CLAIMS

1. An apparatus for generating nitric oxide (NO), the apparatus comprising:

a reaction chamber having a liquid region and a gas region, the liquid region configured to contain a reaction medium, the gas region configured to contain a product gas comprising NO;

a plurality of electrodes disposed in the reaction medium, the plurality of electrodes comprising a cathode;

an energy source electrically connected to the plurality of electrodes and configured to apply a predetermined voltage or a predetermined current to the cathode to generate NO;

a sparger disposed in the reaction medium;

an inlet circuit in fluid communication with the sparger and configured to convey a carrier gas to the sparger; ~~and~~ wherein the carrier gas preferably comprises nitrogen;

an outlet circuit in fluid communication with the gas region of the reaction chamber and configured to convey the product gas from the reaction chamber; and

(A) a pressure vessel in fluid communication with the outlet circuit, the pressure vessel configured to receive the product gas from the outlet circuit, store the received product gas at or below a predetermined pressure, and release the received product gas; and/or

(B) a recirculation~~first circulation~~ circuit ~~configured to circulate a first fluid flow relative to the reaction chamber, the first circulation circuit~~ including:

a ~~first~~ circulation inlet in fluid communication with the gas region of the reaction chamber configured to receive a fluid flow of the product gas from the gas region;

a ~~first~~ circulation outlet in fluid communication with the sparger; and

a ~~first~~ pump configured to create the ~~first~~ fluid flow of the product gas from the ~~first~~ circulation inlet to the sparger through the ~~first~~ circulation outlet.

~~2. The apparatus of claim 1, wherein the carrier gas comprise nitrogen.~~

~~3~~2. The apparatus of claim 1, wherein the ~~first~~ fluid flow comprises a flow of the product gas.

~~4~~3. The apparatus of claim 1, wherein the sparger is disposed adjacent the cathode and configured to emanate bubbles in the reaction medium to propagate along a surface of the cathode.

~~5. The apparatus of claim 1, wherein the sparger comprising a porous structure comprising a plurality of pores having an average size from about 0.1 μm to about 1 mm.~~

~~6~~4. The apparatus of claim 1, wherein the reaction chamber comprises a first side and a second side opposite to the first side, and the cathode comprises an electrode plate positioned substantially perpendicular to the second side of the reaction chamber.

~~7~~5. The apparatus of claim ~~6~~4, wherein the electrode plate comprises a surface, a first edge, and a second edge opposite to the first edge, the first edge extending along the first side of the reaction chamber, the second edge extending along the second side of the reaction chamber.

~~8~~6. The apparatus of claim ~~7~~5, wherein the sparger is disposed between the second side of the reaction chamber and the second edge of the electrode plate and configured to emanate bubbles along a bubble path extending from the second edge to the first edge of the electrode plate.

~~9. The apparatus of claim 1, further comprising a second circulation circuit configured to circulate a second fluid flow relative to the reaction chamber, the second circulation circuit comprising:~~

~~a first port in fluid communication with the liquid region of the reaction chamber;~~

~~a second port in fluid communication with the gas region of the reaction chamber;~~

~~a second pump configured to create the second fluid flow from the first port to the second port or from the second port to the first port; and~~

~~a liquid-gas separation device disposed downstream of the second pump and configured to separate NO from the reaction medium as the reaction medium passes therethrough.~~

~~10. The apparatus of claim 9, wherein the liquid-gas separation device comprises a separation membrane permeable to NO.~~

~~11. The apparatus of claim 10, wherein the separation membrane has a surface area ranging from about 500 cm2 to about 50000 cm2.~~

~~12. The apparatus of claim 9, wherein the second circulation circuit further comprises a switching valve and is configured to operate in a working mode and a cleaning mode, wherein~~

~~in the working mode, the switching valve is in a first position, the second fluid flow comprises a flow of the reaction medium, and the second pump is configured to circulate the second fluid flow from the first port, through the liquid-gas separation device, and to the second port; and~~

~~in the cleaning mode, the switching valve is in a second position, the second fluid flow comprises a gas flow, and the second pump is configured to circulate the second fluid flow from the second port, through the liquid-gas separation device, and to the first port.~~

~~13~~7. The apparatus of claim 1, wherein the reaction medium comprises a buffer solution, a source of nitrite ions, and a catalyst.

