Claims

1. A hydrogen-producing fuel processing system, the system comprising:

a hydrogen-producing region configured to produce a mixed gas stream that includes hydrogen as a majority component;

a hydrogen-separation membrane module including at least one hydrogen-selective membrane and configured to receive at least a portion of the mixed gas stream and to separate the mixed gas stream into a product hydrogen stream and a byproduct stream;

a heating assembly configured to maintain the hydrogen-separation membrane module at a predetermined hydrogen-separation membrane module restoration temperature of at least 200 °C; and

an oxidant delivery system configured to selectively deliver an oxidant-containing stream to the hydrogen-separation membrane module in situ and selectively expose at least a portion of the at least one hydrogen-selective membrane to the oxidant-containing stream to increase a hydrogen permeance of the at least one hydrogen-selective membrane; and

wherein the hydrogen-producing fuel processing system is configured to operate in a restoration regime in which the heating assembly maintains the hydrogen separation membrane module at the predetermined hydrogen-separation membrane module restoration temperature and the oxidant delivery system delivers the oxidant-containing stream to the hydrogen-separation membrane module.

2. The system of claim 1, wherein the at least one hydrogen-selective membrane separates the hydrogen-separation membrane module into a mixed gas region and a permeate region, wherein the mixed gas stream is received within the mixed gas region, wherein the at least one hydrogen-selective membrane is configured to permit hydrogen gas contained within the mixed gas stream to diffuse through the at least one hydrogen-selective membrane to the permeate region to separate the mixed gas stream into the product hydrogen stream and the byproduct stream, wherein the byproduct stream is a portion of the mixed gas stream that does not diffuse through the at least one hydrogen-selective membrane and the product hydrogen stream is a portion of the mixed gas stream that diffuses through the at least one hydrogen-selective membrane, and wherein the oxidant delivery system is configured to deliver the oxidant-containing stream to the mixed gas region of the hydrogen-separation membrane module.

3. The system of claim 2, wherein the at least one hydrogen-selective membrane comprises a mixed gas face and an opposed permeate face, wherein the mixed gas face is positioned in the mixed gas region of the hydrogen-separation membrane module and the permeate face is positioned in the permeate region of the hydrogen-separation membrane module, and wherein the oxidant delivery system is configured to selectively expose the mixed gas face of the at least one hydrogen-selective membrane to the oxidant-containing stream.

4. The system of claim 1, wherein the oxidant delivery system comprises one or more oxidant stream inlets through which the oxidant delivery system is configured to flow the oxidant-containing stream to the hydrogen-separation membrane module, wherein the one or more oxidant stream inlets includes an oxidant stream inlet that is positioned upstream of the hydrogen-producing region.

5. The system of claim 4, wherein at least one of the one or more oxidant stream inlets is interconnected with a fuel inlet port of the hydrogen-producing region.

6. The system of claim 4, wherein the hydrogen-producing region includes a reforming catalyst, and further wherein the reforming catalyst is non-pyrophoric.

7. The system of claim 1, wherein the oxidant delivery system comprises one or more oxidant stream inlets through which the oxidant delivery system is configured to flow the oxidant-containing stream to the hydrogen-separation membrane module, wherein the one or more oxidant stream inlets includes an oxidant stream inlet that is positioned downstream of the hydrogen-producing region.

~~5~~8. The system of claim 1, wherein the oxidant delivery system is configured to deliver the oxidant-containing stream to the hydrogen-separation membrane module while the hydrogen-separation membrane module is operably installed within the hydrogen-producing fuel processing system.

~~6~~9. The system of claim 1, wherein the oxidant delivery system is configured to deliver the oxidant-containing stream to the hydrogen-separation membrane module for a predetermined duration of oxidant supply time, and wherein the predetermined duration of oxidant supply time is at least one of at least 60 minutes and at most 2,880 minutes.

~~7~~10. The system of claim 1, wherein the oxidant delivery system is configured to deliver the oxidant-containing stream with a predetermined oxidant-containing stream flow rate, and wherein the predetermined oxidant-containing stream flow rate is at least one of at least 0.0001 standard liters per minute and at most 3 standard liters per minute.

~~8~~11. The system of claim 1, wherein the oxidant-containing stream includes oxygen as an oxidant.

~~9~~12. The system of claim 1, wherein the hydrogen-producing fuel processing system is configured to operate in a hydrogen-producing regime and in the restoration regime, wherein the hydrogen-producing fuel processing system is configured to generate hydrogen in the hydrogen-producing regime, and wherein the hydrogen-producing fuel processing system is configured to increase hydrogen permeance of the hydrogen-separation membrane module in the restoration regime, wherein the heating assembly is configured to maintain one or more components of the hydrogen-producing fuel processing system in one or more predetermined restoration temperatures when the hydrogen-producing fuel processing system is operated in the restoration regime.

