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(54) **SULFUR CONTROL FOR FUEL
PROCESSING SYSTEM FOR FUEL CELL
POWER PLANT**

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(57) **ABSTRACT**
A fuel cell power plant (110) has a fuel cell stack assembly (CSA) (16) including an anode (18), and a fuel processing system (FPS) (120) providing a hydrogen-rich reformat/fuel stream (34, 134, 62) for the anode (18) of the CSA (16). A relatively active metal catalyst is associated with one or both of the anode (18) and the FPS (120), and is subject to degradation by the presence of even low levels, e.g. 100 ppb to 5 ppb-wt. reformat, of sulfur in the fuel stream. A guard bed (70) containing a guard material (72) is provided in the FPS (120) for protecting the relatively active metal catalysts by adsorbing, and further reducing the level of, sulfur in the fuel stream. The guard material (72) is a metal or metal oxide capable of forming a stable sulfide in the presence of low levels of H₂S in the fuel stream (34), and is preferably selected from the group consisting of: ZnO, CuO on CeO₂-based support, NiO on CeO₂-based support, and Cu/ZnO. Provision is also made (80, 74, 75, 76, 78, 82) for regenerating the guard material (72) in situ.

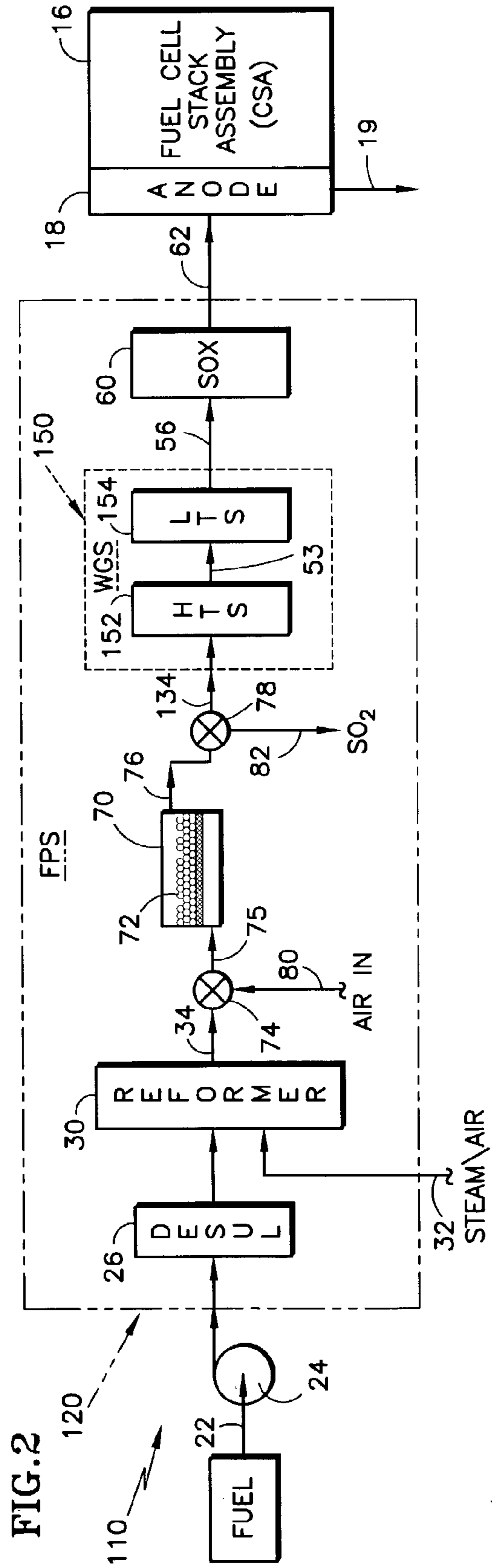
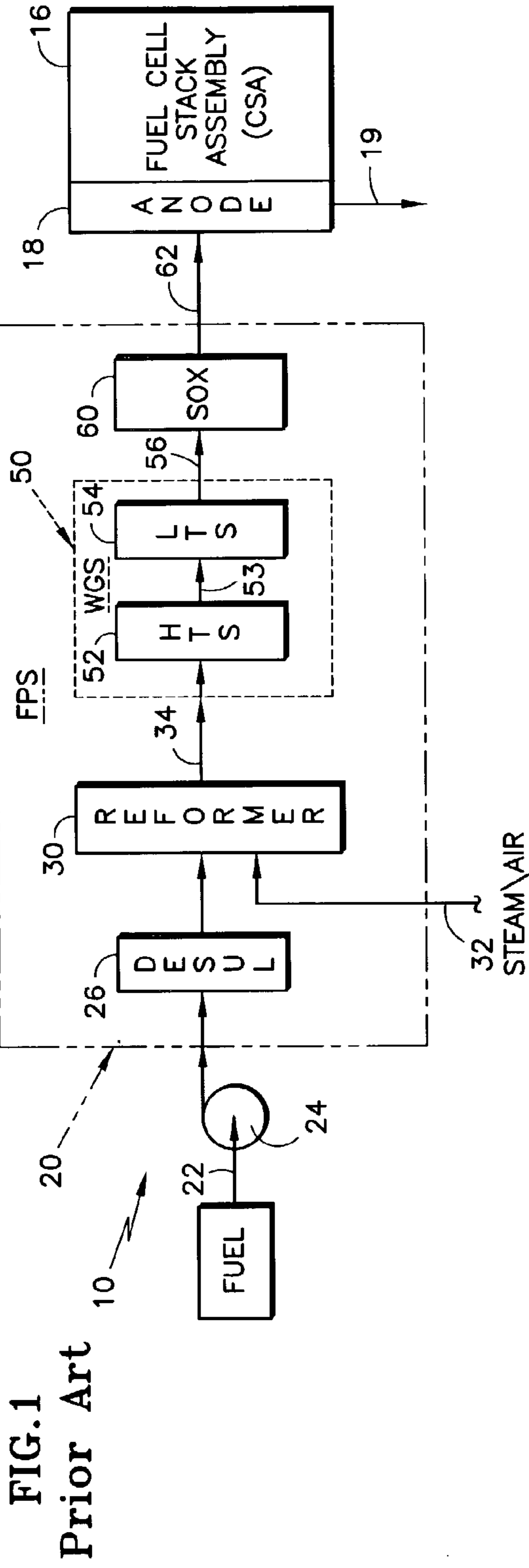
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SULFUR CONTROL FOR FUEL PROCESSING SYSTEM FOR FUEL CELL POWER PLANT