~~14. The apparatus of claim 13, wherein the catalyst includes a metal-ligand complex.~~

~~15. The apparatus of claim 13, the source of nitrite ions comprises one or more nitrite salts.~~

~~16. The apparatus of claim 1, wherein the predetermined voltage is from about 1 V to about 5.0 V.~~

8~~17~~. The apparatus of claim 1, wherein the predetermined current is from about 0 mA to about 600 mA.

~~18. The apparatus of claim 1, further comprising an NO sensor configured to detect a NO concentration of the product gas.~~

~~19. A system for generating nitric oxide (NO), the system comprising:~~

~~an apparatus for generating NO, the apparatus comprising:~~

~~a reaction chamber having a liquid region and a gas region, the liquid region configured to contain a reaction medium, the gas region configured to contain a product gas comprising NO;~~

~~a plurality of electrodes disposed in the reaction medium, the plurality of electrodes comprising a cathode;~~

~~an energy source electrically connected to the plurality of electrodes and configured to apply a predetermined voltage or a predetermined current to the cathode to generate NO;~~

~~a sparger disposed in the reaction medium;~~

~~an inlet circuit in fluid communication with the sparger and configured to convey a carrier gas to the sparger; and~~

~~an outlet circuit in fluid communication with the gas region of the reaction chamber and configured to convey the product gas from the reaction chamber; and~~

~~a pressure vessel in fluid communication with the outlet circuit, the pressure vessel configured to receive the product gas from the outlet circuit, store the received product gas at or below a predetermined pressure, and release the received product gas.~~

~~20. The system of claim 19, wherein the carrier gas comprise nitrogen.~~

21. The system of claim 19, further comprising a first circulation circuit configured to circulate a first fluid flow relative to the reaction chamber, the first circulation circuit comprising:

a first inlet in fluid communication with the gas region of the reaction chamber;

a first outlet in fluid communication with the sparger; and

a first pump configured to create the first fluid flow from the first inlet to the first outlet.

22. The system of claim 21, wherein the first fluid flow comprises a flow of the product gas.

23. The system of claim 19, wherein the sparger is disposed adjacent the cathode and configured to emanate bubbles in the reaction medium to propagate along a surface of the cathode.

24. The system of claim 19, wherein the sparger comprises a porous structure comprising a plurality of pores having an average size from about 0.1 μm to about 1 mm.

25. The system of claim 19, wherein the reaction chamber comprises a first side and a second side opposite to the first side, and the cathode comprises an electrode plate positioned substantially perpendicular to the second side of the reaction chamber.

26. The system of claim 25, wherein the electrode plate comprises a surface, a first edge, and a second edge opposite to the first edge, the first edge extending along the first side of the reaction chamber, the second edge extending along the second side of the reaction chamber.

27. The system of claim 26, wherein the sparger is disposed between the second side of the reaction chamber and the second edge of the electrode plate and configured to emanate bubbles along a bubble path extending from the second edge to the first edge of the electrode plate.

28. The system of claim 19, further comprising a second circulation circuit configured to circulate a second fluid flow relative to the reaction chamber, the second circulation circuit comprising:

a first port in fluid communication with the liquid region of the reaction chamber;
a second port in fluid communication with the gas region of the reaction chamber;
a second pump configured to create the second fluid flow from the first port to the second port or from the second port to the first port; and
a liquid-gas separation device disposed downstream of the second pump and configured to separate NO from the reaction medium as the reaction medium passes therethrough.

29. The system of claim 28, wherein the liquid-gas separation device comprises a separation membrane permeable to NO.

30. The system of claim 28, wherein the separation membrane has a surface area from about 500 cm2 to about 50000 cm2.

31. The system of claim 28, wherein the second circulation circuit further comprises a switching valve and is configured to operate in a working mode and a cleaning mode, wherein

in the working mode, the switching valve is in a first position, the second fluid flow comprises a flow of the reaction medium, and the second pump is configured to circulate the second fluid flow from the first port, through the liquid-gas separation device, and to the second port; and
in the cleaning mode, the switching valve is in a second position, the second fluid flow comprises a gas flow, and the second pump is configured to circulate the second fluid flow from the second port, through the liquid-gas separation device, and to the first port.

