US 20040112741A1

(19) United States
(12) Patent Application Publication
Murdoch
(10) Pub. No.: US 2004/0112741 A1
(43) Pub. Date: Jun. 17, 2004

(54) METHOD AND SYSTEM FOR PRODUCING DRY GAS

(76) Inventor: Karen E. Murdoch, Broad Brook, CT (US)

Correspondence Address:
CARLSON, GASKEY & OLDS, P.C.
400 WEST MAPLE ROAD
SUITE 350
BIRMINGHAM, MI 48009 (US)

(21) Appl. No.: 10/320,912

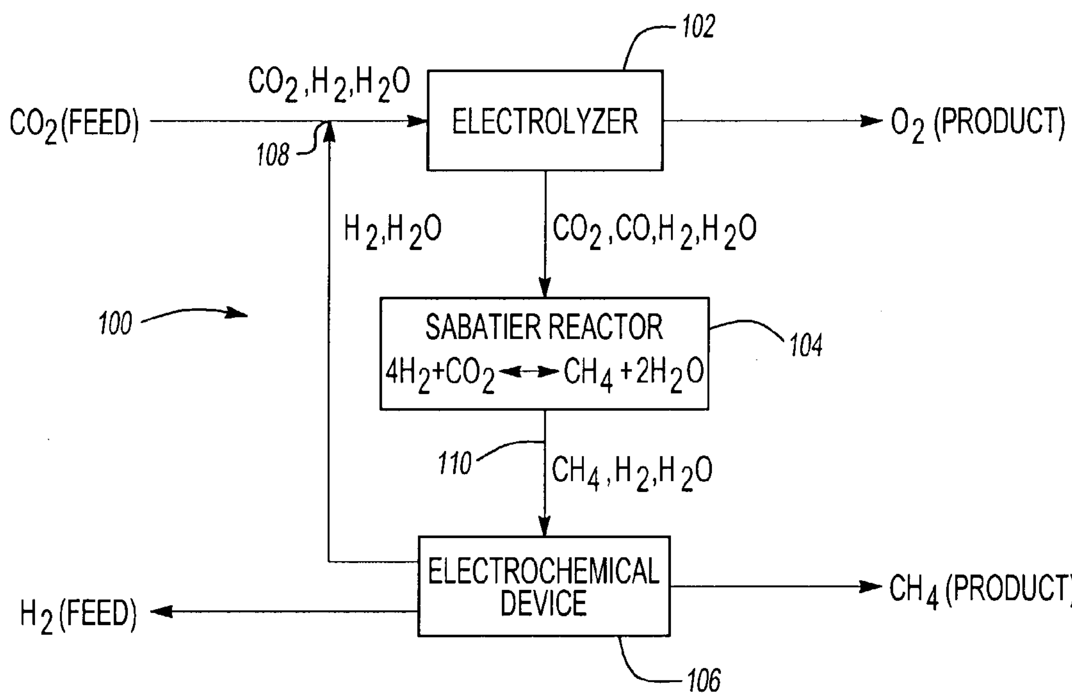
(22) Filed: Dec. 17, 2002

Publication Classification

(51) Int. Cl.[7] C25B 3/00
(52) U.S. Cl. 204/265; 204/266; 205/462; 205/555

(57) ABSTRACT

A system and method for producing dry gas, such as methane or carbon dioxide, incorporates an electrochemical device that removes water and hydrogen from a mixed gas stream. The electrochemical device uses one electrochemical cell to strip hydrogen and water from the mixed gas stream and a second electrochemical cell, combined with a dry feed stream, to remove any residual water from the mixed stream and produce pure, dry gas.



