CLAIMS

1. A method for start-up of a system for liquefying a feed gas stream comprising natural gas, the system having a feed gas compression and expansion loop, and a refrigerant system comprising a primary cooling loop and a sub-cooling loop, the method comprising:

(a) starting up the feed gas compression and expansion loop;

(b) pressurizing the refrigerant system;

(c) starting and establishing circulation in the primary cooling loop;

(d) starting and establishing circulation in the sub-cooling loop; and

(e) ramping up a flow rate of the feed gas stream and circulation rates of the primary cooling loop and the sub-cooling loop, wherein the primary cooling loop is connected to a separation vessel which condenses heavy hydrocarbon components from the compressed, additionally cooled refrigerant stream and produces a gaseous overhead refrigerant stream.

2. The method of claim 1, wherein step (a) comprises:

a1. providing the feed gas stream to be pressurized within the feed gas compression and expansion loop;

a2. starting a feed gas compressor with minimum speed and full recycle through its anti-surge valve, thereby generating a feed gas compressor suction pressure lower than, and a feed gas compressor discharge pressure higher than, a pressure of the feed gas stream in the feed gas compression and expansion loop;

a3. starting circulation of the feed gas stream downstream of the feed gas compressor to be cooled by indirect heat exchange;

a4. de-pressurizing and further cooling the compressed, cooled gas stream to produce a chilled gas stream;

a5. routing the chilled gas stream to a suction side of the feed gas compressor, and mixing the chilled gas stream with the feed gas stream, to thereby maintain suction side pressure targets of the feed gas compressor;

a6. gradually increasing the feed gas compressor discharge pressure;

a7. starting an expander in the feed gas compression and expansion loop when feed gas circulation rates reach a minimum flow required for expander operation; and

a8. establishing steady state circulation of the feed gas compression and expansion loop.

3. The method of claim 2, wherein the feed gas stream is cooled downstream of the feed gas compressor by indirect heat exchange with an ambient temperature air or water in an external cooling unit to form the compressed, cooled gas stream.

4. The method of claim 2, wherein the compressed, cooled gas stream is de-pressurized and further cooled in at least one work-producing expander to produce the chilled gas stream.

5. The method of claim 2, wherein step (b) comprises:

b1. pressurizing the sub-cooling loop to at most 90% of a lowest design pressure of the sub-cooling loop, and then closing a related circulation passage; and

b2. gradually pressurizing the primary cooling loop to a pressure of at most 90% of a lowest design pressure of the primary cooling loop, and then closing a related circulation passage, optionally wherein the primary cooling loop is gradually pressurized by feeding the chilled gas stream to a separation vessel connected to the primary cooling loop.

6. The method of claim 5, wherein step (c) comprises:

c1. starting a primary cooling loop compressor with minimum speed and full recycle through its respective anti-surge valve, thereby generating a primary cooling loop compressor suction pressure lower than, and a primary cooling loop compressor discharge pressure higher than, a pressure of the primary cooling loop;

c2. starting circulation in the primary loop downstream of the primary loop compressor, and cooling and expanding a compressed refrigerant stream, thereby forming the compressed, additionally cooled refrigerant stream;

c3. routing the compressed, additionally cooled refrigerant stream to the separation vessel to mix with a portion of the chilled gas stream, to maintain the primary cooling loop compressor suction pressure targets during start-up, wherein the separation vessel condenses heavy hydrocarbon components from the compressed, additionally cooled refrigerant stream and produces a gaseous overhead refrigerant stream;

c4. passing the gaseous overhead refrigerant stream through the first heat exchanger zone to cool the chilled gas stream by indirect heat exchange therewith, thereby forming a first warm refrigerant stream;

c5. directing the first warm refrigerant stream to a second heat exchanger zone where it exchanges heat with a compressed, cooled refrigerant stream to additionally cool the

compressed, cooled refrigerant stream, thereby forming a second warm refrigerant stream and a compressed, additionally cooled refrigerant stream;

c6. compressing the second warm refrigerant stream in the primary cooling loop compressor produce the compressed refrigerant stream;

c7. gradually increasing the primary cooling loop compressor discharge pressure, and repeating steps c1-c7 while adding chilled feed gas to the primary cooling loop through the separation vessel, to maintain suction pressure of the primary cooling loop compressor, thereby gradually increasing a circulation rate of the primary cooling loop;

c8. starting companders in the primary cooling loop when the circulation rate of the primary cooling loop reaches a minimum required flow for compander operation; and

c9. establishing steady state operation with only the primary cooling loop.

7. The method of claim 6, wherein cooling the compressed refrigerant stream is accomplished using a cooler that exchanges heat with an ambient environment.

8. The method of claim 6, wherein expanding the compressed refrigerant stream is accomplished using a work-producing expander.

9. The method of claim 6, wherein step (d) comprises:

d1. starting a sub-cooling loop compression unit with minimum speed and full recycle through anti-surge valve, generating a sub-cooling loop compression unit suction pressure lower than, and a sub-cooling loop compression unit discharge pressure higher than, a pressure in the sub-cooling loop;

d2. routing sub-cooling refrigerant in the sub-cooling refrigerant stream to the first heat exchange zone to warm at least part of a refrigerant circulating in the primary cooling loop, thereby forming a cooled sub-cooling refrigerant stream, wherein the sub-cooling refrigerant optionally comprises nitrogen;

d3. gradually permitting the cooled sub-cooling refrigerant stream to be de-pressurized and chilled, thereby forming an expanded chilled sub-cooling refrigerant stream;

d4. passing the expanded chilled sub-cooling refrigerant stream to the first heat exchanger zone to cool at least part of the chilled feed gas stream by indirect heat exchange, thereby forming a warm sub-cooling refrigerant stream;

d5. compressing the warm sub-cooling refrigerant stream in the sub-cooling loop compression unit to produce a re-compressed sub-cooling refrigerant stream;

d6. gradually increasing a discharge pressure of the sub-cooling loop compression unit;

d7. adding sub-cooling refrigerant to the sub-cooling loop to maintain the sub-cooling loop compression unit suction pressure targets during start-up;

d8. starting companders in the sub-cooling loop when a circulation rate of the sub-cooling loop reach a minimum required flow for compander operation; and

d9. establishing steady state operation of both the primary loop refrigerant and the sub-cooling loop refrigerant circulation rates at design pressures and turndown rate conditions.

10. A method for start-up of a system for liquefying a feed gas stream comprising natural gas, the system having a refrigerant system comprising a primary cooling loop and a sub-cooling loop, the method comprising:

(a) pressurizing the refrigerant system;

(b) starting and establishing circulation in the primary cooling loop;

(c) starting and establishing circulation in the sub-cooling loop; and

(d) ramping up a flow rate of the feed gas stream and circulation rates of the primary cooling loop and the sub-cooling loop, wherein the primary cooling loop is connected to a separation vessel which condenses heavy hydrocarbon components from the compressed, additionally cooled refrigerant stream and produces a gaseous overhead refrigerant stream.