32. The system of claim 19, wherein the reaction medium comprises a buffer solution, a source of nitrite ions, and a catalyst.

~~33. The system of claim 32, wherein the catalyst includes a metal-ligand complex.~~

~~34. The system of claim 32, the source of nitrite ions comprises one or more nitrite salts.~~

~~35. The system of claim 19, wherein the predetermined voltage is from about 1.4 V to about 5.0 V.~~

~~36. The system of claim 19, wherein the predetermined current is from about 0 mA to about 600 mA.~~

~~37. The system of claim 19, further comprising an NO sensor configured to detect an NO concentration of the product gas.~~

~~38~~9. The ~~system~~ apparatus of claim ~~19~~1, wherein the pressure vessel comprises:

a body defining an interior cavity comprising a first region and a second region, the second region in fluid communication with and disposed downstream of the first region;

a gas inlet and a gas outlet in fluid communication with the first region;

and a plurality of baffles defining a circuitous flow path through the first region and the second region; and

a pressure relief valve disposed on the body and in fluid communication with the second region.

~~39. The system of claim 38, wherein~~

~~the first region comprises a first plurality of chambers defining a first flow path; and~~

~~the second region comprises a second plurality of chambers defining a second flow path in fluid communication with the first flow path.~~

~~40. The system of claim 38, wherein the pressure vessel further comprises a pressure sensor configured to detect a gas pressure in the first region.~~

~~41. The system of claim 19, further comprising a filtration system disposed downstream of and in fluid communication with the outlet circuit, the filtration system configured to reduce one or more impurities in the product gas.~~

~~42. The system of claim 41, wherein the filtration system comprises a moisture filter and a solid matter filter.~~

~~43. The system of claim 42, wherein the solid matter filter comprises a polymeric material having a porous structure.~~

~~44. The system of claim 43, wherein the polymeric material comprises one or more selected from a group comprising polytetrafluoroethylene, polyvinylidene fluoride, polyethersulfone, mixed cellulose ester, polyamide (nylon), nylon 6, and nylon 66.~~

~~45. The system of claim 43, wherein the porous structure has an average pore size from about 0.01 μm to about 2.0 μm.~~

~~46. The system of claim 42, wherein the moisture filter comprises at least one membrane filter.~~

~~47~~10. The apparatus~~system~~ of claim ~~21~~1, further comprising a filtration device disposed downstream of the ~~first~~ circulation inlet and upstream of the ~~first~~ pump of the ~~first circulation~~ recirculation circuit, the filtration device configured to reduce or remove one or more liquid and/or solid impurities in the first fluid flow.

~~48. The system of claim 47, wherein the filtration device is configured to allow the one or more liquid and/or solid impurities to settle out of the first fluid flow based on gravity.~~

~~49. The system of claim 38, further comprising a waste gas treatment device disposed downstream of the pressure vessel and in fluid communication with the pressure relief valve, the waste gas treatment device configured to reduce or remove one or more nitride oxides in a gas received from the pressure vessel via the pressure relief valve.~~

~~50. The system of claim 49, wherein the waste gas treatment device comprises a circuitous flow path at least partially filled with a filter material configured to react with the one or more nitride oxides.~~

~~51. The system of claim 50, wherein the filter material comprises a base material prepared with an oxidizing agent.~~

52. The system of claim 51, wherein the base material comprises at least one material selected from a group comprising a molecular sieve, silica gel, aluminum oxide, sponge, cotton, foam resin, silicon dioxide, and active charcoal.

53. The system of claim 51, wherein the oxidizing agent comprises one or more salts selected from a group comprising permanganate, persulfate, chromate, and dichromate salts.

54. The system of claim 19, further comprising a gas converter disposed downstream of and in fluid communication with the pressure vessel, the gas converter configured to absorb one or more nitrogen dioxides in the product gas and/or convert one or more nitrogen dioxides in the product gas to NO.

55. The system of claim 54, wherein the gas converter comprises:

a body; an inlet;

an outlet; and

a circuitous flow path extending from the inlet to the outlet, the circuitous flow path configured to be at least partially filled with a filter material.