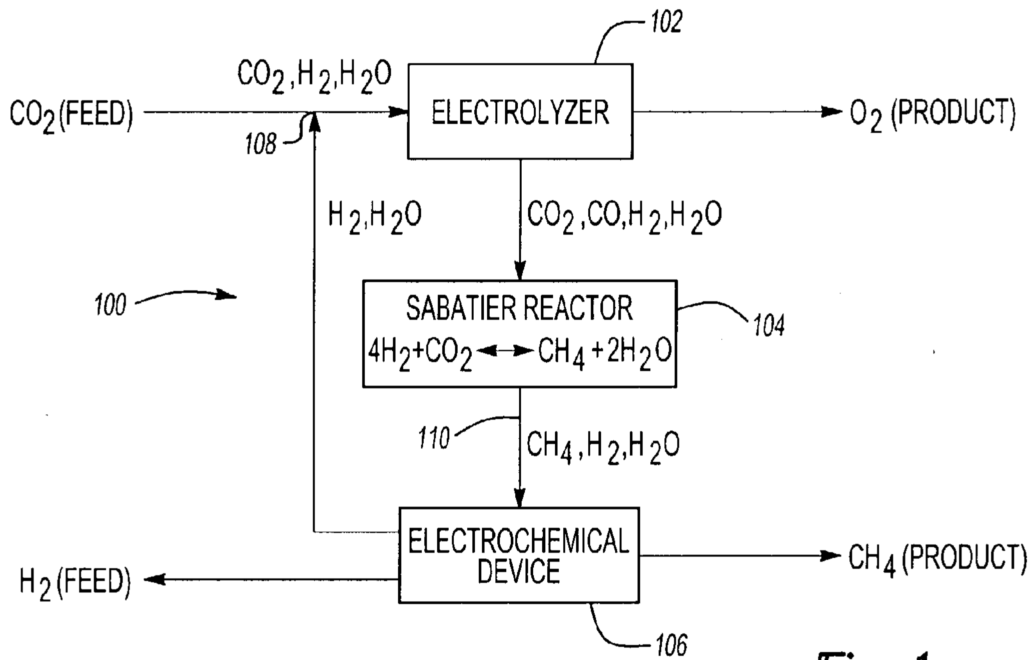

102
CO_2,H_2,H_2O
CO_2(FEED)
ELECTROLYZER
O_2 (PRODUCT)
108
H_2,H_2O
CO_2,CO,H_2,H_2O
100
SABATIER REACTOR
$4H_2+CO_2 \leftrightarrow CH_4+2H_2O$
104
110
CH_4,H_2,H_2O
ELECTROCHEMICAL DEVICE
CH_4 (PRODUCT)
H_2 (FEED)
106

