vízgáz shift reaktorhoz adjuk hozzá, amellyel a szén-monoxid és a hidrogén moláris arányát 0,20-3,00 szén-monoxid molekula per 1 molekula hidrogénre állítjuk.

7. A 6. igénypont szerinti eljárás, amelyben a molárisan beállított szén-monoxidot és hidrogént egy biokatalitikus reaktorhoz adjuk, etanol előállítása céljából.

8. A 7. igénypont szerinti eljárás, amelyben a biokatalitikus reaktor egy Fischer-Tropsch-szintézis reaktor.

9. Az 1-8. igénypontok bármelyike szerinti eljárás, amelyben a szén-monoxidot és hidrogént tartalmazó gázt egy biokatalitikus reaktorhoz adjuk, etanol előállítása céljából.

10. A 9. igénypont szerinti eljárás, amelyben a biokatalitikus reaktornak egy kimenetét egy másik biokatalitikus reaktorhoz adjuk hozzá, további etanol biztosítása céljából.

11. Az 1. igénypont szerinti eljárás, amelyben a reakciókamrát 1330°C hőmérsékleten tartjuk.

12. Az 1. igénypont szerinti eljárás, amelyben a CO_2 hányada a szintézisgázban 53 %-al kisebb, mint az a CO_2 amit a gázáramhoz adtunk.

13. Az 1. igénypont szerinti eljárás, amely továbbá magában foglalja a képződött, szén-monoxidot (CO) és hidrogént (H_2) tartalmazó szintézisgáznak egy víz-gáz shift reaktorhoz való hozzáadását, amellyel a szén-monoxid és a hidrogén moláris hányadát 0,2-5,0 molekula szén-monoxid (CO) és 5,0-0,2 molekula hidrogén (H_2) közötti értékekre állítjuk.

A meghatalmazott:

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