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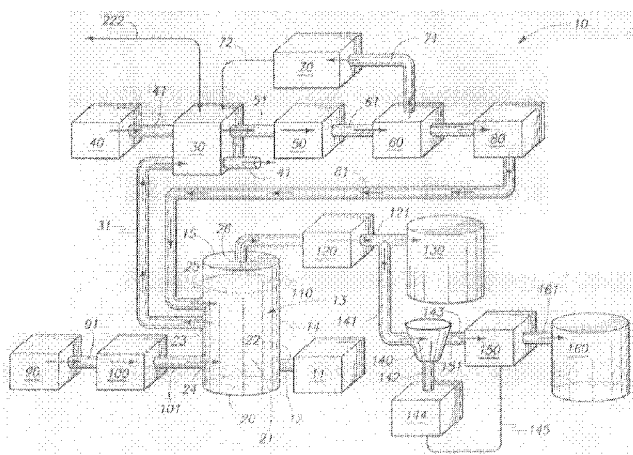
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(54) Title: METHOD OF PRODUCING HYDROGEN, AND RENDERING A CONTAMINATED BIOMASS INERT



(57) Abstract: A method for rendering a contaminated biomass inert includes providing a first composition; providing a second composition; reacting the first and second compositions together to form an alkaline hydroxide; providing a contaminated biomass and reacting the alkaline hydroxide with the contaminated biomass to render the contaminated biomass inert and further produce hydrogen gas, and a byproduct which includes the first composition.

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Method of Producing Hydrogen, and Rendering a Contaminated Biomass Inert

RELATED APPLICATION DATA

This application claims benefit of U.S. Non-provisional application No. 11/425,088,
5 filed June 19, 2006, entitled Method of Producing Hydrogen, and Rendering a Contaminated
Biomass Inert, which is incorporated herein by reference in its entirety.

GOVERNMENT RIGHTS

The United States Government has certain rights in this invention pursuant to Contract
10 No. DE-AC07-05ID14517 between the United States Department of Energy and Battelle
Energy Alliance, LLC.

TECHNICAL FIELD

The present invention relates to a method of producing hydrogen, and rendering a
15 contaminated biomass inert, and more specifically to a method which, in a first aspect,
produces a chemical hydride, which, when reacted with a liquid, produces hydrogen gas, and
a byproduct, which is then later reused, or recycled to form an additional chemical hydride
which is used in later reactions; and to a second aspect of the same method which utilizes an
alkaline hydroxide to render a contaminated biomass inert.

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BACKGROUND OF THE INVENTION

The prior art is replete with numerous examples of methods and devices, and various
means, for storing and generating hydrogen, and later using that same hydrogen for assorted
industrial applications such as a fuel in various electrochemical devices like fuel cells, or
25 which further can be consumed in internal combustion engines of various overland vehicles.

5 enclose a reactive material, such as an alkali metal, or metal hydride, that which, upon
exposure to water, produces hydrogen as a product of that reaction.

gaseous, or liquified, which makes it useful in the applications noted above. Still further, the methods currently disclosed in the prior art of producing useful chemical hydrides for the methodology discussed above, and which could potentially be used to implement, at least in part, a hydrogen infrastructure has remained elusive. Moreover, there remains no one convenient method which could be used to render a large amount of contaminated biomass inert.

Therefore a method which addresses these and other perceived shortcomings in the prior art teachings and practices, and which is also useful for rendering a biomass inert is the subject matter of the present application.

20 SUMMARY OF THE INVENTION

One aspect of the present invention is to provide a method for rendering a contaminated biomass inert which includes providing a first composition; providing a second composition; reacting the first and second compositions together to form an alkaline hydroxide; providing a contaminated biomass and reacting the alkaline hydroxide with the

contaminated biomass to render the contaminated biomass inert and further produce hydrogen gas, and a byproduct which includes the first composition.

Another aspect of the present invention is to provide a method for rendering a contaminated biomass inert which includes providing a source of a contaminated biomass; providing a source of an alkaline hydroxide, and chemically reacting the contaminated biomass with the alkaline hydroxide to render the contaminated biomass inert and to further produce an alkaline metal, and a first gas; and combusting the first gas to generate heat energy which facilitates, at least in part, the chemical reaction of the alkaline hydroxide with the biomass to be destroyed.

Still another aspect of the present invention relates to a method for rendering a contaminated biomass inert which includes providing a first chemical reactor; supplying a source of an alkaline metal to the first chemical reactor; providing a source of water and reacting the alkaline metal and the water within the first chemical reactor to produce an alkaline hydroxide; providing second, and third chemical reactors, and supplying a portion of the alkaline hydroxide to the second and third chemical reactors; providing a source of a contaminated biomass which is to be rendered inert, and chemically reacting the alkaline hydroxide with the source of the contaminated biomass within the second reactor to produce an inert biomass, the alkaline metal, and a gaseous output, and wherein the alkaline metal is returned to the first chemical reactor and reacted again with the source of water to generate additional alkaline hydroxide; combusting the gaseous output to generate heat energy which is delivered, at least in part, to the second and third chemical reactors; providing a source of a hydrocarbon to the third reactor, and reacting the alkaline hydroxide and the hydrocarbon within the third chemical reactor under conditions which are effective to produce a chemical hydride; providing a container and supplying the source of water, under pressure to the container; supplying the chemical hydride to the container and reacting the chemical hydride

with the water under pressure to produce a high pressure hydrogen gas, and the alkaline hydroxide; reusing the alkaline hydroxide, at least in part, in the second chemical reactor to react with the contaminated biomass to render the contaminated biomass inert, and in the third chemical reactor to react with the hydrocarbon to generate additional chemical hydride which is again reacted with the water in the container to produce additional high pressure hydrogen gas; and storing the high pressure hydrogen gas for use.

