CLAIMS

1. A method of producing liquefied natural gas (LNG), the method comprising:

providing a natural gas stream from a supply of natural gas;

compressing the natural gas stream in at least two serially arranged compressors to a pressure of at least 2,000 psia to form a compressed natural gas stream;

cooling the compressed natural gas stream to form a cooled compressed natural gas stream, wherein cooling the compressed natural gas stream comprises cooling the compressed natural gas stream in at least one heat exchanger that exchanges heat with a natural environment;

expanding, in at least one work producing natural gas expander, the cooled compressed natural gas stream to a pressure that is less than 3000 psia and no greater than the pressure to which the at least two serially arranged compressors compress the natural gas stream, to thereby form a chilled natural gas stream;

liquefying the chilled natural gas stream in an open loop feed gas expander-based liquefaction module; and

combining a recycle refrigerant stream of the open loop feed gas expander-based liquefaction module with the natural gas stream prior to the natural gas stream being compressed by the at least two serially arranged compressors, wherein the chilled natural gas stream is a first chilled natural gas stream that is separated at a step into three separate streams comprising a second chilled natural gas stream, a first refrigerant stream, and a second refrigerant stream.

2. The method of claim 1, wherein liquefying the chilled natural gas stream is performed in one or more single mixed refrigerant (SMR) liquefaction trains.

3. The method of claim 1, wherein the chilled natural gas stream is a first chilled natural gas stream, and further comprising:

discharging a first cooling stream from a warm-end expander forming part of the feed gas expander-based liquefaction module, the first cooling stream having a first temperature; and

discharging a second cooling stream from a cold-end expander forming part of the feed gas expander-based liquefaction module, the second cooling stream having a second temperature;

wherein the first temperature is higher than the second temperature.

4. The method of claim 3, further comprising:

expanding the first refrigerant stream in the warm-end expander to produce the first cooling stream; and

expanding the second refrigerant stream in the cold-end expander to produce the second cooling stream.

5. The method of claim 1, further comprising:

discharging a first cooling stream from a warm-end expander forming part of the feed gas expander-based liquefaction module, the first cooling stream having a first temperature; discharging a two-phase stream from a cold-end expander forming part of the feed gas expander-based liquefaction module, the two-phase stream having a second temperature, wherein the first temperature is higher than the second temperature;

expanding the first refrigerant stream in the warm-end expander to produce the first cooling stream;

expanding the second refrigerant stream in the cold-end expander to produce the two-phase stream; and

separating the two-phase stream into a second cooling stream and a first pressurized LNG stream.

6. The method of any one of claims 3-5, wherein a pressure of the first cooling stream is one of: the same or similar to a pressure of the second cooling stream, or higher than a pressure of the second cooling stream.

7. The method of any one of claims 3-5, wherein the liquefying step comprises cooling the second chilled natural gas stream to form a second pressurized LNG stream by exchanging heat with the first cooling stream and the second cooling stream.

8. The method of claim 7, wherein the second pressurized LNG stream is mixed with the first pressurized LNG stream prior to expanding the second pressurized LNG stream.

9. The method of claim 7, further comprising:

reducing a pressure of the second pressurized LNG stream such that the second pressurized LNG stream undergoes at least one stage of pressure reduction;

separating the reduced-pressure second pressurized LNG stream into an end-flash gas stream and an LNG stream;

cooling the second pressurized LNG stream and the second chilled natural gas stream using the end-flash gas stream; and

compressing the end-flash gas stream and

mixing the compressed end-flash gas stream with one or more recycling refrigerant streams, or

using the compressed end-flash gas stream as fuel.

10. The method of any one of claims 1-9, wherein the at least two compressors compress the natural gas stream to a pressure greater than 3,000 psia.

11. The method of any one of claims 1-10, wherein the natural gas expander is a work producing expander that expands the cooled compressed natural gas stream to a pressure less than 2,000 psia.

12. The method of any one of claims 1-11, wherein the natural gas expander is mechanically coupled to at least one compressor.

13. The method of any one of claims 1-12, wherein one of the at least two serially arranged compressors is driven by the natural gas expander.

14. The method of any one of claims 1-13, further comprising:
performing the compressing, cooling, expanding, and liquefying steps on a topside of a floating LNG structure.

15. The method of claim 14, wherein the compressing, cooling, and expanding steps are performed within a single module on the topside of the floating LNG structure.

16. An apparatus for the liquefaction of natural gas, comprising:

at least two serially arranged compressors configured to compress a natural gas stream to a pressure greater than 2,000 psia, thereby forming a compressed natural gas stream;

a cooling element configured to cool the compressed natural gas stream, thereby forming a cooled compressed natural gas stream wherein the cooling element comprises a heat exchanger configured to cool the compressed natural gas stream by exchanging heat with a natural environment;

at least one work-producing expander configured to expand the cooled compressed natural gas stream to a pressure less than 3,000 psia and no greater than the pressure to which the at least two serially arranged compressors compress the natural gas stream, to thereby form a chilled natural gas stream; and

a liquefaction train configured to liquefy the chilled natural gas stream;

wherein the liquefaction train comprises an open loop feed gas expander-based liquefaction module, and further comprising a recycle refrigerant stream of the open loop feed gas expander-based process that is combined with the natural gas stream prior to the natural gas stream being compressed by the two or more serially-arranged compressors, wherein the chilled natural gas stream is a first chilled natural gas stream that is separated at a step into three separate streams comprising a second chilled natural gas stream, a first refrigerant stream, and a second refrigerant stream.

17. The apparatus of claim 16, wherein the feed gas expander-based liquefaction module comprises:

a warm-end expander configured to expand the first refrigerant stream to form a first cooling stream discharged therefrom, the first cooling stream having a first temperature; and

a cold-end expander configured to expand the second refrigerant stream to form one of a second cooling stream and a two-phase stream discharged therefrom, the second cooling stream having a second temperature;

wherein the first temperature is higher than the second temperature.

18. The apparatus of claim 16 or claim 17, wherein the natural gas expander is a work producing expander configured to expand the cooled compressed natural gas stream to a pressure less than 2,000 psia.

19. The apparatus of any one of claims 16-18, wherein the at least two serially arranged compressors, the cooling element, the at least one work-producing expander, and the liquefaction train are disposed on a floating LNG structure.

20. The apparatus of claim 19, wherein the at least two serially arranged compressors, the cooling element, and the at least one work-producing expander are disposed within a single module on a topside of the floating LNG structure.