Fig-1

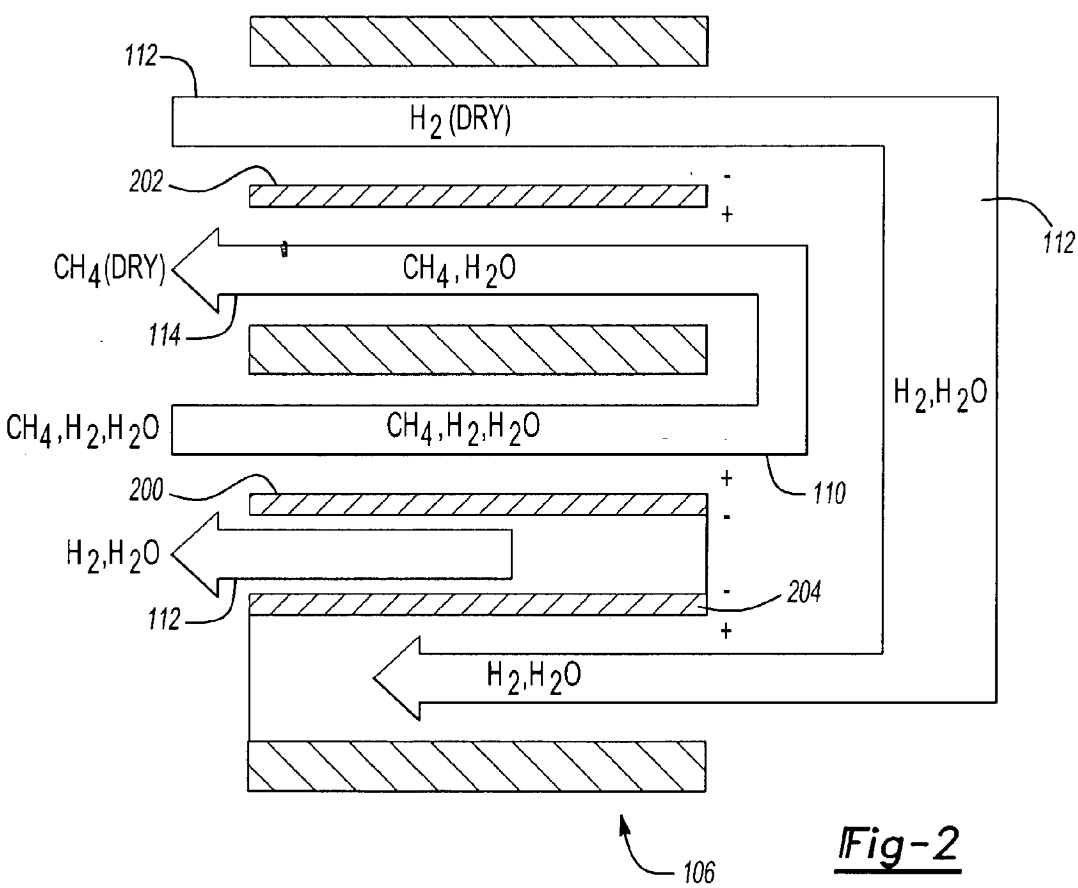

112
H_2 (DRY)
202
112
CH_4(DRY)
CH_4,H_2O
114
H_2,H_2O
CH_4,H_2,H_2O
CH_4,H_2,H_2O
110
200
H_2,H_2O
204
112
H_2,H_2O
106

Fig-2

METHOD AND SYSTEM FOR PRODUCING DRY GAS

TECHNICAL FIELD

[0001] The invention relates to methane gas production, and more particularly to a system and method that obtains pure, dry gas by removing hydrogen and water from a mixed gas stream.

BACKGROUND OF THE INVENTION

[0002] Sabatier reactors are known in the art for converting carbon dioxide (CO2) and hydrogen (H2) into methane (CH4) and water (H2O). These reactors can be used to obtain pure methane for use in other applications, such as fuel. Known methane production systems include an electrolyzer, which separates water into gaseous hydrogen and oxygen, a Sabatier reactor that receives the carbon dioxide, carbon monoxide, hydrogen and water and converts them into methane and water, forming a "wet" methane stream, where methane gas is intermingled with water vapor. Excess hydrogen left over from the Sabatier reaction may also be mixed into the wet methane stream.

[0003] Although an electrochemical separator can be used to easily remove the excess hydrogen from the wet methane stream, it is difficult to completely remove the residual water from the stream. Currently known water pumps remove less than all of the water from the stream and do not produce pure, dry methane as a final product. If the methane will later be cooled in a liquefaction process, any residual water will form undesirable ice crystals before the methane gas condenses to liquid. Thus, any methane gas to be liquefied in a later process must be absolutely dry, with no residual water. Currently known systems, however, have been able to remove only a portion of the water from the methane gas stream. Other gas production systems (e.g., carbon dioxide gas production systems) encounter similar difficulties in forming a completely pure, dry gas.

[0004] There is a desire for a gas production system that can produce pure, dry gas.

SUMMARY OF THE INVENTION

[0005] The present invention is directed to a system and method that removes water from a mixed gas stream containing a desired gas, hydrogen, and water via an inventive electrochemical device acting as a pump and a separator that removes both excess hydrogen and water from the stream. In one embodiment, the electrochemical device includes two electrochemical cells. Hydrogen and water are removed from the mixed gas stream as the stream passes through the first electrochemical cell. As the mixed gas stream passes the anode of the second electrochemical cell, a dry feed stream, such as a hydrogen stream, is fed to the cathode side of the second electrochemical cell. The dry feed stream creates a partial pressure differential with respect to the mixed gas stream, causing the dry feed stream to absorb any residual water from the mixed gas stream. Further, the potential applied across the second electrochemical cell prevents any portion of the dry feed stream from diffusing into the mixed gas stream. As a result, the gas stream that is output from the second electrochemical cell is pure, dry gas, with virtually no water mixed into the desired gas.

[0006] An alternative embodiment incorporates a third electrochemical cell that act as metering device to send the dry feed gas stream back to the electrolyzer after the stream has absorbed excess water from the mixed gas stream. The third electrochemical cell can be controlled to feed the feed hydrogen in a metered fashion as needed to maintain sufficient reduction of carbon dioxide in a methanation reactor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] **FIG. 1** is a block diagram illustrating a gas production system incorporating an electrochemical pump and separator device according to one embodiment of the invention; and

[0008] **FIG. 2** is a representative diagram of the electrochemical device used in the system shown in **FIG. 1**.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0009] **FIG. 1** illustrates one embodiment of an overall gas production system **100** that incorporates a novel electrochemical device to obtain pure, dry gas. Note that although the example described below focuses on removing hydrogen and water from a wet methane stream, the invention can be applied to any gas production system requiring removal of water and hydrogen from a mixed gas stream.