These and other aspects of the present invention will be discussed in greater detail hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described below with reference to the following accompanying drawing.

Fig. 1 is a greatly simplified schematic drawings illustrating an arrangement for producing hydrogen of the present invention.

Fig. 2 is a greatly simplified schematic drawing illustrating an arrangement for rendering a biomass inert of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This disclosure of the invention is submitted in furtherance of the constitutional purposes of the U.S. Patent Laws "to promote the progress of science and useful arts" (Article 1, Section 8).

An arrangement which is useful in practicing one aspect of the present invention is designated by the numeral 10 and is seen in Fig. 1. As illustrated therein, the methodology,

as seen therein, and which is useful in producing hydrogen, includes as a first step providing a first composition hereinafter referred to as a supply of sodium hydroxide 11. The supply of sodium hydroxide 11 is coupled in fluid flowing relation relative to a passageway or conduit which is generally indicated by the numeral 12. This conduit or passageway couples the first
5 composition or the source of sodium hydroxide 11 in fluid flowing relation relative to a container which is indicated by the numeral 13. The source of sodium hydroxide may be produced, at least in part, by the methodology which is seen in Fig. 2, and which will be described in further detail hereinafter. The container 13 is defined by a sidewall 14, and further includes a top surface 15, and a bottom surface 20. Both of the top and bottom
10 surfaces are attached to the sidewall 12 and further define an internal cavity 21. First, second, third and fourth passageways or apertures 22, 23, 24 and 25 are formed through the sidewall 14, and couple the internal cavity 21 in fluid flowing relation relative to other assemblies which will be discussed hereinafter. Still further, an aperture or passageway 26 is formed in the top surface 15. The passageway or conduit 12 is received in or through the first
15 aperture 22.

The supply of sodium hydroxide, as may be provided, at least in part, by the methodology as seen in Fig. 2, and which constitutes a first composition 11 is received in the cavity 21, and which is further defined by the container 13. As will be discussed in greater
20 detail hereinafter, the first composition 11 is chemically reacted with a second composition, as will be described below, to produce a chemical hydride which, when subsequently reacted with a liquid, produces hydrogen gas, and byproducts which include the first composition 11. Still further, the sodium hydroxide may be reacted with a contaminated biomass feedstock, as will be described hereinafter, to render it inert and to produce other by-products. This aspect
25 of the invention will be discussed in greater detail in the paragraphs which follow. Thus, by

means of the present methodology, the first composition can be later reused or recycled to form additional chemical hydride which is used in later chemical reactions, or in the alternative can be reacted with a contaminated biomass as will become more apparent from the discussion which is found in the paragraphs below. The supply of sodium hydroxide 11, and which is received within the internal cavity 21 of the container 13, or which further is produced as a byproduct of the chemical reaction discussed, above, passes from the internal cavity 21 of the container 13 through the second aperture 23, and is received within a chemical reactor which is generally indicated by the numeral 30. The sodium hydroxide 11 travels to the chemical reactor 30 by way of a conduit or other passageway 31. As will be discussed below, the sodium hydroxide provides a source of sodium to the reaction which is disclosed. It should be recognized that sodium may be added to the system or methodology as presently described at a number of different locations in order to meet the needs of the chemical reactions. These locations include directly at the chemical reactor 30, or further downstream in the process, which will be discussed below, or further by means of the methodology which is best understood by a study of Fig. 2.

The methodology 10 of the present invention further includes the step of providing a source of a second composition 40 which provides a source of hydrogen, and which is reacted with the first composition 11 to produce a chemical hydride as will be described below. The second composition 40 may include various hydrocarbons such as methane, which may suitably react with the first composition in order to release hydrogen which is utilized to form a resulting chemical hydride. The reaction which takes place within reactor 30 is as follows: $\text{CH}_4 + \text{NaOH} \rightarrow \text{CO} + \text{Na} + 2.5\text{H}_2$. This chemical reaction and the methodology for implementing same is well known in the art and is discussed in significant detail in references such as U.S. Patent No. 6,235,235 and 6,221,310, the teachings of which are incorporated by

reference herein. The second composition or source of methane 40 is coupled in fluid flowing relation with the chemical reactor 30, by way of a conduit or passageway 41. Therefore, the methodology of the present invention 10 provides a step whereby the first composition 11, which may include sodium hydroxide, and the second composition 40, which may include methane are supplied to the chemical reactor 30, and chemically react together to produce a chemical hydride, such as sodium hydride and other byproducts. The byproducts produced by this chemical reaction of the first and second compositions 11 and 40 may include undesirable compositions such as carbon monoxide, and the like. Consequently, the methodology of the present invention 10 further includes the step of providing a shift converter 50, and supplying the byproducts which may include carbon monoxide to the shift converter, and chemically converting the carbon monoxide to carbon dioxide within the shift converter. The shift converter 50 is coupled to the chemical reactor 30 by way of a conduit or passageway 51. By employing the methodology as discussed in the previous prior art patents, some liquid sodium 41 may be drawn from the chemical reactor 30 and thereafter supplied to other steps in the present invention. The remaining sodium and hydrogen combine together to produce sodium hydride.

