CLAIMS

~~**What is claimed is:**~~

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 ~~gradually permitting~~ 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 ~~expansion and~~ 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 ~~expansion and~~ 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 ~~refrigerant~~ cooling loop to a pressure of at most 90% of a lowest design pressure of the primary ~~refrigerant~~ 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 the primary refrigerant loop is gradually pressurized by feeding the chilled gas stream to a separation vessel connected to the primary refrigerant loop.~~

~~7~~6. The method of claim ~~6~~5, wherein step (c) comprises:

c1. starting a primary cooling loop compressor with minimum speed and full recycle through its respective ~~ASV~~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 ~~gradually permitting~~ 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.

~~8~~7. The method of claim ~~7~~6, wherein cooling the compressed refrigerant stream is accomplished using a cooler that exchanges heat with an ambient environment.

~~9~~8. The method of claim ~~7~~6, wherein expanding the compressed refrigerant stream is accomplished using a work-producing expander.

~~10~~9. The method of claim ~~7~~6, wherein step (d) comprises:

d1. starting a sub-cooling loop compression unit with minimum speed and full recycle through ~~ASV~~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.

~~11. The method of claim 10, wherein the sub-cooling refrigerant comprises nitrogen.~~

~~12. The method of claim 10, wherein gradually permitting the cooled sub-cooling refrigerant stream to be de-pressurized and chilled is performed using an expander.~~

~~13. The method of claim 10, wherein step (e) comprises:~~

~~e1. gradually ramping up a rate of the feed gas stream and the circulation rates of the primary cooling loop and the sub-cooling loop to production flow rates.~~

~~14~~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.

~~15. The method of claim 14, wherein step (a) comprises:~~

~~a1. providing the feed gas stream at a pressure less than 1,200 psia;~~

~~a2. pressurizing a sub-cooling refrigerant in the sub-cooling loop to at most 90% of a lowest design pressure of the sub-cooling loop, then restricting or closing circulation through~~

the sub-cooling loop thereafter; and

a3. feeding the feed gas stream to the primary cooling loop, forming a primary loop refrigerant, until the primary cooling loop is pressurized to a pressure of at most 90% of a lowest design pressure of the primary cooling loop.

16. The method of claim 15, wherein the sub-cooling refrigerant comprises nitrogen.

17. The method of claim 15, wherein the sub-cooling refrigerant is pressurized using a sub-cooling loop compressor.

18. The method of claim 15, wherein step (b) comprises:

b1. starting a primary cooling loop compressor with a minimum speed and full recycle through ASV, 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;

b2. gradually permitting circulation in the primary cooling loop downstream of the primary cooling loop compressor to generate a compressed, cooled second gas stream, which is depressurized to generate the expanded, cooled second gas stream;

b3. separating the expanded, cooled second gas stream into a first expanded refrigerant stream and a chilled feed gas stream;

b4. depressurizing the first expanded refrigerant stream to produce a second expanded refrigerant stream;

b5. routing the second expanded refrigerant stream to at least one separator, thereby condensing heavy hydrocarbon components therefrom and producing a gaseous overhead refrigerant stream;

b6. passing the gaseous overhead refrigerant stream through a first heat exchanger zone to cool at least part of the chilled feed gas stream by indirect heat exchange, thereby forming a first warm refrigerant stream;

b7. passing the first warm refrigerant stream through a second heat exchanger zone to cool at least part of the compressed, cooled second gas stream, thereby forming a second warm refrigerant stream;

b8. compressing the second warm refrigerant stream in the primary cooling loop compressor to produce the refrigerant stream;

b9. gradually increasing the discharge pressure of the primary cooling loop compressor and continuing some or all of steps b2-b8 while increasing the feed gas stream to

maintain suction pressure of a feed compressor, thereby gradually increasing the circulation rate in the primary cooling loop;

b10. starting companders in the primary cooling loop when the circulation rate in the primary cooling loop reaches a minimum required flow for compander operation; and

b11. establishing steady state operation with only the primary loop refrigerant.

19. The method of claim 18, wherein forming the compressed, additionally cooled second gas stream further comprises:

exchanging heat with ambient water or ambient air in an external cooling unit, and

passing through a second heat exchanger zone to be additionally cooled.

20. The method of claim 18, further comprising:

accumulating the heavy hydrocarbon components in the separator; and

periodically discharging the heavy hydrocarbon components from the separator as a separator bottom stream, to thereby maintain a desired liquid level in the separator.

21. The method of claim 18, wherein step (c) comprises:

c1. starting the sub-cooling loop compression unit with minimum speed and full recycle through an associated ASV, thereby generating a sub-cooling loop compression unit suction pressure lower than, and a sub-cooling loop compression unit discharge pressure higher than, a pressure of the subcooling loop;

c2. routing the sub-cooling refrigerant stream to the first heat exchanger zone to warm at least part of a refrigerant circulating in the primary cooling loop, thereby forming a cooled sub-cooling refrigerant stream;

c3. gradually permitting the cooled sub-cooling refrigerant stream to be depressurized and chilled, thereby forming an expanded sub-cooling refrigerant stream;

c4. passing the expanded 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;

c5. compressing the warm sub-cooling refrigerant stream in the sub-cooling loop compression unit to produce the compressed sub-cooling loop refrigerant;

c6. gradually increasing the discharge pressure of the sub-cooling loop compression unit;

c7. adding sub-cooling coolant to the sub-cooling loop to maintain suction pressure targets of the sub-cooling loop compression unit during start-up;

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

c9. establishing steady state operation of the system, with the circulation rate of the primary loop refrigerant and the circulation rate of the sub-cooling loop refrigerant at a operating pressures and turndown rate conditions.

22. The method of claim 21, wherein step (d) comprises:

d1. gradually ramping up a feed gas rate and the circulation rates of the primary cooling loop and the sub-cooling loop to desired flow rates.