TECHNICAL FIELD

[0001] This invention relates to fuel processing for fuel cells, and more particularly to the provision of a low-sulfur, hydrogen-rich fuel stream for a fuel cell power plant. More particularly still, the invention relates to sulfur control in a fuel cell power plant fuel processing system, for catalysts having relatively high susceptibility to sulfur in a fuel.

BACKGROUND ART

[0002] Fuel cell power plants that utilize a fuel cell stack for producing electricity from a hydrocarbon fuel source are well known. The raw hydrocarbon fuel may be natural gas, gasoline, diesel fuel, naphtha, fuel oil, or the like. In order for the hydrocarbon fuel to be useful in the fuel cell stack's operation, it must first be converted to a hydrogen-rich fuel stream through use of a fuel processing system. Such hydrocarbon fuels are typically passed through a reforming process (reformer) to create a process fuel (reformate) having an increased hydrogen content that is introduced into the fuel cell stack. The resultant process fuel contains primarily water, hydrogen, carbon dioxide, and carbon monoxide. The process fuel has about 10% carbon monoxide (CO) upon exit from the reformer as reformate.

[0003] Anode electrodes, which form part of the fuel cell stack, can be "poisoned" by a high level of carbon monoxide. Thus, it is necessary to reduce the level of CO in the process fuel, prior to flowing the process fuel to the fuel cell stack. This is typically done by passing the process fuel through one or more water gas shift (WGS) converters, or shift reactors, and possibly additional reactors, such as one or more selective oxidizers, prior to flowing the process fuel to the fuel cell stack. The shift reactor also increases the yield of hydrogen in the process fuel stream.