The methodology of the present invention 10 further includes a step of providing a separator 60 which is coupled in fluid flowing relation relative to the shift converter 50 by way of a conduit or passageway 61. The separator 60 is operable to receive the resulting chemical hydride such as sodium hydride, and other byproducts produced by the reaction of the first composition 11, with the second composition 40, and provide a portion of the byproducts, which may include any remaining carbon monoxide, and carbon dioxide produced as a result of the conversion of carbon monoxide to carbon dioxide which has occurred in the shift converter 50, to a burner 70. The burner is coupled to the separator 60

by way of a conduit 71. The byproducts, which may include carbon monoxide, carbon dioxide and some hydrogen are received in the burner where they are consumed by combustion and produce resulting heat energy. This same burner may also receive Syngas produced by means of the methodology as seen in Fig. 2, and combust same to produce
5 additional heat. Moreover, this same heat produced by the burner 70, may be diverted, at least in part, and be delivered to a reactor, which will be described hereinafter, and which receives contaminated biomass feedstock which is to be rendered inert. This heat energy produced by the burner 70 forms a heat output which is generally indicated by the numeral 72. The heat output 72 is subsequently provided to the chemical reactor 30 to increase the
10 temperature of the first and second compositions 11 and 40 which are chemically reacting within same in order to produce a source of chemical hydride 80, which may include sodium hydride, and various byproducts, or delivered to the aforementioned reactor which will be discussed in greater detail below.

15 The source of the chemical hydride 80, which may include sodium hydride, is coupled in fluid flowing relation relative to the internal cavity 21 of the container 13 by way of a conduit or passageway 81. The source of the chemical hydride 80 passes into the internal cavity 21 by way of the fourth aperture or passageway 25. The methodology of the present invention 10 further includes the step of providing a source of a liquid 90, such as water, and
20 reacting the source of the chemical hydride 80 with the liquid 90 in a manner which produces a high pressure hydrogen gas, and a byproduct which includes the first composition 11. While the discussion, above, indicates that the source of chemical hydride is provided first, and then reacted with the water 90, it should be understood that this order of introduction is not important, and these compositions could be supplied in reverse order, or together to
25 achieve the benefits of the present methodology 10. In this regard, the source of the liquid,

such as water 90, is supplied by way of conduit 91 to a charging pump and which is generally indicated by the numeral 100. The charging pump 100 is further coupled by way of a conduit, or other passageway 101, to the container 13 where the liquid, such as water, passes into the internal cavity 21 by way of the third aperture or passageway formed in the sidewall

5 14. The charging pump is operable to supply the liquid, such as water, to the internal cavity and then maintain the liquid received within the cavity at a pressure of at least 150 PSI.

In the method of the present invention 10, and following the step of supplying the source of the chemical hydride 80, such as sodium hydride to the cavity 21 of the container

10 13, and mixing the source of liquid 90, such as water, with same, a chemical reaction results that produces high pressure hydrogen gas 110, and other byproducts including the first composition 11. As earlier discussed, the sodium hydroxide 11, which is generated as a result of this chemical reaction, may then be recycled or reused by exiting or passing from the container 13, and being returned by way of the conduit or passageway 31 to the chemical

15 reactor 30 where it may be subsequently reacted with the second composition 40, which may include additional methane, to produce a further chemical hydride such as sodium hydride 80. As a result of the liquid pressure provided within the container 13, as maintained by the charging pump 100, a high pressure hydrogen gas 110 is produced.

20 The methodology of the present invention further includes the step of providing the source of high pressure hydrogen gas 110 produced in the container 13 to a hydrogen dryer which is generally indicated by the numeral 120. This dryer could be any type of commercial dryer. The hydrogen dryer is utilized to remove any water, or other liquids which may be mixed with the high pressure hydrogen gas 110, thereby making it more useful for particular

25 applications. In the application as shown, the dryer could be a configuration of sodium which

would react with any remaining water to remove same from the high pressure hydrogen gas. If this option is utilized, a hydrogen dryer would not be required. As should be understood, this hydrogen dryer may not be necessary for certain applications because there are benefits to be derived from having, for example, gaseous water mixed with the resulting high pressure hydrogen gas. This mixture would be useful, for example, as a fuel which may be utilized in proton exchange membrane fuel cells, and the like.

The methodology of the present invention 10 further includes the step of withdrawing the high pressure hydrogen gas 110 from the cavity 21 of the container 13, and which has passed through the hydrogen dryer 120, and receiving it in a storage container 130, where it may be subsequently drawn off, at high pressure and supplied as a fuel for various end uses. The high pressure hydrogen gas 110 exits the hydrogen dryer 120, and is received in the storage container 130 by way of a conduit 121.

The method of the present invention 10 further includes a step of providing an expansion engine 140, and coupling the expansion engine in fluid flowing relation relative to the cavity 21 of the container 13 by way of a conduit 141. The conduit 141 is coupled in fluid flowing relation relative to the conduit 121 as seen in Fig. 1. As earlier discussed, the previous step of pressurizing the liquid, such as the water 90, within the container 13, and mixing the source of sodium hydride 80 with same, produces a high pressure hydrogen gas 110. As seen in Fig. 1, the high pressure gas 110, following treatment by the hydrogen dryer 120, is delivered to the expansion engine 140. Expansion engines are well known in the art and include internal turbines (not shown) and which, when exposed to the flow of the high pressure gas 110, produces a first mechanical output 142, and a second gas output 143 having a reduced pressure and temperature. The mechanical output 142 of the expansion engine is

converted into various power or work outputs 144 which may include but are not limited to mechanical, electrical, hydraulic and others, and which are subsequently transmitted by way of a transmission pathway 144, or other force or work transmission means, to a refrigeration assembly which is generally indicated by the numeral 150. The refrigeration assembly is of conventional design and is coupled in fluid flowing relation relative to the gas output 143 of the expansion engine 140 by way of a fluid conduit or passageway 151. The expansion engine 140 is operable to generate, at least in part, the power or work output necessary to energize or actuate the refrigeration assembly 150. The gas output 143 of the expansion engine 140, once received by the refrigeration assembly 150 is further reduced in temperature thereby liquifying same. The liquified hydrogen gas 110 now moves from the refrigeration assembly to a storage container 160 by way of a conduit or other passageway 161.

