Claims

What is claimed is:

1. A reducing gas generator, comprising:

an oxidant system configured to generate from air an oxidant having a variable oxygen content, and configured to provide an oxygen content of the oxidant at a selected value greater than that of ambient atmospheric air;

the oxidant system including a first merging chamber configured to receive an oxygen-rich gas and a nitrogen-rich gas, and a valve controlling an amount of the nitrogen-rich gas received in the first merging chamber for mixing with the oxygen-rich gas, such that the oxidant is discharged from the first merging chamber with the oxygen content at the selected value;

a second merging chamber in fluid communication with the oxidant system and a source of a hydrocarbon fuel, wherein the second merging chamber is configured to receive the hydrocarbon fuel and the oxidant and to discharge a feed stream containing both the hydrocarbon fuel and the oxidant; and

a reformer in fluid communication with the second merging chamber and including a catalytic reactor, wherein the reformer is configured to receive the feed stream from the second merging chamber, to reform the feed stream into a reducing gas, and to discharge the reducing gas;

a temperature sensor positioned downstream of an inlet to the reformer so as to measure at least one of a temperature of catalyst in the catalytic reactor and a temperature of reducing gas output by the catalytic reactor; and

a control system in communication with the temperature sensor, the control system being programmed to control a flow rate of the feed stream and to control both the oxygen content of the oxidant, via controlling the valve responsive to signals from the temperature sensor, and an oxidant/fuel ratio of the feed stream to maintain a predetermined control temperature while achieving a desired flammables content of the reducing gas output by the reducing gas generator.

2. The reducing gas generator of claim 1, wherein the oxidant system includes a nitrogen separator having a nitrogen separation membrane configured to extract nitrogen from air supplied thereto, and to discharge the balance of the air supplied as the oxygen-rich gas to the first merging chamber.

3. The reducing gas generator of claim 2, wherein the oxygen-rich gas has an oxygen content in the range of approximately 21% to 50% by volume.

4. The reducing gas generator of claim 2, wherein the nitrogen separator is also configured to discharge a nitrogen-rich gas, the nitrogen-rich gas having a nitrogen content greater than that of ambient atmospheric air.

5. The reducing gas generator of claim 5, further comprising at least one valve configured to combine the nitrogen-rich gas with the oxygen-rich gas to form the oxidant.

6. The reducing gas generator of claim 6, configured to generate a reducing gas having a flammables content in the range of approximately 0% to 80% by volume.

7. The reducing gas generator of claim 1, wherein the reformer is a catalytic reactor.

8. The reducing gas generator of claim 1, configured to generate a reducing gas having a flammables content in the range of approximately 0% to 80% by volume.

9. A reducing gas generator, comprising:

an oxidant system configured to provide an oxidant, and configured to provide an oxygen content of the oxidant having a value that exceeds the oxygen content of ambient atmospheric air, wherein the oxidant system is configured to provide the oxidant without the use of stored oxygen;

the oxidant system further including a first merging chamber configured to receive an oxygen-rich gas and a nitrogen-rich gas, and a valve controlling an amount of the nitrogen-rich gas received in the first merging chamber for mixing with the oxygen-rich gas, such that the oxidant is provided from the first merging chamber with the oxygen content at the selected value;

a second merging chamber in fluid communication with the first merging chamber and a source of a hydrocarbon fuel, so as to discharge a feed stream containing both the hydrocarbon fuel and the oxidant;

a reformer including a catalytic reactor, and being configured to receive the feed stream, to reform the oxidant and fuel into a reducing gas, and to discharge the reducing gas;

a temperature sensor positioned downstream of an inlet to the reformer so as to measure at least one of a temperature of catalyst in the catalytic reactor and a temperature of reducing gas output by the catalytic reactor; and

a control system in communication with the temperature sensor, the control system being programmed to control a flow rate of the feed stream, and to control both the oxygen content of the oxidant, via controlling the valve responsive to signals from the temperature sensor, and an oxidant/fuel ratio of the feed stream to maintain a predetermined control temperature while achieving a desired flammables content of the reducing gas output by the reducing gas generator.

10. The reducing gas generator of claim 9, wherein the oxidant system is configured generate the oxidant from ambient atmospheric air.

11. The reducing gas generator of claim 9, wherein the oxidant system is configured to provide a variable oxygen content in the oxidant in a range having a maximum value that exceeds the oxygen content of air.

12. The reducing gas generator of claim 9, wherein the oxidant system is configured to provide a selectable oxygen content of the oxidant in a range of approximately 21% to 50% by volume.

13. The reducing gas generator of claim 9, wherein the oxidant system is configured to provide a selectable oxygen content in the oxidant in a range of approximately 5% to 50% by volume.

14. The reducing gas generator of claim 9, wherein the oxidant system includes a nitrogen generator having a nitrogen separation membrane operable to extract nitrogen from air, and wherein the nitrogen generator is configured to discharge the balance of the air supplied thereto as an oxygen-rich gas.

15. The reducing gas generator of claim 14, wherein the nitrogen generator is also configured to discharge the nitrogen-rich gas, the nitrogen-rich gas having a nitrogen content greater than that of ambient atmospheric air.

16. A method of generating a reducing gas, comprising:

generating an oxidant having an oxygen content at a selected value greater than that of ambient atmospheric air without the use of stored oxygen, wherein the generating of the oxidant includes supplying pressurized air to a nitrogen separation membrane; extracting an oxygen-rich gas and a nitrogen-rich gas using the nitrogen separation membrane; controlling the amount of the nitrogen-rich gas mixed with the oxygen-rich gas to form the oxidant having the oxygen content as the selected value;

forming a feed stream with the oxidant and a hydrocarbon fuel;

reforming the feed stream, wherein the reforming of the feed stream includes directing the feed stream to a catalyst; and catalytically converting the feed stream into a reducing gas;

measuring at least one of a temperature of the catalyst and a temperature of reducing gas output by the catalytic conversion; wherein the measuring includes controlling a flow rate of the feed stream, the oxygen content of the oxidant and an oxidant/fuel ratio of the feed stream to maintain a predetermined control temperature while achieving a desired flammables content of the reducing gas generated.