[0004] However, the raw hydrocarbon fuel source may also contain sulfur or sulfur compounds, and hydrogen generation in the presence of sulfur results in a poisoning effect on all of the catalysts used in the hydrogen generation system, as well as the fuel cell anode catalyst itself. To mitigate this problem, the hydrocarbon fuel source is typically passed through a desulfurizer, either prior to or following the reforming process, to remove in a known manner, as by converting sulfur from the gaseous form to a solid, substantial quantities of sulfur prior to the fuel entering the sulfur-sensitive components of the fuel processing system and fuel cell. Examples of such desulfurizers and descriptions of the associated process may be found in U.S. Pat. Nos. 5,769,909 and 6,159,256. Additionally, a U.S. Pat. No. 6,299,994 discloses the use of desulfurizers and other components of various fuel processing systems with the goal of providing a "pure" hydrogen stream for the fuel cell.

[0005] In a typical example, natural gas feedstock may have a sulfur content of 6 ppm-wt. fuel. Though substantial sulfur is removed by the desulfurizer from the hydrocarbon fuel stream being processed, nevertheless sulfur levels of 25 ppb-500 ppb-wt. fuel or greater, typically remain. Such diminished levels of sulfur in the fuel may be tolerated by the catalysts in the reformer, in part due to higher operating temperatures. The reformation process dilutes the fuel stream such that the reformate issuing from the reformer

may typically have sulfur levels in the range of 5 ppb-100 ppb wt. reformate. While the catalysts used in the prior art in the remaining elements of the fuel processing system and the fuel cell itself may have tolerated such sulfur levels in the reformate, the present more active catalysts tend to result in increased sensitivity to sulfur, even at the reduced sulfur levels in the reformate, due to their ability to be used in smaller quantities.

[0006] Referring to **FIG. 1**, there is depicted, in simplified functional schematic diagram form, the fuel cell stack assembly (CSA) **16** and fuel processing system (FPS) **20** of a fuel cell power plant **10** in accordance with the Prior Art as described above. Briefly, a sulfur-containing hydrocarbon fuel feedstock, represented by supply line **22**, is delivered by a pump or blower **24** to a desulfurizer **26** at the input, or upstream end, of FPS **20**. The sulfur may be present in the form of hydrogen sulfide (H₂S), as well as mercaptans, sulfur oxides, etc. Following high-level desulfurization, the hydrocarbon fuel feedstock is admitted to a reformer **30** where, in the presence of steam, and possibly air, supplied on line **32**, it is reformed in a well known manner to provide a hydrogen-rich reformate on line **34**. The reformate, in addition to containing H₂ and CO, also contains any residual low level sulfur not removed by the desulfurizer **26**. That sulfur may be present at the level of about 5 ppb-100 ppb-wt. reformate, or greater. The result is substantially the same if the high-level desulfurization occurs immediately after the reformer **30** rather than before.

[0007] The reformate on line **34** is supplied to a water gas shift reaction section **50** that typically contains a first high temperature shift reactor **52** connected by line **53** to a second low temperature shift reactor **54**. The shift reaction section **50** serves in a known manner to shift CO in the reformate to become CO₂ and to increase the yield of H₂. In the main, the prior art shift reactors **52** and **54** have employed catalysts such as Cu/ZnO, Fe/Cr oxide, and the like, with noble metals occasionally being used in the low temperature shift reactor **54**. The presence of the non-noble-metal catalysts, such as Fe/Cr oxide in the high temperature shift reactor **52** and Cu/ZnO in the low temperature shift reactor **54**, has provided sufficient additional sulfur sorbing action with respect to the residual low level sulfur to further decrease the sulfur levels such that they would not poison the more-sulfur-sensitive catalysts downstream thereof. Following passage through the shift reaction section **50**, the hydrogen-rich reformate may then pass through a selective oxidizer (SOX) **60** connected through line **56** from low temperature shift reactor **54**, and thence to the anode **18** of CSA **16** connected through line **62** from the selective oxidizer **60**. Partially-spent hydrogen is discharged from anode **18** via discharge line **19**, and may be recycled and/or may be combusted to provide a source of heat.