In the method 10, as described above, the step of pressurizing the liquid 90 includes pressurizing the liquid to a pressure which causes the resulting high pressure hydrogen gas 110 to have a pressure of at least 150 PSI. Still further, the step of supplying the high pressure hydrogen gas 110 to the expansion engine 140 comprises providing a gas output 143 having a reduced temperature of less than about 50° C., and a pressure greater than about 1 atmosphere or ambient. In the embodiment as shown in Fig. 1, the expansion engine 140 may comprise a turbo-expander which is coupled in fluid receiving relation relative to the high pressure hydrogen gas 110. In this arrangement, the turbo-expander generates an electrical power output which is transmitted by way of the transmission pathway 145, and which provides a preponderance of the electrical power, or work energy needed by the refrigeration assembly 150, to liquify the hydrogen gas 110. The expansion engine 140 in combination with the refrigeration assembly 150 are operable to reduce the temperature of

the high pressure hydrogen gas 110 to at least about -200° F, and further reduce the pressure of the gas 110 to less than about 150 PSI.

A second aspect of the present invention relates to a method for rendering a
5 contaminated biomass inert and which is generally indicated by the numeral 200 in Fig. 2. As should be understood, the methodology as seen in Fig. 2, can in one form, operate as a separate stand-alone method. Or alternatively, is operable to be coupled and cooperate in various ways with the methodology 10 of the present invention as seen in Fig. 1. As should be understood, the methodology as seen in Fig. 2 is useful for rendering a source of a
10 contaminated biomass feedstock 201 inert. The contaminated biomass may be contaminated with various chemicals including hydrocarbons, and the like and which render it not useful for human or other animal consumption or exposure. The contaminants that may render the biomass contaminated or dangerous for consumption or exposure may be selected from the group comprising hydrocarbon compounds containing fluorine; chlorine; bromine; iodine;
15 metals; and metal oxides thereof. In the present methodology, as seen in Fig. 2, the method includes a first step of providing a first composition which typically comprises a source of sodium 202. The source of sodium may be supplied solely or in part from the liquid sodium
41 which is drawn off from the reactor 30, as was described by reference to the methodology 10 as seen in Fig. 1, or may, in the alternative, be supplied from a separate source. The
20 source of sodium or first composition 202 is supplied to a sodium pump 203 of conventional design so that it may be moved or transferred to a first chemical reactor which will be discussed below. Still further, the method includes a second step of providing a second composition 204 which may comprise, in one form, a contaminated/carbonaceous water source as indicated in Fig. 2, or alternatively, a source 205 of uncontaminated water. The
25 second composition 204/205 is delivered to a water pump 206 of conventional design. The

water pump 206 supplies the second composition comprising either or both of the contaminated or uncontaminated water to a first chemical reactor 210 which is operated under high pressure (HP) conditions in order to react the first and second compositions, that is, sodium and water together to form a source of alkaline hydroxide (such as sodium hydroxide) and other byproducts generally indicated by the numeral 211. As seen in Fig. 2, a typical reaction in the first chemical reactor is illustrated, however, it should be appreciated, and if a contaminated water input is supplied and which includes a hydrocarbon, for example, other byproducts could potentially be produced by this reaction. The sodium hydroxide, and other byproducts which may include hydrogen gas, and carbon monoxide are received in a high pressure (HP) separator assembly 212. The high pressure separator, which is well known in the art, is useful for separating the sodium hydroxide into a stream which is now indicated by the numeral 213, from the remaining Syngas which is now indicated by the numeral 214. In the present application, Syngas is defined as a mixture of carbon monoxide and hydrocarbons which are derived from hydrocarbon fuels. This first Syngas stream 214 is subsequently combusted to provide a heat source 215 which is supplied to a second chemical reactor 220 as will be described in greater detail hereinafter. Alternatively, the Syngas may be supplied directly to the second chemical reactor 214A in order to react with the contaminated biomass 201. The combustion of the Syngas 214, which may include other byproducts produces, a gas or liquid waste stream 216 which is then disposed of in an environmentally acceptable fashion or further may be supplied or otherwise combined with the carbonaceous/ contaminated water 204 and processed again.

As seen in Fig. 2, the methodology 200 broadly includes the steps of providing a contaminated biomass 201; and reacting the alkaline hydroxide 213 with the contaminated biomass 201 to render the contaminated biomass inert and further produce hydrogen gas, and

a byproduct which includes the first composition such as sodium 202. In this regard, the methodology of the present invention 200 includes another step of providing a second chemical reactor 220; and delivering the alkaline hydroxide 213, and the contaminated biomass feedstock 201 to the second chemical reactor 220. As seen in Fig. 2, the source of the alkaline hydroxide has a first course of travel 221 whereby the source of alkaline hydroxide 213 is delivered into the second chemical reactor 220; and a second course of travel 222 whereby a portion of the alkaline hydroxide 213 may be utilized in the methodology 10 as seen in Fig. 1. Alternatively, alkaline hydroxide, such as sodium hydroxide 11 may be supplied from the methodology 10 to the methodology 200 as seen in Fig. 2. As can be readily discerned from a study of Fig. 2, the combustion of the first stream of Syngas 214 produces a heat source 215 which is supplied to the second chemical reactor 220 in order to affect or otherwise facilitate the chemical reaction as identified in Fig. 2, that is, the sodium hydroxide reacts with a contaminated biomass feedstock 201 under the influence of heat, and pressure, to produce a second stream of Syngas 223, which contains hydrogen, and sodium or other alkaline metal 224 which is then delivered back to the sodium pump 203 for use again in the first chemical reactor 210. The second stream of Syngas 223, which may comprise carbon monoxide; hydrogen; and other byproducts may be combusted, at least in part, to provide the heat source 215, which sustains or otherwise facilitates the chemical reaction within the second chemical reactor 220. Still further, this second stream of Syngas may be diverted into another chemical process 225 where it is catalytically reformulated into a predetermined specific product stream which may include various hydrocarbons depending upon the source of contamination which effects the biomass feedstock. As should be understood, this same catalytic reformulation of the second stream of Syngas 223 could further be employed, at least in part, with the first Syngas stream 214. It will be further understood, that the heat source 215 may be additionally supplemented with

heat energy as provided from the burner 70 as seen in Fig. 1. Still further, it should be appreciated, that the first and second streams of Syngas 214 and 223, respectively may be supplied in whole, or in part, to the burner 70 as seen in Fig. 1 to support the methodology 10.