56. The system of claim 55, wherein the filter material comprises a base material prepared with a reducing agent.

57. The system of claim 56, wherein the base material comprises at least one material selected from a group comprising a molecular sieve, silica gel, aluminum oxide, sponge, cotton, and foam resin.

58. The system of claim 56, wherein the reducing agent comprises at least one selected from a group comprising Vitamin C, Vitamin E, and Vitamin A.

59. The system of claim 55, wherein the gas converter further comprises a plurality of baffles configured to divide an interior cavity of the body into a plurality of chambers defining the circuitous flow path.

6011. The ~~system~~ apparatus of claim ~~19~~1, further comprising a carrier gas source disposed upstream of and in fluid communication with the inlet circuit, the carrier gas source configured to generate or supply the carrier gas to the inlet circuit.

~~61. The system of claim 60, wherein the carrier gas source comprises a nitrogen generation apparatus configured to generate the carrier gas from compressed air, the nitrogen generation apparatus comprising a nitrogen separation membrane.~~

~~62. The system of claim 60, wherein the carrier gas comprises nitrogen higher than about 99.0% by volume.~~

~~63. The system of claim 60, wherein the carrier gas source comprises a flow control device configured to control a flow rate of the carrier gas to the inlet circuit.~~

6412. The ~~system~~ apparatus of claim ~~19~~1, further comprising a ventilation circuit configured to connect to a respiratory device, the ventilation circuit comprising an inspiratory circuit disposed downstream of and in fluid communication with the respiratory device and the pressure vessel.

6513. The ~~system~~ apparatus of claim ~~64~~12, wherein the inspiratory circuit comprises:

an inlet configured to receive an air flow or an oxygen flow from the respiratory device;

a port disposed downstream of the inlet, the port configured to receive the product gas from the pressure vessel;

a flow rate sensor disposed downstream of the inlet and configured to measure a flow rate of the air flow or the oxygen flow; and

an outlet configured to deliver a gas mixture comprising the product gas from the pressure vessel and the air or oxygen from the respiratory device.

6614. The apparatus~~system~~ of claim ~~65~~13, wherein the inspiratory circuit further comprises a sampling port disposed upstream of the outlet and configured to output a sample gas flow of the gas mixture.

~~67~~15. The ~~system~~ apparatus of claim ~~66~~14, further comprising a gas monitoring device comprising one or more gas sensors configured to receive the sample gas flow and measure one or more concentrations of NO_2, NO, and O_2 of the sample gas flow.

~~68~~16. The ~~system~~ apparatus of claim ~~67~~15, further comprising:

a flow control device configured to control a flow rate of the product gas entering the inspiratory circuit from the pressure vessel;

a control device in communication with the flow rate sensor, the flow control device, and the gas monitoring device, wherein the control device is configured to

receive one or more sensing signals or readings from the gas monitoring device and/or the flow rate sensor;

generate instructions based on the one or more sensing signals or readings; and

send the instructions to the flow control device to adjust the flow rate of the product gas entering the inspiratory circuit.

~~69. A system for generating nitric oxide (NO), the system comprising:~~

~~an apparatus for generating NO, the apparatus comprising:~~

~~a reaction chamber having a liquid region and a gas region, the liquid region configured to contain a reaction medium, the gas region configured to contain a product gas, the product gas comprising NO;~~

~~a plurality of electrodes disposed in the reaction medium, the plurality of electrodes comprising a cathode;~~

~~an energy source electrically connected to the plurality of electrodes and configured to apply a predetermined voltage or a predetermined current to the cathode to generate NO; and~~

~~a sparger disposed in the reaction medium;~~

~~an inlet circuit in fluid communication with the sparger and configured to convey a carrier gas to the sparger;~~

an outlet circuit in fluid communication with the gas region of the reaction chamber and configured to convey the product gas from the reaction chamber; and

a first circulation circuit configured to circulate a first fluid flow relative to the reaction chamber, the first circulation circuit comprising:

a first inlet in fluid communication with the gas region of the reaction chamber;

a first outlet in fluid communication with the sparger; and

a first pump configured to create the first fluid flow from the first inlet to the first outlet; and

a second circulation circuit configured to circulate a second fluid flow relative to the reaction chamber, the second circulation circuit comprising:

a first port in fluid communication with the liquid region of the reaction chamber;

a second port in fluid communication with the gas region of the reaction chamber;

a second pump configured to create the second fluid flow from the first port to the second port or from the second port to the first port; and

a liquid-gas separation device disposed downstream of the second pump and configured to separate NO from the reaction medium as the reaction medium passes therethrough;

a filtration system disposed downstream of and in fluid communication with the outlet circuit, the filtration system configured to reduce one or more impurities in the product gas;

a pressure vessel disposed downstream of and in fluid communication with the filtration system, the pressure vessel configured to receive the product gas from the outlet circuit, store the received product gas at or below a predetermined pressure, and release the received product gas; and

