CLAIMS

What is claimed is:

1. A hydrocarbon processing system for formation of a liquefied natural gas (LNG), comprising:

a first fluorocarbon refrigeration system configured to chill a natural gas using a first fluorocarbon refrigerant;

a second fluorocarbon refrigeration system configured to further chill the natural gas using a second fluorocarbon refrigerant;

a nitrogen refrigeration system configured to cool the natural gas using a nitrogen refrigerant to produce LNG; and

a nitrogen rejection unit configured to remove nitrogen from the LNG.

2. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigeration system is configured to cool the second fluorocarbon refrigerant of the second fluorocarbon refrigeration system.

3. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigeration system or the second fluorocarbon refrigeration system, or both, is configured to cool the nitrogen refrigerant of the nitrogen refrigeration system.

4. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigeration system or the second fluorocarbon refrigeration system, or both, comprises multiple cooling cycles.

5. The hydrocarbon processing system of claim 1, wherein the nitrogen refrigeration system comprises a plurality of heat exchangers configured to allow for cooling of the natural gas via an indirect exchange of heat between the natural gas and the nitrogen refrigerant.

6. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigeration system comprises:

a compressor configured to compress the first fluorocarbon refrigerant to provide a compressed first fluorocarbon refrigerant;

a chiller configured to cool the compressed first fluorocarbon refrigerant by indirect heat exchange with a cooling fluid;

a valve configured to expand the compressed first fluorocarbon refrigerant to cool the compressed first fluorocarbon refrigerant, thereby producing a cooled first fluorocarbon refrigerant; and

a heat exchanger configured to cool the natural gas via indirect heat exchange with the cooled first fluorocarbon refrigerant.

7. The hydrocarbon processing system of claim 1, wherein the second fluorocarbon refrigeration system comprises:

a compressor configured to compress the second fluorocarbon refrigerant to provide a compressed second fluorocarbon refrigerant;

a chiller configured to cool the compressed second fluorocarbon refrigerant by indirect heat exchange with a cooling fluid;

a valve configured to expand the compressed second fluorocarbon refrigerant to cool the compressed second fluorocarbon refrigerant, thereby producing a cooled second fluorocarbon refrigerant; and

a heat exchanger configured to cool the natural gas via indirect heat exchange with the cooled second fluorocarbon refrigerant.

8. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigerant comprises R-410A.

9. The hydrocarbon processing system of claim 1, wherein the second fluorocarbon refrigerant comprises R-508B.

10. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigerant or the second fluorocarbon refrigerant, or both, comprises a nontoxic, nonflammable refrigerant.

11. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigeration system or the second fluorocarbon refrigeration system, or both, comprises two or more chillers and two or more compressors.

12. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigeration system and the second fluorocarbon refrigeration system are implemented in series.

13. The hydrocarbon processing system of claim 1, wherein the nitrogen refrigerant is in a gas phase.

14. The hydrocarbon processing system of claim 1, wherein the nitrogen refrigeration system comprises two or more chillers, two or more expanders, and two or more compressors.

15. The hydrocarbon processing system of claim 1, wherein the hydrocarbon processing system is configured to chill the natural gas for hydrocarbon dew point control.

16. The hydrocarbon processing system of claim 1, wherein the hydrocarbon processing system is configured to chill the natural gas for natural gas liquid extraction.

17. The hydrocarbon processing system of claim 1, wherein the hydrocarbon processing system is configured to separate methane and lighter gases from carbon dioxide and heavier gases.

18. The hydrocarbon processing system of claim 1, wherein the hydrocarbon processing system is configured to prepare hydrocarbons for liquefied petroleum gas production storage.

19. The hydrocarbon processing system of claim 1, wherein the hydrocarbon processing system is configured to condense a reflux stream.

20. A method for formation of a liquefied natural gas (LNG), comprising:
cooling a natural gas in a first fluorocarbon refrigeration system;
cooling the natural gas in a second fluorocarbon refrigeration system;
liquefying the natural gas to form LNG in a nitrogen refrigeration system; and
removing nitrogen from the LNG in a nitrogen rejection unit.

21. The method of claim 20, comprising cooling a second fluorocarbon refrigerant of the second fluorocarbon refrigeration system within the first fluorocarbon refrigeration system.

22. The method of claim 20, comprising cooling a nitrogen refrigerant of the nitrogen refrigeration system within the first fluorocarbon refrigeration system or the second fluorocarbon refrigeration system, or both.