5

A method for rendering a contaminated biomass inert, and which is generally indicated by the numeral 200, broadly includes a first step of providing a first composition 202/224, and a second step of providing a second composition 204/205 and reacting the first and second compositions together to form a source of alkaline hydroxide 213. The method 200 10 further includes another step of providing a contaminated biomass 201, and reacting the alkaline hydroxide 213 with the contaminated biomass 201 to render the contaminated biomass inert, and further produce hydrogen gas which is incorporated in the Syngas stream 223; and a byproduct 224 which includes the first composition. Still further, the methodology 200 of the present invention includes a step of reusing or recycling the first 15 composition 224 formed as a byproduct in a subsequent chemical reaction in the first chemical reactor 210 to form additional alkaline hydroxide 213. In the methodology 200 as described above, the method includes another step of providing a first chemical reactor 210, and wherein the step of reacting the first and second compositions 202/224 and 204/205 to form the alkaline hydroxide 213 comprises delivering the first and second compositions to 20 the first chemical reactor. In the methodology as described above, the method includes another step of providing a second chemical reactor 220, and wherein the step of reacting the alkaline hydroxide 213 with the contaminated biomass feedstock 201 further comprises delivering the alkaline hydroxide 213, and the contaminated biomass 201 to the second chemical reactor 220. In the methodology as described above, the first composition 202/224 25 comprises an alkaline metal, such as sodium, and the second composition comprises water

204/205, which may, or may not, be contaminated with other materials. In the methodology 200 as described above, and referring to Figs. 1 and 2, the method further comprises the steps of providing a third chemical reactor 30; and supplying the alkaline hydroxide 11/213 to the third chemical reactor 30. The methodology further includes another step of providing a
5 source of a hydrocarbon 40; and reacting the source of the hydrocarbon 40 with the alkaline hydroxide 11/213 to produce a chemical hydride 80 and a byproduct.

In the methodology 200 as described above, and still referring to Figs. 1 and 2, the method includes a further step of reacting a source of water 90/205 with the chemical hydride
10 80 in a manner to produce a high pressure hydrogen gas 110, and the alkaline hydroxide 11/213. The method includes yet another step of providing a burner 70 and combusting, at least in part, the hydrogen gas which forms a portion of the second Syngas stream 223 and which is produced by the reaction of the alkaline hydroxide 213 with the contaminated biomass feedstock 201, to produce heat energy 72/215. This heat energy may be supplied in
15 a subsequent step, at least in part, to the second reactor 220, and the third reactor 30 as seen from Figs. 1 and 2, respectively.

As seen in Fig. 1, the method 200 includes another step of providing a container 13, defining a cavity 21, and supplying the water 90 to the cavity of the container. The method
20 10 of the present invention further includes another step of increasing the pressure of the water 90 within the container to a high pressure by means of a pump 100, and supplying the chemical hydride 11/213 to the cavity 21 of the container 13 to chemically react with the water 90, which is under high pressure, to produce the high pressure hydrogen gas 110, and the alkaline hydroxide. In the methodology as seen at numeral 10 in Fig. 1, the method
25 further includes another step of utilizing the high pressure hydrogen gas 110, at least in part,

to produce a work product. In this regard, the methodology as seen at numeral 10 includes a further step of providing an expansion engine 144, and coupling the expansion engine in fluid flowing relation relative to the high pressure hydrogen gas 110, and wherein the expansion engine 144 produces a hydrogen gas output 151 having a reduced temperature and pressure, and which further generates an electrical power output 145. The present methodology as seen at numeral 10 includes another step of coupling the expansion engine 144 in fluid flowing relation relative to a refrigeration assembly 150, and wherein the hydrogen gas output having the reduced temperature, and pressure 151 is provided to the refrigeration assembly 150. The methodology 10 further includes another step of energizing the refrigeration assembly, at least in part, by supplying the power output 145 generated by the expansion engine 144 to further reduce the temperature of the hydrogen gas output 151 to liquefy the hydrogen gas.

Another aspect of the present invention relates to a method for rendering a contaminated biomass inert 200 which includes a first step of providing a source of a contaminated biomass feedstock 201, and a second step of providing a source of an alkaline hydroxide 213, and chemically reacting the contaminated biomass 201 with the alkaline hydroxide 213 to render the contaminated biomass feedstock inert and to further produce an alkaline metal 224, and a first gas which is within Syngas stream 223. Still further, the method includes another step of combusting the first gas which is within stream 223 to produce a heat source or energy 215 which facilitates, at least in part, the chemical reaction of the alkaline hydroxide 213 and the contaminated biomass feedstock 201. In the methodology 200 as described above, the method further includes another step of catalytically reformulating the first gas within stream 223 into a predetermined product stream. In this regard, the first gas which is included within a second Syngas stream 223 is selected from the

group comprising carbon monoxide and hydrogen; and wherein the step of catalytically reformulating the first gas comprises the creation of a specific product stream from the first gas 223.