~~a ventilation circuit disposed downstream of and in fluid communication with the pressure vessel, the ventilation circuit configured to deliver NO in the product gas to a patient.~~

~~70~~17. A method for generating nitric oxide (NO), the method comprising:

applying, by an energy source, a predetermined voltage or a predetermined current to one or more of ~~a plurality of~~ electrodes disposed in a reaction medium contained in a reaction chamber to generate NO, the plurality of electrodes comprising a cathode, the reaction chamber comprising a gas region and a liquid region, the liquid region configured to contain the reaction medium, the gas region configured to contain a product gas comprising NO;

receiving a carrier gas through an inlet circuit in fluid communication with a sparger disposed in the reaction medium;

emanating, by the sparger, bubbles of the carrier gas in the reaction medium to sweep a surface of one or more of the plurality of electrodes; and

~~circulating, in a first circulation circuit, a first fluid flow relative to the reaction chamber, the first fluid flow comprising a flow of the product gas; and~~

conveying the product gas from the reaction chamber through an outlet circuit, the outlet circuit in fluid communication with the gas region of the reaction chamber~~.~~,

wherein (A) the product gas is further conveyed through a pressure vessel in fluid communication with the outlet circuit, or (B) at least a portion of the product gas is circulated, in a recirculation circuit, back to the sparger in the reaction chamber.

~~71~~18. The method of claim ~~70~~17, wherein ~~circulating~~ the portion of the product gas is circulated from ~~first fluid flow relative to the reaction chamber comprises creating, by a first pump, the first fluid flow from a first inlet of the first circulation circuit to a first outlet of the first circulation circuit, the first inlet in fluid communication with~~ the gas region of the reaction chamber, by the pump in the recirculation circuit, to~~the first outlet in fluid communication with~~ the sparger.

~~72. The method of claim 71, further comprising circulating the first fluid flow at a flow rate from about 0.5 L/min to about 5.0 L/min.~~

~~73~~19. The method of claim ~~71~~17, further comprising combining the ~~first fluid flow~~circulated product gas with the carrier gas upstream of the sparger.

~~74. The method of claim 70, wherein the sparger comprises a porous structure comprising a plurality of pores having an average size from about 0.1 μm to about 1 mm.~~

~~75. The method of claim 70, wherein the reaction chamber comprises a first side and a second side opposite to the first side, and the cathode comprises an electrode plate positioned substantially perpendicular to the second side of the reaction chamber.~~

~~76. The method of claim 75, wherein the electrode plate comprises a surface, a first edge, and a second edge opposite to the first edge, the first edge extending along the first side of the reaction chamber, the second edge extending along the second side of the reaction chamber.~~

~~77. The method of claim 76, the sparger is disposed between the second side of the reaction chamber and the second edge of the electrode plate, the method further comprising emanating, by the sparger, the bubbles along a bubble path extending from the second edge to the first edge of the electrode plate.~~

~~78. The method of claim 70, further comprising:~~

~~terminating applying the predetermined voltage or the predetermined current; and~~
~~creating, in a second circulation circuit, a second fluid flow relative to the reaction chamber.~~

~~79. The method of claim 78, wherein the second circulation circuit further comprises a switching valve and is configured to operate in a working mode and a cleaning mode, the method further comprising:~~

~~configuring the switching valve in a first position; and~~
~~operating the second circulation circuit in the working mode comprising:~~

circulating, by a second pump, the second fluid flow from a first port, through a liquid-gas separation device, and to a second port, the first port in fluid communication with the liquid region of the reaction chamber, the second port in fluid communication with the gas region of the reaction chamber, the second fluid flow comprising a flow of the reaction medium; and

separating, by the liquid-gas separation device, NO from the reaction medium as the reaction medium passes therethrough.