23. The method of claim 20, wherein cooling the natural gas in the first fluorocarbon refrigeration system comprises:
compressing a first fluorocarbon refrigerant to provide a compressed first fluorocarbon refrigerant;
optionally cooling the compressed first fluorocarbon refrigerant by indirect heat exchange with a cooling fluid;
expanding the compressed first fluorocarbon refrigerant to cool the compressed first fluorocarbon refrigerant, thereby producing an expanded, cooled first fluorocarbon refrigerant;
passing said expanded, cooled first fluorocarbon refrigerant to a first heat exchange area;
optionally compressing the natural gas;
optionally cooling the natural gas by indirect heat exchange with an external cooling fluid; and
heat exchanging the natural gas with the expanded, cooled first fluorocarbon refrigerant.

24. The method of claim 20, wherein cooling the natural gas in the second fluorocarbon refrigeration system comprises:

compressing a second fluorocarbon refrigerant to provide a compressed second fluorocarbon refrigerant;

optionally cooling the compressed second fluorocarbon refrigerant by indirect heat exchange with a cooling fluid;

expanding the compressed second fluorocarbon refrigerant to cool the compressed second fluorocarbon refrigerant, thereby producing an expanded, cooled second fluorocarbon refrigerant;

passing said expanded, cooled second fluorocarbon refrigerant to a first heat exchange area;

optionally compressing the natural gas;

optionally cooling the natural gas by indirect heat exchange with an external cooling fluid; and

heat exchanging the natural gas with the expanded, cooled second fluorocarbon refrigerant.

25. The method of claim 20, comprising maintaining a nitrogen refrigerant of the nitrogen refrigeration system in a gas phase using one or more expansion turbines.

26. The method of claim 20, comprising chilling the natural gas in the first fluorocarbon refrigeration system or the second fluorocarbon refrigeration system, or both, using two or more refrigeration stages.

27. The method of claim 20, comprising liquefying the natural gas in the nitrogen refrigeration system using one or more refrigeration stages.

28. A hydrocarbon processing system for formation of a liquefied natural gas (LNG), comprising:

a first refrigeration system configured to cool a natural gas using a first fluorocarbon refrigerant, wherein the first refrigeration system comprises a plurality of first

heat exchangers configured to allow for cooling of the natural gas via an indirect exchange of heat between the natural gas and the first fluorocarbon refrigerant;

a second refrigeration system configured to chill the natural gas using a second fluorocarbon refrigerant, wherein the second refrigeration system comprises a plurality of second heat exchangers configured to allow for cooling of the natural gas via an indirect exchange of heat between the natural gas and the second fluorocarbon refrigerant;

a third refrigeration system configured to form LNG from the natural gas using a nitrogen refrigerant, wherein the third refrigeration system comprises a plurality of third heat exchangers configured to allow for cooling of the natural gas via an indirect exchange of heat between the natural gas and the nitrogen refrigerant; and

a nitrogen rejection unit configured to remove nitrogen from the LNG.

29. The hydrocarbon processing system of claim 28, wherein the nitrogen refrigerant is in a gas phase.

30. The hydrocarbon processing system of claim 28, wherein the plurality of first heat exchangers comprise evaporators configured to cool the natural gas by at least partially vaporizing the first fluorocarbon refrigerant via a transfer of heat from the natural gas to the first fluorocarbon refrigerant.

31. The hydrocarbon processing system of claim 28, wherein the plurality of second heat exchangers comprise evaporators configured to chill the natural gas by at least partially vaporizing the second fluorocarbon refrigerant via a transfer of heat from the natural gas to the second fluorocarbon refrigerant.

32. A hydrocarbon processing system for formation of a liquefied natural gas (LNG), comprising:

a first fluorocarbon refrigeration system configured to chill a natural gas using a first fluorocarbon refrigerant;

a second fluorocarbon refrigeration system configured to further chill the natural gas using a second fluorocarbon refrigerant; and

a methane autorefrigeration system configured to cool the natural gas to produce LNG.

33. The hydrocarbon processing system of claim 32, comprising a nitrogen rejection unit upstream of the methane autorefrigeration system, and wherein the methane autorefrigeration system comprises a plurality of expansion valves and a plurality of flash drums.

CLAIMS

What is claimed is:

1. A hydrocarbon processing system for formation of a liquefied natural gas (LNG), comprising:

a first fluorocarbon refrigeration system configured to chill a natural gas using a first fluorocarbon refrigerant;

a second fluorocarbon refrigeration system configured to further chill the natural gas using a second fluorocarbon refrigerant;

a nitrogen refrigeration system configured to cool the natural gas using a nitrogen refrigerant to produce LNG; and

a nitrogen rejection unit configured to remove nitrogen from the LNG.

2. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigeration system is configured to cool the second fluorocarbon refrigerant of the second fluorocarbon refrigeration system.

3. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigeration system or the second fluorocarbon refrigeration system, or both, is configured to cool the nitrogen refrigerant of the nitrogen refrigeration system.

4. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigeration system or the second fluorocarbon refrigeration system, or both, comprises multiple cooling cycles.