5 In the methodology 200 as described above, the step of providing a source of the alkaline hydroxide 213 further includes the steps of providing a first chemical reactor 210; providing a source of water 204/205, and supplying the source of water to the first chemical reactor 210; and further supplying the alkaline metal 202/224 to the first chemical reactor 210 to form the source of the alkaline hydroxide 213. As seen by reference to Fig. 2, the source
10 of water 205 may be uncontaminated. Still further, the source of water 204 may contain contaminants which are to be rendered inert along with the contaminated biomass feedstock 201. As noted earlier, the contaminants are selected from the group comprising hydrocarbon compounds containing fluorine; chlorine; bromine; iodine; metals; and metal oxides thereof. Of course, the present methodology could be used with a wide range of contaminants. The
15 preceding list of contaminants is merely exemplary. In the arrangement as seen in Fig. 2, the chemical reaction of the alkaline metal 202/224, and the source of water 204/205 to produce the source of the alkaline hydroxide 213 generates a second gas which may be included in the first Syngas stream 214, and wherein the method further comprises the step of combusting the first and second gases found within streams 223 and 214, respectively, at least in part, to
20 generate heat energy 215 which facilitates, at least in part, the chemical reaction of the contaminated biomass feedstock 201 which is to be rendered inert, with the alkaline hydroxide 213. As earlier noted, the heat energy produced by the combustion of these gases may also be delivered, at least in part, to the third reactor 30 as seen in Fig. 1. As earlier noted, the first and second gases which may be included in a first Syngas stream 214, and a

second Syngas stream 223 may comprise, at least in part, hydrogen gas and carbon monoxide.

In the present arrangement, as seen in Fig. 2, alkaline hydroxide 213, and the
5 contaminated biomass feedstock 201 are chemically reacted together in the second chemical
reactor 220 at a temperature of greater than about 275 degrees C, and a pressure of greater
than about 5 pounds per square inch absolute. In the arrangement 200 as seen in Fig. 2, the
step of chemically reacting the contaminated biomass feedstock 201 with the source of
alkaline hydroxide 213 to produce the alkaline metal 224, and the first gas which is included
10 within Syngas stream 223 further includes the steps of providing a second reactor 220, and
supplying the contaminated biomass feedstock 201 and the source of the alkaline hydroxide
213 to the second reactor 220; and maintaining the second reactor 220 at a temperature and a
pressure which renders the contaminated biomass 220 substantially inert, and which further
produces the first gas in stream 223, and the alkaline metal 224. As seen by reference to Fig.
15 2, the biomass which has been rendered inert forms solid waste 225 which is then disposed of
in an environmentally acceptable fashion. In the arrangement as seen in Fig. 2, the source of
heat or heat energy 215 generated from the combustion of the first gas and second gases in
streams 223 and 214, respectively, is supplied, at least in part, to the second reactor 20. In
the methodology as seen in Fig. 2, it will also be recognized that the method 200 also
20 includes another step of separating the second gas from stream 214 from the source of
alkaline hydroxide 213 prior to the chemical reaction of the alkaline hydroxide 213 with the
contaminated biomass feedstock 201.

Referring now to Fig. 1, it will be seen that the methodology 10 includes the step of
25 providing a third chemical reactor 30; and supplying, at least in part, a portion of the alkaline

hydroxide 213 to the third chemical reactor. Still further, the method includes a step of selecting a composition 40 which provides a source of hydrogen and supplying the source of hydrogen to the third reactor 30. Still further, this method includes another step of providing conditions within the third reactor 30 to react the alkaline hydroxide and the composition 40 to produce a chemical hydride 80. Still further, the method includes another step of providing a container 13 and supplying a source of water 90 to the container under pressure; and reacting the chemical hydride 80 with the water under pressure within the container 13 to produce high pressure hydrogen gas 110, and byproducts which include the alkaline hydroxide. The method 10 as described above, further includes another step of supplying, at least in part, the alkaline hydroxide produced by the reaction of the chemical hydride 80 with the water 90 back to the third chemical reactor 30 for further reaction. In the arrangement as seen in Fig. 1, the composition 40 which provides the source of hydrogen comprises methane, and wherein one of the byproducts produced by the chemical reaction of the alkaline hydroxide 11/213 and the methane 40 to produce the chemical hydride 80 comprises, at least in part, carbon monoxide, and wherein the method further comprises providing a shift converter 50 where the byproducts, including the carbon monoxide, are chemically converted into carbon dioxide. As should be understood by reference to the paragraphs above, the alkaline hydroxide as utilized herein can, in one form of the invention, comprise sodium hydroxide; and the chemical hydride may comprise sodium hydride. The method as seen at numeral 10 further includes the step of storing a portion of the high pressure hydrogen gas 110 for use in remote location 130/160; and combusting a portion of the hydrogen gas to produce heat energy which is delivered, at least in part, to the first 210, second 220, and third 330 chemical reactors. In the methodology as described above, after the step of chemically reacting the contaminated biomass feedstock 201 with the alkaline hydroxide 213 to render the contaminated biomass feedstock inert, the method further comprises a step of recovering

or otherwise recycling the alkaline metal 224 in the first chemical reactor 210 to produce additional alkaline hydroxide 213.

OPERATION

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The operation of the described embodiments of the present invention are believed to be readily apparent and are briefly summarized at this point.

Referring now to Figs. 1 and 2, it will be seen that a method 200 for rendering a
10 contaminated biomass 201 inert includes a first step of providing a first chemical reactor 210;
and supplying a source of an alkaline metal 202/224 to the first chemical reactor 210. Still
further, the method 200 includes another step of providing a source of water 204/205, and
reacting the alkaline metal 202/224 with the water 204/205 within the first chemical reactor
210 to produce a source of alkaline hydroxide 213. In the methodology 200 as seen in Fig. 2,
15 the method 200 includes another step of providing second, and third chemical reactors 220
and 30 respectively, and supplying a portion of the alkaline hydroxide 213 to the second and
third chemical reactors 220 and 30 respectively. The method 200 includes another step of
providing a source of a contaminated biomass 201 which is to be rendered inert, and
chemically reacting the alkaline hydroxide 213, with the source of the contaminated biomass
20 201 within the second reactor 220 to produce an inert biomass in the form of solid waste 225;
the alkaline metal 224; and a gaseous output 223. In the arrangement as seen in Fig. 2, the
alkaline metal 224 is returned or otherwise recycled to the first chemical reactor 210 and
chemically reacted again with the source of water 204/205 to generate additional alkaline
hydroxide 213. In the methodology 200 as seen in Fig. 2, the method includes another step of
25 combusting the gaseous output 223 to generate a heat source or heat energy 215 which is

delivered, at least in part, to the second and third chemical reactors 220 and 30 respectively.