[0008] Heretofore, the water gas shift catalysts of the shift converter portion of the fuel processing system have typically been Cu/ZnO and/or Fe/Cr oxide, and have incidentally served to adsorb the residual sulfur sufficiently to prevent poisoning of the system there and downstream thereof. This is due partly to the fact that they are/were/used in relatively large quantities due to their limited catalytic activity. Recently, however, there has been a change in the type of shift catalyst used in the shift conversion process, from Cu/ZnO and/or Fe/Cr oxide to relatively more active catalysts, such as noble metal-based catalysts and/or some

active base metal catalysts. These more active catalysts offer advantages in the shift conversion reaction process and elsewhere in the system, principally by requiring smaller quantities than heretofore. However, these very attributes may increase the potential for sulfur poisoning, particularly in the absence of the sorbing action of the Cu/ZnO. This is so, even at the low levels of sulfur in the range of 5 ppb-100 ppb-wt. reformat, and may be particularly a problem during surges, or upsets, when the sulfur levels go higher.

[0009] Accordingly, it is an object of the present invention to provide, in a fuel cell power plant having a fuel processing system and employing relatively active metal catalyst(s), means for guarding those catalyst(s) against sulfur in the fuel/reformat.

[0010] It is a further object of the invention to provide such means for guarding relatively active metal catalyst(s) against sulfur in fuel in fuel cell fuel processing systems that include a shift converter with relatively active metal shift catalyst(s).

[0011] It is a still further object of the invention to provide an effective and economic means for removing, or reducing, low, objectionable levels of sulfur from a hydrocarbon fuel process stream for a fuel cell.

DISCLOSURE OF INVENTION

[0012] The present invention relates to an improved fuel processing system (FPS) for a fuel cell stack assembly (CSA) in a fuel cell power plant, which is operative to protect relatively active metal catalysts in the FPS and/or CSA from the poisoning effects of even low levels of sulfur (S) in a hydrogen (H₂) fuel stream. As used herein, the phrase "relatively active metal . . . catalyst(s)" is intended to mean those noble metal catalysts and base metal catalysts having a relatively greater catalytic activity than the Cu/ZnO and/or Fe/Cr oxide catalysts of the prior art. A guard bed of "guard material" is included in the FPS, upstream of the one or more components that contain relatively active metal catalysts that require protection against sulfur poisoning. The guard material is material capable of adsorbing or removing sulfur, and is a metal or metal oxide capable of forming a stable sulfide in the presence of low levels of H₂S in the process fuel stream, and is preferably selected from the group consisting of ZnO, CuO, NiO, Cu/ZnO, Ce oxides, metal-doped Ce oxides, Mn oxide, Mg oxide, Mo oxide, Zr oxide, Co oxide, Fe oxide, Sn oxide and combined Zn/Ti, either alone or in combination with a CeO₂ support. Preferred within that group is a guard material from the group consisting of ZnO, CuO on CeO₂-based support, NiO on CeO₂-based support, and Cu/ZnO.

[0013] In a representative fuel cell power plant, gross high level sulfur removal, to levels in the range of 25 ppb-500 ppb-wt. fuel, or greater is performed by a desulfurizer located upstream of a reformer. Reformat from the reformer may have sulfur levels further diluted to levels in the range of 5 ppb-100 ppb wt. reformat, and is supplied to a guard bed having a guard material as mentioned above, for removal of even low levels of sulfur prior to the process fuel stream entering relatively-active metal catalyst-containing, lower-temperature portions of the FPS and/or the CSA, as for instance the shift reactor(s). Typically, there is a high temperature shift reactor and a low temperature shift reactor, each employing a relatively active metal catalyst, such as a

noble metal or base metal, with the guard bed being located prior to (i.e., upstream of) the high temperature shift reactor. Other elements of the FPS, such as one or more selective oxidizers, may be included, and the resulting H₂-rich fuel stream from the FPS is provided to the anode of a CSA, relatively free of H₂S, for use as a fuel reactant. The sulfur content after the low-level removal by the guard bed is typically less than about 20 ppb-wt. reformat, and preferably less than about 5 ppb-wt. reformat.

[0014] Provision is made for regenerating the guard material in the guard bed and discharging the resulting SO₂. In this way, the FPS and the CSA anode may use preferred relatively active metal catalysts, some of which, such as the noble metals, being relatively expensive, while, in an extended and economical manner, minimizing concern for the possibility of sulfur poisoning.