5. The hydrocarbon processing system of claim 1, wherein the nitrogen refrigeration system comprises a plurality of heat exchangers configured to allow for cooling of the natural gas via an indirect exchange of heat between the natural gas and the nitrogen refrigerant.

6. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigeration system comprises:

a compressor configured to compress the first fluorocarbon refrigerant to provide a compressed first fluorocarbon refrigerant;

a chiller configured to cool the compressed first fluorocarbon refrigerant by indirect heat exchange with a cooling fluid;

a valve configured to expand the compressed first fluorocarbon refrigerant to cool the compressed first fluorocarbon refrigerant, thereby producing a cooled first fluorocarbon refrigerant; and

a heat exchanger configured to cool the natural gas via indirect heat exchange with the cooled first fluorocarbon refrigerant.

7. The hydrocarbon processing system of claim 1, wherein the second fluorocarbon refrigeration system comprises:

a compressor configured to compress the second fluorocarbon refrigerant to provide a compressed second fluorocarbon refrigerant;

a chiller configured to cool the compressed second fluorocarbon refrigerant by indirect heat exchange with a cooling fluid;

a valve configured to expand the compressed second fluorocarbon refrigerant to cool the compressed second fluorocarbon refrigerant, thereby producing a cooled second fluorocarbon refrigerant; and

a heat exchanger configured to cool the natural gas via indirect heat exchange with the cooled second fluorocarbon refrigerant.

8. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigerant comprises R-410A.

9. The hydrocarbon processing system of claim 1, wherein the second fluorocarbon refrigerant comprises R-508B.

10. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigerant or the second fluorocarbon refrigerant, or both, comprises a nontoxic, nonflammable refrigerant.

11. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigeration system or the second fluorocarbon refrigeration system, or both, comprises two or more chillers and two or more compressors.

12. The hydrocarbon processing system of claim 1, wherein the first fluorocarbon refrigeration system and the second fluorocarbon refrigeration system are implemented in series.

13. The hydrocarbon processing system of claim 1, wherein the nitrogen refrigerant is in a gas phase.

14. The hydrocarbon processing system of claim 1, wherein the nitrogen refrigeration system comprises two or more chillers, two or more expanders, and two or more compressors.

15. A method for formation of a liquefied natural gas (LNG), comprising:
cooling a natural gas in a first fluorocarbon refrigeration system;
cooling the natural gas in a second fluorocarbon refrigeration system;
liquefying the natural gas to form LNG in a nitrogen refrigeration system; and
removing nitrogen from the LNG in a nitrogen rejection unit.

16. The method of claim 15, comprising cooling a second fluorocarbon refrigerant of the second fluorocarbon refrigeration system within the first fluorocarbon refrigeration system.

17. The method of claim 15, comprising cooling a nitrogen refrigerant of the nitrogen refrigeration system within the first fluorocarbon refrigeration system or the second fluorocarbon refrigeration system, or both.

18. The method of claim 15, wherein cooling the natural gas in the first fluorocarbon refrigeration system comprises:

compressing a first fluorocarbon refrigerant to provide a compressed first fluorocarbon refrigerant;

optionally cooling the compressed first fluorocarbon refrigerant by indirect heat exchange with a cooling fluid;

expanding the compressed first fluorocarbon refrigerant to cool the compressed first fluorocarbon refrigerant, thereby producing an expanded, cooled first fluorocarbon refrigerant;

passing said expanded, cooled first fluorocarbon refrigerant to a first heat exchange area;

optionally compressing the natural gas;

optionally cooling the natural gas by indirect heat exchange with an external cooling fluid; and

heat exchanging the natural gas with the expanded, cooled first fluorocarbon refrigerant.

19. The method of claim 15, wherein cooling the natural gas in the second fluorocarbon refrigeration system comprises:

compressing a second fluorocarbon refrigerant to provide a compressed second fluorocarbon refrigerant;

optionally cooling the compressed second fluorocarbon refrigerant by indirect heat exchange with a cooling fluid;

expanding the compressed second fluorocarbon refrigerant to cool the compressed second fluorocarbon refrigerant, thereby producing an expanded, cooled second fluorocarbon refrigerant;

passing said expanded, cooled second fluorocarbon refrigerant to a first heat exchange area;

optionally compressing the natural gas;

optionally cooling the natural gas by indirect heat exchange with an external cooling fluid; and

heat exchanging the natural gas with the expanded, cooled second fluorocarbon refrigerant.

20. The method of claim 15, comprising maintaining a nitrogen refrigerant of the nitrogen refrigeration system in a gas phase using one or more expansion turbines.

21. The method of claim 15, comprising chilling the natural gas in the first fluorocarbon refrigeration system or the second fluorocarbon refrigeration system, or both, using two or more refrigeration stages.

22. The method of claim 15, comprising liquefying the natural gas in the nitrogen refrigeration system using one or more refrigeration stages.