Still further, the method 10 as seen in Fig. 1 further includes another step of providing a

source of a hydrocarbon 40 to the third reactor 30, and reacting the alkaline hydroxide

11/213, and the hydrocarbon 40 within the third chemical reactor 30 under conditions which

5 are effective to produce a chemical hydride 80. In the methodology as seen in Figs. 1 and 2,

the method further includes another step of providing a container 13, and supplying the

source of water, such as 90/205 under pressure to the container 13; and further supplying the

chemical hydride 80 to the container 13 and reacting the chemical hydride 80 with the water

90/205 under pressure to produce a high pressure hydrogen gas 110, and the resulting

10 alkaline hydroxide. In the methodology as seen in Figs. 1 and 2, the method includes another

step of regenerating additional alkaline hydroxide, at least in part, in the second chemical

reactor 220 to react with additional contaminated biomass 201 to render the contaminated

biomass inert; and in the third chemical reactor 30 to react with additional hydrocarbon 40 to

generate additional chemical hydride 80 which is again reacted with the water 90/205 in the

15 container 13 to produce additional high pressure hydrogen gas 110. The methodology as

described in the present application further includes the step of storing the high pressure

hydrogen gas 130/160 for further use.

Therefore, it will be seen that the present invention provides many advantages over the

20 prior art devices and methods which have been utilized heretofore, and further is effective to

produce chemical hydrides which are useful in the production of hydrogen gas at remote

locations, and additionally is useful in the rendering of contaminated biomass inert for the

purposes described above.

In compliance with the statute, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, 5 therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

CLAIMS

We claim:

1. A method for rendering a contaminated biomass inert, comprising:
providing a first composition;
providing a second composition;
reacting the first and second compositions together to form an alkaline hydroxide;
providing a contaminated biomass and reacting the alkaline hydroxide with the contaminated biomass to render the contaminated biomass inert and further produce hydrogen gas, and a byproduct which includes the first composition.
2. A method as claimed in claim 1, and further comprising:
reusing the first composition formed as a byproduct in a subsequent chemical reaction to form additional alkaline hydroxide.
3. A method as claimed in claim 1, and further comprising:
providing a first chemical reactor, and wherein reacting the first and second compositions together to form the alkaline hydroxide comprises delivering the first and second compositions to the first chemical reactor.
4. A method as claimed in claim 1, and further comprising:
providing a second chemical reactor, and wherein reacting the alkaline hydroxide with the contaminated biomass further comprises delivering the alkaline hydroxide and the contaminated biomass to the second chemical reactor.
5. A method as claimed in claim 4, and wherein the first composition comprises an alkaline metal, and the second composition comprises water.

6. A method as claimed in claim 5, and further comprising:
providing a third chemical reactor;
supplying the alkaline hydroxide to the third chemical reactor;
providing a source of a hydrocarbon, and reacting the source of the hydrocarbon with the alkaline hydroxide to produce a chemical hydride and a byproduct.

7. A method as claimed in claim 6 and further comprising:
reacting a source of water with the chemical hydride in a manner to produce a high pressure hydrogen gas and the alkaline hydroxide; and
reusing the alkaline hydroxide in a subsequent chemical reaction to form additional chemical hydride.

8. A method as claimed in claim 7, and further comprising:
providing a burner and combusting, at least in part, both the hydrogen gas produced by the reaction of the alkaline hydroxide with the contaminated biomass, and the hydrogen gas produced by the reaction of the alkaline hydroxide, with the water, to produce heat energy; and
supplying the heat energy, at least in part, to the second and third reactors.

9. A method as claimed in claim 7, and further comprising:
providing a container defining a cavity;
supplying the water to the cavity of the container;
increasing the pressure of the water within the container to a high pressure; and
supplying the chemical hydride to the cavity of the container to chemically react with
the water which is under high pressure to produce the high pressure hydrogen gas and the
alkaline hydroxide.

10. A method as claimed in claim 9, and further comprising:
utilizing the high pressure hydrogen gas, at least in part, to produce a work product.

11. A method as claimed in claim 9, and further comprising:
providing an expansion engine, and coupling the expansion engine in fluid flowing
relation relative to the high pressure hydrogen gas, and wherein the expansion engine
produces a hydrogen gas output having a reduced temperature and pressure and which further
generates a power output;

coupling the expansion engine in fluid flowing relation relative to a refrigeration
assembly, and wherein the hydrogen gas output having the reduced temperature and pressure
is provided to the refrigeration assembly; and

energizing the refrigeration assembly, at least in part, by supplying the power output
generated by the expansion engine to the refrigeration assembly to further reduce the
temperature of the hydrogen gas output to liquefy the hydrogen gas.

12. A method for rendering a contaminated biomass inert, comprising:
providing a source of a contaminated biomass;

providing a source of an alkaline hydroxide, and chemically reacting the contaminated biomass with the alkaline hydroxide to render the contaminated biomass inert and to further produce an alkaline metal, and a first gas; and

combusting the first gas to generate heat energy which facilitates, at least in part, the chemical reaction of the alkaline hydroxide with the biomass to be destroyed.

13. A method as claimed in claim 12, and further comprising:
catalytically reformulating the first gas into a predetermined product stream.