[0015] The foregoing features and advantages of the present invention will become more apparent in light of the following detailed description of exemplary embodiments thereof as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0016] FIG. 1 is a simplified functional schematic diagram of a fuel cell power plant having a fuel cell stack assembly and a fuel processing system in accordance with the prior art; and

[0017] FIG. 2 is simplified functional schematic diagram of a fuel cell power plant similar to FIG. 1, but showing an improved fuel processing system having a guard bed to control sulfur in accordance with the invention

BEST MODE FOR CARRYING OUT THE INVENTION

[0018] Referring to FIG. 2, there is illustrated a fuel cell power plant 110 similar to that depicted in FIG. 1 with respect to the prior art, but differing principally in that it includes an improved fuel processing system (FPS) 120 in accordance with the invention. The elements of FIG. 2 that are essentially the same as their counterparts in FIG. 1 are given the same reference numeral as in FIG. 1, whereas those elements that are functionally similar but include some change in accordance with the invention, are similarly numbered but with a "1" prefix. Added elements are given new numbers. The CSA 16 is typically of the proton exchange membrane (PEM) type, operating at temperatures less than 100° C. and pressures less than 1 atmosphere gauge, for example at 5 psig. It will be understood that the power plant 110 includes various elements and sub-systems that are well understood and a part of the normal functioning of the system, but which are not described herein because they are not essential to an understanding of the invention and its benefit to the system.

[0019] As noted previously, a sulfur-containing hydrocarbon fuel feedstock, represented by supply line 22, is delivered by a pump or blower 24 to a desulfurizer 26 at the input, or upstream end, of FPS 120. The hydrocarbon feedstock 22 may typically be natural gas, gasoline, propane, diesel fuel, naphtha, fuel oil, or the like, and is likely to contain various forms of sulfur at levels sufficient to pose a poisoning potential for the various noble metal catalysts in the system.

Moreover, the term "hydrocarbons", as used herein, should be viewed as including not only the heavier C-H-only hydrocarbons, but also the alcohols and other oxygen-containing hydrocarbons, at least to the extent they contain the presence of objectionable levels of sulfur. The hydrocarbon fuel feedstock is delivered to the FPS **120**, and specifically a desulfurizer **26**, by means of a pump, blower, or the like. The desulfurizer **26** is generally capable of reducing sulfur levels in the hydrocarbon feedstock **22** to levels of about 500 ppb-25 ppb-wt. fuel, following which the feedstock is supplied to a reformer **30**, for conversion or reformation at high temperature, e.g., 600°-800° C., through the addition of steam (and possibly air) **32**, to form a hydrogen-rich reformat that also includes significant CO. That reformat is provided on output line **34** from the reformer **30**, and continues to contain residual sulfur at or below the levels provided by the desulfurizer **26**, typically diluted by the reformation process, such that sulfur levels of 100 ppb-5 ppb wt. reformat remain. It should be understood that the relative locations of the desulfurizer **26** and the reformer **30** may be reversed, with a similar result occurring, because of the reformer's higher operating temperature-tolerance of sulfur and/or if possibly lower levels of sulfur are present in the hydrocarbon fuel feedstock.

[0020] To reduce the level of CO in the reformat **34**, the reformat undergoes a shift reaction in the water gas shift (WGS) section **150** to shift CO to CO₂ and to further enrich the H₂ in the process fuel stream. The WGS section **150** consists, in this embodiment, of a high temperature shift reactor **152** as a first stage, typically operating at 300°-450° C., and a low temperature shift reactor **154**, typically operating at 200°-300° C., as a second stage. Importantly, the traditional Fe/Cr oxide and/or Cu/ZnO shift catalyst used in prior art shift reactors has been replaced, instead, with a relatively active metal shift catalyst (not separately shown) in the high temperature shift reactor **152**. A similar, though not necessarily the same, relatively active metal shift catalyst is present in the low temperature shift reactor **154**.

[0021] The relatively active metal shift catalyst consists of noble metal catalysts and/or base metal catalysts having a relatively greater catalytic activity than Fe/Cr oxide and Cu/ZnO. That activity, is 2 times, and preferably 5 or more times, greater at 300° C. than the activity of Fe/Cr oxide or Cu/ZnO at that temperature. As the temperature increases, the activity of the relatively active metal catalyst, relative to those prior art catalysts, is even greater, and vice versa. Because of the foregoing, smaller WGS reactors and/or less WGS catalyst is required relative to the prior art.