~~10~~13. The system of claim ~~9~~12, wherein the heating assembly is configured to maintain at least a portion of the oxidant delivery system at a predetermined oxidant delivery system restoration temperature when the hydrogen-producing fuel processing system is in the restoration regime, and wherein the predetermined oxidant delivery system restoration temperature is at least 200 °C and at most 600 °C.

~~11~~14. The system of claim ~~9~~1, wherein the predetermined hydrogen-separation membrane module restoration temperature is at least 375 °C and at most 425 °C.

~~12~~15. The system of claim 1, wherein the oxidant delivery system is configured to increase the hydrogen permeance of the at least one hydrogen-selective membrane by selectively removing permeance-decreasing contaminants from the at least one hydrogen-selective membrane.

~~13~~16. The system of claim ~~12~~15, wherein the oxidant delivery system is configured to selectively oxidize the permeance-decreasing contaminants to remove the permeance-decreasing contaminants from the at least one hydrogen-selective membrane.

~~14~~17. The system of claim 1, wherein the oxidant delivery system is configured to increase the hydrogen permeance of the at least one hydrogen-selective membrane by selectively increasing a surface roughness of the at least one hydrogen-selective membrane.

~~15~~18. The system of claim 1, wherein the at least one hydrogen-selective membrane is constructed of a palladium alloy.

~~16~~19. A method of increasing hydrogen permeance of a hydrogen-separation membrane module in situ within a hydrogen-producing fuel processing system, the method comprising:

operating the hydrogen-producing fuel processing system in a hydrogen-producing regime, comprising:

supplying, by a feedstock delivery system, a feedstock stream to a hydrogen-producing region;

producing, by the hydrogen-producing region, a mixed gas stream containing hydrogen gas as a majority component and delivering the mixed gas stream to the hydrogen-separation membrane module;

separating, by the hydrogen-separation membrane module, the mixed gas stream into a product hydrogen stream and a byproduct stream; and

operating the hydrogen-producing fuel processing system in a restoration regime, comprising:

delivering, by an oxidant delivery system, an oxidant-containing stream to the hydrogen-separation membrane module in situ;

selectively exposing at least a portion of at least one hydrogen-selective membrane of the hydrogen-separation membrane module to the oxidant-containing stream; and

maintaining the hydrogen-separation membrane module at a membrane restoration temperature of at least 200 °C.

~~17~~20. The method of claim ~~16~~19, further comprising:

detecting one or more operational parameters within the hydrogen-producing fuel processing system during the operating in the hydrogen-producing regime, and determining whether at least one operational parameter of the one or more ~~the~~ operational parameters has passed a respective predetermined threshold; and

transitioning the hydrogen-producing fuel processing system from the hydrogen-producing regime to the restoration regime when the determining comprises determining that an operational parameter of the one or more operational parameters has passed the respective predetermined threshold.

~~18~~21. The method of claim ~~17~~20, wherein the method comprises continuing to operate under the hydrogen-producing regime when each operational parameter is within the respective predetermined threshold.

~~19~~22. The method of claim ~~17~~20, wherein at least one of the one or more operational parameters is a permeance-responsive operational parameter.

~~20~~23. The method of claim ~~17~~20, wherein the determining comprises determining whether a hydrogen-producing region temperature of the hydrogen-producing region has passed a predetermined hydrogen-producing region threshold temperature, wherein the transitioning comprises transitioning the hydrogen-producing fuel processing system from the hydrogen-producing regime to the restoration regime when the hydrogen-producing region temperature has passed the predetermined hydrogen-producing region threshold temperature, and wherein the hydrogen-producing region threshold temperature is at least one of at least 550 °C and at most 650 °C.

~~21~~24. The method of claim ~~17~~20, wherein the determining comprises determining whether a hydrogen permeance of the hydrogen-separation membrane module is at least a preselected threshold fraction of a preselected target hydrogen permeance, and wherein the transitioning comprises transitioning the hydrogen-producing fuel processing system from the hydrogen-producing regime to the restoration regime when the hydrogen permeance of the hydrogen-separation membrane module is less than the preselected threshold fraction of the preselected target hydrogen permeance.

~~22~~25. The method of claim ~~16~~19, wherein the operating the hydrogen-producing fuel processing system in the restoration regime comprises increasing hydrogen permeance of the at least one hydrogen-selective membrane.

26. The method of claim 19, wherein the at least one hydrogen-selective membrane is constructed of a palladium alloy.