80. The method of claim 79, wherein the liquid-gas separation device comprises a separation membrane permeable to NO.

81. The method of claim 80, wherein the liquid-gas separation device comprises a membrane filter having a surface area from 500 cm2 to 50000 cm2.

82. The method of claim 79, further comprising circulating the second fluid flow at a flow rate from about 0.25 L/min to about 10.0 L/min.

83. The method of claim 79, further comprising operating the second circulation circuit in the working mode for less than about 20 minutes.

84. The method of claim 79, further comprising:

configuring the switching valve in a second position; and

operating the second circulation circuit in the cleaning mode comprising: circulating, by the second pump, the second fluid flow from the second port, through the liquid-gas separation device, to the first port, the second fluid flow comprising a gas flow.

85. The method of claim 84, further comprising circulating the second fluid flow through the liquid-gas separation device at a flow rate from 0.25 L/min to 5.0 L/min.

86. The method of claim 84, further comprising operating the second circulation circuit in the cleaning mode for a period from about 0.5 minutes to about 5 minutes.

~~87. The method of claim 70, wherein the reaction medium comprises a buffer solution, a source of nitrite ions, and a catalyst.~~

~~88. The method of claim 87, wherein the catalyst includes a metal-ligand complex.~~

~~89. The method of claim 87, the source of nitrite ions comprises one or more nitrite salts.~~

~~90. The method of claim 70, wherein the predetermined voltage is from about 1.4 V to about 5.0 V.~~

~~91. The method of claim 70, wherein the predetermined current is from about 0 mA to about 600 mA.~~

~~92. The method of claim 70, further comprising measuring, by an NO sensor, an NO concentration of the product gas.~~

93<u>20</u>. The method of claim ~~70~~<u>17</u>, further comprising before applying the predetermined voltage or the predetermined current, applying a stimulation voltage or a stimulation current to at least one of the plurality of electrodes for a stimulation period.

~~94. The method of claim 93, wherein the stimulation period is from about 0.5 minutes to about 5 minutes.~~

~~95. The method of claim 93, wherein the stimulation voltage is about 2 to about 8 times of the predetermined voltage.~~

~~96. The method of claim 93, wherein the stimulation current is about 2 to about 8 times of the predetermined current.~~

~~97. The method of claim 70, further comprising conveying the product gas having a steady state NO concentration through the outlet circuit within a ramp period.~~

~~98. The method of claim 97, wherein the ramp period is from about 2 minutes to about 10 minutes.~~

99. The method of claim 70, further comprising receiving the carrier gas at a flow rate from about 50 mL/min to about 12 L/min.

100. The method of claim 70, further comprising conveying the product gas to a pressure vessel in fluid communication with the outlet circuit, wherein the pressure vessel comprises:

a body defining an interior cavity comprising a first region and a second region, the second region in fluid communication with and disposed downstream of the first region;

a gas inlet and a gas outlet in fluid communication with the first region;

a plurality of baffles defining a circuitous flow path through the first region and the second region; and

a pressure relief valve disposed on the body and in fluid communication with the second region.

101. The method of claim 100, further comprising conveying the product gas from the pressure vessel via the gas outlet after a pressure-holding period.

102. The method of claim 101, further comprising detecting, by a pressure sensor, a gas pressure in the first region.

103. The method of claim 70, further comprising:

conveying the product gas from the outlet circuit to a filtration system disposed downstream of and in fluid communication with the outlet circuit; and

reducing, by the filtration system, one or more impurities in the product gas.

104. The method of claim 103, wherein the filtration system comprises a moisture filter and a solid matter filter.

105. The method of claim 104, wherein the solid matter filter comprises a polymeric material having a porous structure.

106. The method of claim 105, wherein the polymeric material is selected from a group comprising polytetrafluoroethylene, polyvinylidene fluoride, polyethersulfone, mixed cellulose ester, polyamide (nylon), nylon 6, and nylon 66.

107. The method of claim 105, wherein the porous structure has an average pore size from 0.1 μm to 2.0 μm.

108. The method of claim 104, wherein the moisture filter comprises at least one membrane filter.

109. The method of claim 70, further comprising reducing or removing, by a filtration device, one or more liquid and/or solid impurities in the first fluid flow based on gravity.