[0010] In the example shown in **FIG. 1**, the system **100** includes an electrolyzer **102**, a Sabatier reactor **104**, and an electrochemical device **106** that acts as a water pump and a hydrogen separator. To produce methane, a stream **108** containing carbon dioxide, hydrogen gas, and water is fed into the electrolyzer **102**. As is known in the art, the electrolyzer **102** separates the water into hydrogen and oxygen gases. The oxygen gas is then output from the electrolyzer **102** as a separate product that may be captured and used in a separate application.

[0011] In addition to outputting oxygen, the electrolyzer **102** sends carbon dioxide, carbon monoxide, hydrogen and water to the Sabatier reactor **104**. The Sabatier reactor **104** reduces the hydrogen and carbon dioxide into methane gas and water vapor. Extra hydrogen may be sent to the Sabatier reactor **104** to ensure that all of the carbon dioxide it receives is converted to methane. Any excess, unconverted water from the electrolyzer **102** is fed to the Sabatier reactor **104** along with the hydrogen and carbon dioxide.

[0012] Once the carbon dioxide has been converted to methane and water, the methane, water and any excess hydrogen gas is sent as a wet methane stream **110** to the electrochemical device **106**. The device **106** acts as both a water pump and a hydrogen separator. As is known in the art, the excess hydrogen can be easily separated from the stream using an electrochemical cell because there is a direct relationship between current and the number of protons pumped through the electrochemical cell.

[0013] To remove excess water from the wet methane stream **110**, the electrochemical device **106** incorporates a second electrochemical cell that acts as a pump to send the water in the stream **110** into a dry hydrogen feed stream **112** via a partial pressure differential between the two streams **110**, **112**. The dry hydrogen feed stream **112** is supplied from a separate hydrogen gas source (not shown).

[0014] **FIG. 2** illustrates one embodiment of the electrochemical device **106** and the flow path of the wet methane stream **110** in more detail. As noted above, the device **106** receives a wet methane stream **110** containing methane, hydrogen, and water from the Sabatier reactor **104**. The wet methane stream **110** is introduced to an anode of a first electrochemical cell **200**. The cell voltage applied to the first electrochemical cell **200** is kept at a level that is sufficient to move protons through the cell **110** while still low enough to avoid electrolyzing the water in the methane stream **110**. This first electrochemical cell **200** will be able to transfer some of the water and virtually all of the hydrogen in the methane stream **110** to the cathode of the cell **200**, but the methane stream **110** may still contain significant amounts of remaining water that need to be removed to obtain pure, dry methane. The residual water occurs when there is too much water in the methane stream **110** relative to the hydrogen protons needed to carry the water away from the stream **110**. In some cases, the methane stream **110** may still contain as much as 10% hydrogen and 50-100% water saturation.

[**0015**] After being sent past the first electrochemical cell **200**, the methane stream **110** is diverted to the anode side of a second electrochemical cell **202**. Dry hydrogen gas is sent to the device **106** as a feed stream **112** on the cathode of the second cell **202**. When a potential is applied across the second cell **202**, any remaining hydrogen in the methane stream **110** is pumped to the cathode of the second cell **202** along with more of the water vapor from the methane stream **110**. The dry hydrogen feed stream **112** on the cathode of the second cell **202** helps remove even more water from the methane stream **110** by creating a partial water pressure differential between the hydrogen feed stream **112** and the methane stream **110**. More particularly, water molecules in the wet methane stream **110** will be pulled by protons in the hydrogen feed stream **112**, drawing water molecules away from the methane stream **110**.

[**0016**] The potential applied across the second cell **202** prevents hydrogen from the hydrogen feed stream **112** from diffusing into the methane stream **110** as the hydrogen feed stream **112** absorbs the excess water from the methane stream **110** by driving protons back to the hydrogen feed stream **112**. Once the excess water has been removed from the methane stream **110** in the second cell **202**, pure, dry methane gas **114** is output from the device **106**.

[**0017**] The hydrogen feed stream **112**, which has now absorbed water from the methane stream **112**, is routed to a third electrochemical cell **204**. The current through the third cell **204** is controlled via any known manner so that the third cell **204** acts as a metering device, outputting controlled amounts of hydrogen and water to the electrolyzer **102**. This information is used to control the rate at which hydrogen is generated in the electrolyzer **102**. As a result, the moisture in the hydrogen/water feed stream **112** sent to the electrolyzer **102** allows control over the moisture content in the hydrogen electrolyte.