14 A method as claimed in claim 13 and wherein the first gas is selected from the group comprising carbon monoxide and hydrogen; and wherein the step of catalytically reformulating the first gas further comprises the creation of a specific hydrocarbon product stream.

15. A method as claimed in claim 12, and wherein providing a source of the alkaline hydroxide further comprises:
providing a first chemical reactor;
providing a source of water and supplying the source of water to the first chemical reactor; and
supplying the alkaline metal to the first chemical reactor to form the source of the alkaline hydroxide.

16. A method as claimed in claim 15, and wherein the source of water is uncontaminated.

17. A method as claimed in claim 15, and wherein the source of water contains contaminants which are to be rendered inert along with the contaminated biomass.

18. A method as claimed in claim 17, and wherein the contaminants are selected from the group comprising hydrocarbon compounds containing fluorine; chlorine; bromine; iodine; metals; and metal oxides thereof.

19. A method as claimed in claim 15, and wherein the chemical reaction of the alkaline metal, and the source of water to produce the source of the alkaline hydroxide generates a second gas, and wherein the method further comprises:

combusting the first and second gases, at least in part, to generate heat energy which facilitates, at least in part, the chemical reaction of the contaminated biomass which is to be rendered inert, with the alkaline hydroxide.

20. A method as claimed in claim 19, and wherein the first and second gases comprise, at least in part, hydrogen gas.

21. A method as claimed in claim 19, and wherein the first and second gases comprise, at least in part, carbon monoxide.

22. A method as claimed in claim 15, and wherein the alkaline hydroxide, and the contaminated biomass are chemically reacted at a temperature of greater than about 275 degrees C, and a pressure of greater than about 5 pounds per square inch absolute.

23. A method as claimed in claim 15, and wherein chemically reacting the contaminated biomass with the alkaline hydroxide to produce the alkaline metal, and the first gas further comprises:

providing a second reactor and supplying the contaminated biomass and the source of the alkaline hydroxide to the second reactor; and

maintaining the second reactor at a temperature and a pressure which renders the contaminated biomass inert, and which produces the first gas, and the alkaline metal.

24. A method as claimed in claim 23, and wherein the heat energy generated from the combustion of the first gas is supplied, and least in part, to the second reactor.

25. A method as claimed in claim 23, and wherein the second reactor is maintained at a temperature of greater than about 275 degrees C, and a pressure of greater than about 5 pounds per square inch absolute.

26. A method as claimed in claim 19, and further comprising:
separating the second gas from the alkaline hydroxide prior to the chemical reaction of the alkaline hydroxide with the contaminated biomass which is to be rendered inert.

27. A method as claimed in claim 12, and further comprising:
providing a third chemical reactor;
supplying, at least in part, a portion of the alkaline hydroxide to the third chemical reactor;

selecting a composition which provides a source of hydrogen and supplying the source of hydrogen to the third reactor;

providing conditions within the third reactor to react the alkaline hydroxide and the composition to produce a chemical hydride;

providing a container and supplying a source of water to the container under pressure;

reacting the chemical hydride with the water under pressure within the container to produce high pressure hydrogen gas, and byproducts which include the alkaline hydroxide; and

supplying, at least in part, the alkaline hydroxide produced by the reaction of the chemical hydride with the water back to the third chemical reactor.

28. A method as claimed in claim 26, and wherein the composition which provides the source of hydrogen comprises methane, and wherein one of the byproducts produced by the chemical reaction of the alkaline hydroxide and the methane to produce the chemical hydride comprises, at least in part, carbon monoxide, and wherein the method further comprises:

providing a shift converter and supplying the byproducts which include the carbon monoxide to the shift converter where the byproducts, including the carbon monoxide are chemically converted into carbon dioxide.

29. A method as claimed in claim 28, and wherein the alkaline hydroxide is sodium hydroxide, and the chemical hydride comprise sodium hydride.

30. A method as claimed in claim 28, and further comprising:
storing a portion of the high pressure hydrogen gas for use in remote location; and
combusting a portion of the hydrogen gas to produce heat energy which is delivered, at least in part, to the first, second, and third chemical reactors.

31 A method as claimed in claim 15 and wherein after step of chemically reacting the contaminated biomass with the alkaline hydroxide to render the contaminated biomass inert, the method further comprises:

recovering the alkaline metal and reusing the alkaline metal in the first chemical reactor to produce additional alkaline hydroxide.

32. A method for rendering a contaminated biomass inert, comprising:

providing a first chemical reactor;

supplying a source of an alkaline metal to the first chemical reactor;

providing a source of water and reacting the alkaline metal and the water within the first chemical reactor to produce an alkaline hydroxide;

providing second, and third chemical reactors, and supplying a portion of the alkaline hydroxide to the second and third chemical reactors;

providing a source of a contaminated biomass which is to be rendered inert, and chemically reacting the alkaline hydroxide with the source of the contaminated biomass within the second reactor to produce an inert biomass, the alkaline metal, and a gaseous output, and wherein the alkaline metal is returned to the first chemical reactor and reacted again with the source of water to generate additional alkaline hydroxide;

combusting the gaseous output to generate heat energy which is delivered, at least in part, to the second and third chemical reactors;

providing a source of a hydrocarbon to the third reactor, and reacting the alkaline hydroxide and the hydrocarbon within the third chemical reactor under conditions which are effective to produce a chemical hydride;

providing a container and supplying the source of water, under pressure to the container;

supplying the chemical hydride to the container and reacting the chemical hydride with the water under pressure to produce a high pressure hydrogen gas, and the alkaline hydroxide;

reusing the alkaline hydroxide, at least in part, in the second chemical reactor to react with the contaminated biomass to render the contaminated biomass inert, and in the third chemical reactor to react with the hydrocarbon to generate additional chemical hydride which is again reacted with the water in the container to produce additional high pressure hydrogen gas; and

storing the high pressure hydrogen gas for use.