110. The method of claim 100, further comprising:

conveying a gas released from the pressure vessel by the pressure relief valve to a waste gas treatment device; and

reducing, by the waste gas treatment device, one or more nitride oxides in the gas.

111. The method of claim 110, further comprising conveying the product gas through a circuitous flow path of the waste gas treatment device at least partially filled with a filter material configured to react with the one or more nitride oxides.

112. The method of claim 111, wherein the filter material comprises a base material prepared with an oxidizing agent.

113. The method of claim 112, wherein the base material comprises at least one material selected from a group comprising a molecular sieve, silica gel, aluminum oxide, sponge, cotton, foam resin, silicon dioxide, and active charcoal.

114. The method of claim 112, wherein the oxidizing agent comprises one or more salts selected from a group comprising permanganate, persulfate, chromate, and dichromate salts.

115. The method of claim 100, further comprising: conveying the product gas from the pressure vessel to and through a gas converter, the gas converter comprising a circuitous flow path extending from an inlet to an outlet, the circuitous flow path configured to be at least partially filled with a filter material; and absorbing one or more nitrogen dioxides in the product gas, and/or converting one or more nitrogen dioxides in the product gas to NO.

116. The method of claim 115, wherein the filter material comprises a base material treated prepared with a reducing agent

117. The method of claim 116, wherein the base material comprising at least one material selected from a group comprising a molecular sieve, silica gel, aluminum oxide, sponge, cotton, and foam resin.

118. The method of claim 116, wherein the reducing agent comprises at least one selected from a group comprising Vitamin C, Vitamin E, and Vitamin A.

119. The method of claim 70, further comprising generating, by a nitrogen generation apparatus, the carrier gas from compressed air, the nitrogen generation apparatus comprising a nitrogen separation membrane.

120. The method of claim 119, wherein the carrier gas comprises nitrogen higher than about 99.0% by volume.

121. The method of claim 119, wherein the nitrogen separation membrane comprises a plurality of pores having an average pore size from about 0.005 μm to about 0.02 μm.

122. The method of claim 121, wherein the nitrogen separation membrane comprises at least one material selected from a group comprising poly(4-methyl-l-pentene), brominated polycarbonate, polypropylene, polyimide, and polydimethylsiloxane.

123. The method of claim 119, further comprising controlling, by a flow control device, a flow rate of the carrier gas to the inlet circuit.

124. The method of claim 100, further comprising conveying the product gas through a ventilation circuit disposed downstream of and in fluid communication with the pressure vessel, the ventilation circuit configured to connect to a respiratory device.

125. The method of claim 124, further comprising:

receiving, via an inlet of an inspiratory circuit of the ventilation circuit, an air flow or an oxygen flow from the respiratory device;

receiving, via a port disposed downstream of the inlet of the inspiratory circuit, the product gas from the pressure vessel; and

delivering, via an outlet of the inspiratory circuit, a gas mixture comprising the product gas from the pressure vessel and the air or oxygen from the respiratory device.

126. The method of claim 125, further comprising receiving, by a gas monitoring device from a sampling port of the inspiratory circuit, a sample gas flow of the gas mixture, the gas monitoring device comprising one or more gas sensors.

127. The method of claim 126, further comprising measuring, by the gas monitoring device, one or more concentrations of NO_2, NO, and O_2 of the sample gas flow.

128. The method of claim 126, further comprising:

receiving, by a control device, one or more sensing signals or readings from the gas monitoring device;

generating, by the control device, instructions based on the one or more sensing signals; and

sending, by the control device, instructions to a flow control device disposed downstream of the pressure vessel to adjust a flow rate of the product gas entering the inspiratory circuit.

129. The method of claim 126, further comprising:

receiving, by control device, one or more sensing signals or readings from a flow rate sensor disposed downstream of the inlet and configured to measure a flow rate of the air flow or the oxygen flow;

generating, by the control device, instructions based on the one or more sensing signals or readings; and

sending, by the control device, instructions to a flow control device disposed downstream of the pressure vessel to adjust the flow rate of the product gas entering the inspiratory circuit.