[0022] These relatively-active metal shift catalysts are chosen from the group consisting of the noble metals rhenium, platinum, palladium, rhodium, ruthenium, osmium, iridium, silver, and gold, and the base metals having activities comparable to the noble metal catalysts. Examples of such base metals include Cu on ceria and Cu on perovskites. Preferred amongst the noble metal catalysts are platinum, palladium, rhodium and/or gold, alone or in combination, with platinum being particularly preferred because of a desirable level of activity per volume. The relatively active metal shift catalysts may be advantageously supported by, or on, a metal oxide promoted support, in which the metal oxide may be an oxide of cerium (ceria), zirconium (zirconia), titanium (titania), yttrium (yttria), vanadium (vanadia), lanthanum (lanthania), and neodymium

(neodymia), with ceria and/or zirconia being generally preferred, and a combination of the two being particularly preferred. The shift catalysts may take the form of coated beads or pellets and be arranged in a reactor bed, or they may constitute a coating on a honeycomb-type structure, or various other forms known for use in shift reactors. Because of the greater activities of these catalysts relative to Fe/Cr oxide and Cu/ZnO, smaller quantities may be used to get similar results.

[0023] Because of the susceptibility of the smaller quantities of the relatively active metal shift catalysts, as well any relatively active metal catalysts of the selective oxidizer **60** and fuel cell anode **18**, to sulfur poisoning by even low levels of sulfur at their respective relatively low operating temperatures, the invention provides a guard bed **70** to remove sufficient sulfur from the reformat/process fuel stream **34** to allow safe and effective processing/utilization of that stream downstream thereof. The selective oxidizer **60** typically operates at 100°-150° C., and the temperatures in the CSA **16** are typically less than 100° C. The guard bed **70** is preferably located immediately prior to (i.e., upstream of) the high temperature shift reactor **152**, although additional such guard beds may be included elsewhere in the fuel-processing stream if required. The guard bed **70** is represented here as a chamber, or enclosure, containing a "bed" of guard material **72**. The guard material **72** may be in the form of tablets, or pellets, or may be wash-coated onto a monolith or a foam, or extruded, and is disposed in the bed chamber in a manner for fluid flow of the reformat **34** thereover and therethrough to facilitate sulfur adsorption. In the illustrated example, a bed of pellets is supported by a porous screen or plate, though other structural support arrangements are also well known.

[0024] Reformat **34** is supplied to the guard bed **70** via a multi-way inlet valve **74** and inlet conduit **75**. Effluent processed by the guard material **72** exits the guard bed **70** via outlet conduit **76** and a further multi-way valve **78**, and is supplied to the high temperature shift reactor **152** via conduit **134** as processed reformat having any sulfur content reduced to an acceptable level, normally below about 20 ppb wt. reformat, and preferably below about 5 ppb-wt. reformat.

[0025] Referring to the guard material **72** in greater detail, it is required to be a material, such as a metal or metal oxide, that can adsorb or remove sulfur and form stable sulfides, from levels of H₂S in the process fuel stream temporarily as high as 1 ppm-fuel wt., such as during upsets, or the more usual lower levels of between 100 ppb to 5 ppb-wt. reformat downstream of the desulfurizer **26** and reformer **30** during normal operation. Moreover, the guard material **72** must be capable of durable and satisfactory operation at the temperatures and flow environment encountered at its selected location in the fuel-processing stream. In this regard, the guard material is selected from the group of materials consisting of ZnO, CuO, NiO, Cu/ZnO, Ce oxides, metal-doped Ce oxides typically of Ce/Zr or Ce/Pr, Mn oxide, Mg oxide, Mo oxide, Zr oxide, and Co oxide, either alone or in combination with a CeO₂-based support. Other metal oxides that may be used include oxides of Fe, Sn, and a combination of Zn/Ti. Preferred from this group are ZnO, CuO on CeO₂-based support, NiO₂ on CeO₂-based support, and Cu/ZnO, with ZnO being particularly preferred, assuming the temperature of the fuel flow stream at that location

is below the ZnO decomposition temperature and the water (H₂O) level in the reformat is not so high as to result in an equilibrium level of H₂S that is unacceptable. The relevant reaction is: $ZnO + H_2S \rightarrow ZnS + H_2O$.