[**0018**] The inventive system and method therefore provides higher water removal efficiency than currently known systems by incorporating additional at least one additional electrochemical cell and a dry feed gas to extract additional water from a mixed gas stream via partial pressure driving force. By sending the mixed gas stream, such as a wet methane stream, through more than one drying stage, the inventive system can generate a pure, dry desired gas without adding undue complexity to the system. Further, by recycling the dry feed gas after it has absorbed water from the mixed gas stream and sending it back to the electrolyzer in the system, the system can use the output of the electrochemical device to maintain the moisture level in the electrolyzer. Regardless of the type of gas sent through the inventive system, an electrochemical device according to the present invention can reliably remove excess water and hydrogen from a mixed gas stream containing the desired gas.

[**0019**] It should be understood that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention. It is intended that the following claims define the scope of the invention and that the method and apparatus within the scope of these claims and their equivalents be covered thereby.

What is claimed is:

1. An electrochemical device for a gas production system, comprising:

a first electrochemical cell that receives a mixed gas stream containing at least a desired gas, hydrogen and water, wherein the first electrochemical cell removes at least a portion of the water from the mixed gas stream to form a mixed gas stream having residual water; and

a second electrochemical cell that receives the mixed gas stream and a dry feed stream, wherein the second electrochemical cell removes the residual water from the mixed gas stream and wherein the dry feed stream absorbs the residual water to obtain the desired gas.

2. The electrochemical device of claim 1, wherein the dry feed stream is hydrogen.

3. The electrochemical device of claim 1, wherein the first electrochemical cell removes the hydrogen from the mixed gas stream along with said at least a portion of the water.

4. The electrochemical device of claim 1, wherein the electrochemical device feeds the mixed gas stream on an anode side of the second electrochemical cell and feeds the dry feed stream on a cathode side of the second electrochemical cell.

5. The electrochemical device of claim 1, further comprising a third electrochemical cell that receives the dry feed stream after the dry feed stream has absorbed the residual water from the mixed gas stream, wherein the third electrochemical cell outputs the dry feed stream and the residual water in a metered fashion.

6. The electrochemical device of claim 1, wherein the desired gas is one selected from the group consisting of methane and carbon dioxide.

7. A methane production system, comprising:

an electrolyzer that receives a first stream containing carbon dioxide and water and outputs a second stream containing carbon dioxide and hydrogen;

a Sabatier reactor that receives the second stream from the electrolyzer and outputs a methane stream containing methane, hydrogen and water; and

an electrochemical device comprising

a first electrochemical cell that receives the methane stream, wherein the first electrochemical cell removes at least a portion of the water from the methane stream having residual water, and

a second electrochemical cell that receives the methane stream and a dry feed stream, wherein the second electrochemical cell removes the residual water from the methane stream and wherein the dry feed stream absorbs the residual water.

8. The methane production system of claim 7, wherein the electrochemical device feeds the methane stream on an anode side of the second electrochemical cell and feeds the dry feed stream on a cathode side of the second electrochemical cell.

9. The methane production system of claim 7, further comprising a third electrochemical cell that receives the dry feed stream after the dry feed stream has absorbed the residual water, wherein the third electrochemical cell outputs the dry feed stream and the residual water in a metered fashion to the electrolyzer.

10. A method for producing a dry desired gas, comprising:

obtaining a mixed gas stream containing the desired gas, hydrogen and water;

feeding the mixed gas stream and a dry feed stream into an electrochemical device;

removing the hydrogen and the water from the mixed gas stream via the electrochemical device, wherein the dry feed stream absorbs at least a portion of the water from the mixed gas stream to produce the dry desired gas.

11. The method of claim 10, wherein the electrochemical device comprises a first electrochemical cell and a second electrochemical cell, and wherein the removing step comprises:

removing at least a portion of the water from the mixed gas stream via the first electrochemical cell to form a gas stream having residual water;

sending the gas stream having residual water and the dry feed stream to the second electrochemical cell, wherein the dry feed stream absorbs the residual water to produce the dry desired gas.

12. The method of claim 10, further comprising directing the dry feed stream to an electrolyzer after the dry feed stream has absorbed the residual water.

* * * * *