17. The method of claim 16, wherein the generating of the oxidant includes providing the selectable oxygen content of the oxidant in a range of approximately 21% to 50% oxygen by volume.

18. The method of claim 16, wherein the generating of the oxidant includes generating the oxidant with the oxygen content of the oxidant being in a range of approximately 5% to 50% oxygen by volume.

Claims

1. A reducing gas generator, comprising:

an oxidant system configured to generate from air an oxidant having a variable oxygen content, and configured to provide an oxygen content of the oxidant at a selected value greater than that of ambient atmospheric air;

the oxidant system including a first merging chamber configured to receive an oxygen-rich gas and a nitrogen-rich gas, and a valve controlling an amount of the nitrogen-rich gas received in the first merging chamber for mixing with the oxygen-rich gas, such that the oxidant is discharged from the first merging chamber with the oxygen content at the selected value;

a second merging chamber in fluid communication with the oxidant system and a source of a hydrocarbon fuel, wherein the second merging chamber is configured to receive the hydrocarbon fuel and the oxidant and to discharge a feed stream containing both the hydrocarbon fuel and the oxidant; and

a reformer in fluid communication with the second merging chamber and including a catalytic reactor, wherein the reformer is configured to receive the feed stream from the second merging chamber, to reform the feed stream into a reducing gas, and to discharge the reducing gas;

a temperature sensor positioned downstream of an inlet to the reformer so as to measure at least one of a temperature of catalyst in the catalytic reactor and a temperature of reducing gas output by the catalytic reactor; and

a control system in communication with the temperature sensor, the control system being programmed to control a flow rate of the feed stream and to control both

the oxygen content of the oxidant, via controlling the valve responsive to signals from the temperature sensor, and an oxidant/fuel ratio of the feed stream to maintain a predetermined control temperature while achieving a desired flammables content of the reducing gas output by the reducing gas generator, wherein the desired flammables content is in the range of approximately 45% to 80% by volume.

2. The reducing gas generator of claim 1, wherein the oxidant system includes a nitrogen separator having a nitrogen separation membrane configured to extract nitrogen from air supplied thereto, and to discharge the balance of the air supplied as the oxygen-rich gas to the first merging chamber.

3. The reducing gas generator of claim 2, wherein the oxygen-rich gas has an oxygen content in the range of approximately 21% to 50% by volume.

4. The reducing gas generator of claim 2, wherein the nitrogen separator is also configured to discharge a nitrogen-rich gas, the nitrogen-rich gas having a nitrogen content greater than that of ambient atmospheric air.

5. The reducing gas generator of claim 5, further comprising at least one valve configured to combine the nitrogen-rich gas with the oxygen-rich gas to form the oxidant.

6. The reducing gas generator of claim 1, wherein the reformer is a catalytic reactor.

7. A reducing gas generator, comprising:

an oxidant system configured to provide an oxidant, and configured to provide an oxygen content of the oxidant having a value that exceeds the oxygen content of ambient atmospheric air, wherein the oxidant system is configured to provide the oxidant without the use of stored oxygen;

the oxidant system further including a first merging chamber configured to receive an oxygen-rich gas and a nitrogen-rich gas, and a valve controlling an amount of the nitrogen-rich gas received in the first merging chamber for mixing with the oxygen-rich gas, such that the oxidant is provided from the first merging chamber with the oxygen content at the selected value;

a second merging chamber in fluid communication with the first merging chamber and a source of a hydrocarbon fuel, so as to discharge a feed stream containing both the hydrocarbon fuel and the oxidant;

a reformer including a catalytic reactor, and being configured to receive the feed stream, to reform the oxidant and fuel into a reducing gas, and to discharge the reducing gas;

a temperature sensor positioned downstream of an inlet to the reformer so as to measure at least one of a temperature of catalyst in the catalytic reactor and a temperature of reducing gas output by the catalytic reactor; and

a control system in communication with the temperature sensor, the control system being programmed to control a flow rate of the feed stream, and to control both the oxygen content of the oxidant, via controlling the valve responsive to signals from the temperature sensor, and an oxidant/fuel ratio of the feed stream to maintain a predetermined control temperature while achieving a desired flammables content of the reducing gas output by the reducing gas generator; wherein the desired flammables content is in the range of approximately 45% to 80% by volume .

8. The reducing gas generator of claim 7, wherein the oxidant system is configured generate the oxidant from ambient atmospheric air.

9. The reducing gas generator of claim 7, wherein the oxidant system is configured to provide a variable oxygen content in the oxidant in a range having a maximum value that exceeds the oxygen content of air.

10. The reducing gas generator of claim 7, wherein the oxidant system is configured to provide a selectable oxygen content of the oxidant in a range of approximately 21% to 50% by volume.

11. The reducing gas generator of claim 7, wherein the oxidant system is configured to provide a selectable oxygen content in the oxidant in a range of approximately 5% to 50% by volume.

12. The reducing gas generator of claim 7, wherein the oxidant system includes a nitrogen generator having a nitrogen separation membrane operable to extract nitrogen from air, and wherein the nitrogen generator is configured to discharge the balance of the air supplied thereto as an oxygen-rich gas.

13. The reducing gas generator of claim 12, wherein the nitrogen generator is also configured to discharge the nitrogen-rich gas, the nitrogen-rich gas having a nitrogen content greater than that of ambient atmospheric air.