[0026] Cu/ZnO is a suitable alternative to ZnO as a preferred guard material 72. Either ZnO or Cu/ZnO is preferred because of cost and/or chemical activity considerations. Still further, copper oxide (CuO) or nickel oxide (NiO) on a ceria-based support is an equally acceptable alternative to ZnO or Cu/ZnO as the guard material 72. The ceria has been found to provide a support that acts chemically, cooperatively with the CuO or NiO coating or deposition thereon, to enhance the adsorbant characteristics of the supported material. The ceria supports CuO or NiO, but adsorbs S itself. When ceria is reduced, Cu or Ni help to keep it reduced, and reduced CeO₂ has oxygen vacancies that can be sulfur adsorbers. The Ni or Cu, at sufficiently low levels, will not generate a high enough exotherm to damage the adsorbant material.

[0027] The above-mentioned guard materials can operate, in the main, over a temperature range between about 20° C. and 650° C., with each of CuO-on-ceria and NiO-on-ceria having the upper end of the range at about 600° C. and Fe₂O₃ having the upper end of the range at about 480° C. These operating temperature ranges are generally compatible with the temperatures of reformat 34 at that stage in the FPS 120. The principal mode of sulfur removal is through the action of surface adsorption by the guard material 72, which serves to capture the sulfur in the passing H₂S and convert it to a sulfide of the guard material. In instances where the mass flow rate of the reformat 34 by, over, and/or through the guard material 72 is relatively slow, the guard material may additionally act to remove the sulfur via absorption. As noted earlier, the use of these guard materials 72 at this stage in the fuel processing operation is capable of removing even low levels of sulfur from the reformat/processed fuel stream to attain levels of 5 ppb-wt. reformat and below, with a range of 20 ppb to less than 5 ppb-wt. reformat being most typical. These "cleansed" levels of sulfur allow the reformat/processed fuel stream to be further processed and utilized by the shift reactors 150, the SOX 60 and the fuel cell anode 18 with little or no poisoning of the associated relatively active metal catalysts.

[0028] After extended usage of the guard bed 70 to remove sulfur, the effectiveness of the guard material 72 is degraded by the accumulation of sulfide at the surface. The rate of degradation is a function of the size of the guard bed 70, the concentration of sulfur in the fuel (reformat) stream entering the guard bed 70, etc. While it is possible to avoid loss of the guarding effect provided by the guard bed 70 by periodically replacing the degraded guard material 72 with fresh guard material, such action may be both expensive and time consuming. In accordance with a further aspect of the invention, provision is made for regenerating the guard material 72 in situ within the guard bed 70. An oxidant, such as air, is admitted to the guard bed 70, either directly or preferably via an inlet 80 to the multi-way valve 74. This is typically done while the FPS 120 is otherwise inactive, as for instance during shutdown of a vehicle in which the power plant 110 may be located. The introduction of oxidant through inlet 80 may be facilitated by a flow-assisting pump or blower (not shown), to assure that adequate oxidant is provided in a given period. The oxidant reacts with the

sulfide formed at the surface (at least) of the guard material 72 to readily form sulfur dioxide, SO₂, which then may be discharged as a gas, either directly or preferably via a further discharge outlet 82 from the multi-way valve 78. The discharged SO₂ may be further cleansed or used elsewhere in the power plant system, or may simply be discharged from the system all together.

[0029] Although the invention has been described and illustrated with respect to the exemplary embodiments thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions and additions may be made without departing from the spirit and scope of the invention. For instance, although the FPS of the fuel cell power plant has been described as including a desulfurizer upstream of a reformer, it will be understood that their relative positions may be reversed. Still further, the guard bed might be positioned immediately upstream of only the CSA, the SOX, or a LTS if the catalysts of the FPS components upstream thereof are tolerant of the particular sulfur levels.

What is claimed is:

1. In a fuel cell power plant (110) having a fuel cell stack assembly (CSA)(16), including an anode (18), and a fuel processing system (FPS) (120) for converting a hydrocarbon feedstock fuel (22) to a hydrogen-rich fuel stream (34, 134, 62) for the anode (18) of the CSA (16), the FPS (120) including at least a shift reactor (150, 152, 154) having a shift catalyst for converting CO in the fuel stream (34, 134) to CO₂ and increasing the yield of H₂, the improvement comprising:

- a) the shift catalyst comprising a relatively active metal; and
- b) the FPS (120) including a guard bed (70) to protect at least the relatively active metal shift catalyst of the shift reactor (150, 152, 154), the guard bed (70) being positioned upstream of the relatively active metal catalyst of the shift reactor (150, 152, 154) and comprising a guard material (72) for at least adsorbing sulfur from the fuel stream (34).

2. The fuel cell power plant (110) of claim 1 wherein the guard material (72) is a metal or metal oxide capable of forming a stable sulfide in the presence of low levels of H₂S in the fuel stream (34).

3. The fuel cell power plant (110) of claim 2 wherein the guard material (72) is selected from the group consisting of: ZnO, CuO, NiO, Cu/ZnO, Ce oxides, metal-doped Ce oxides, Mn oxide, Mg oxide, Mo oxide, Zr oxide, Co oxide, Fe oxide, Sn oxide and Zn/Ti oxide, either alone or in combination with a CeO₂-based support.

4. The fuel cell power plant (110) of claim 3 wherein the guard material is selected from the group consisting of: ZnO, CuO on CeO₂-based support, NiO on CeO₂-based support, and Cu/ZnO.

5. The fuel cell power plant (110) of claim 2 wherein the relatively active metal of the shift catalyst comprises a noble metal, and the guard material (72) is other than a noble metal.

6. The fuel cell power plant (110) of claim 1 wherein the FPS (120) includes a desulfurizer (26) upstream of the guard bed (70), the desulfurizer (26) being capable of removing high levels of sulfur from the hydrocarbon feedstock (22).

7. The fuel cell power plant (110) of claim 6 wherein the FPS (120) includes a reformer (30) upstream of the guard bed (70) for reforming the hydrocarbon feedstock (22) to a reformat (34) comprising a H₂-rich fuel stream.

8. The fuel cell power plant (110) of claim 1 further including means (80, 74, 75, 76, 78, 82) operatively connected to the guard bed (70) for regenerating the guard material (72) in situ.

9. The fuel cell power plant (110) of claim 8 wherein the means (80, 74, 75, 76, 78, 82) for regenerating the guard material (72) comprises first means (80, 74, 75) for selectively admitting an O₂-containing fluid to the guard bed (70) to oxidize the adsorbed sulfur as SO₂ and second means (76, 78, 82) for discharging the SO₂ from the guard bed (70).

10. The fuel cell power plant (110) of claim 1 wherein the shift reactor (150, 152, 154) comprises a high temperature shift reactor (152) and a low temperature shift reactor (154) relatively downstream of the high temperature shift reactor (152), each of said high temperature and said low temperature shift reactors (152, 154) having a relatively active metal shift catalyst, and the guard bed (70) being upstream of the high temperature shift reactor (152).

11. In a fuel cell power plant (110) having a fuel cell stack assembly (CSA) (16) including an anode (18), and a fuel processing system (FPS) (120) providing a hydrogen-rich fuel stream (34, 134, 62) for the anode (18) of the CSA (16), and a relatively active metal catalyst in at least one of the anode (18) and the FPS (120), the improvement comprising:

the FPS (120) including a guard bed (70) for said relatively active metal catalyst, the guard bed (70) being positioned upstream of said relatively active metal catalyst and comprising a guard material (72) for at least adsorbing sulfur from the fuel stream (34).

12. The fuel cell power plant (110) of claim 11 wherein the guard material (72) is a metal or metal oxide capable of forming a stable sulfide in the presence of low levels of H₂S in the fuel stream (34).

13. The fuel cell power plant (110) of claim 12 wherein the fuel processing system (FPS) (120) includes a reformer (30) to provide a reformat as the hydrogen-rich fuel stream (34) and the level of sulfur in the reformat stream (34) just prior to the guard bed (70) is in the range of 100 ppb to 5 ppb-wt. reformat

14. The fuel cell power plant (110) of claim 11 wherein the relatively active metal of the shift catalyst comprises a noble metal, and the guard material (72) is other than a noble metal.

15. The fuel cell power plant (110) of claim 13 wherein the relatively active metal of the shift catalyst comprises a noble metal, and the guard material (72) is other than a noble metal.

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