CLAIMS

1. A system for conditioning a sour gas feed stream for a cryogenic distillation tower, comprising:

a dehydration unit configured to separate the sour gas feed stream into a first stream comprising water and a feed stream; and

a sequential cooling assembly coupled to both the dehydration unit and the cryogenic distillation tower, wherein the sequential cooling assembly is connected by a cooled feed stream header to a cryogenic distillation tower feed inlet and comprises:

a first stage configured to separate the feed stream into a partially cooled feed stream and a second stream comprising acid gas;

a second stage configured to cool the partially cooled feed stream into a cooled feed stream and a third stream comprising acid gas;

a scrubber for removing moisture;

wherein the scrubber is configured to receive an acid-gas rich recycle stream, comprising

a stream from an outlet of a bottom section of the cryogenic distillation tower, or

a slip stream from an intermediate location in the distillation tower bottom section,

as part of an upset event recovery technique to recover from or eliminate an upset condition in which ice and/or hydrates have formed in the sequential cooling assembly;

wherein the first stage, the second stage, or both are configured to send at least one of the second and third streams to a bottom section of the cryogenic distillation tower.

2. The system of claim 1, wherein the scrubber is coupled to a stream outlet from the second stage.

3. The system of any one of claims 1-2, further comprising a heat exchanger between the cryogenic distillation tower bottom section outlet and the scrubber.

4. The system of any one of claims 1-3, wherein the temperature of the partially cooled feed stream is between about +10 °C to about -60 °C and the temperature of the cooled feed stream is between about -10 °C to about -60 °C.

5. The system of any one of claims 1-4, wherein the second stage is further configured to separate the partially cooled feed stream into a cooled feed stream and a third stream comprising water and acid gas, and wherein the second stage comprises a second separator coupled to a second cryogenic distillation tower bottom section inlet.

6. The system of any one of claims 1-5, wherein the cryogenic distillation tower comprises a controlled freeze zone section.

7. A method of sequentially cooling a sour gas feed stream for a cryogenic distillation tower, comprising:

receiving the sour gas feed stream;

separating the sour gas feed stream into a water stream and a partially dehydrated feed stream;

passing the partially dehydrated feed stream to a sequential cooling assembly;

cooling the partially dehydrated feed stream to a first temperature;

separating the partially dehydrated feed stream into a partially cooled feed stream comprising vapor and a first stream comprising liquid;

cooling the partially cooled feed stream to a second temperature;

separating the partially cooled feed stream into a cooled feed stream comprising vapor and a second stream comprising liquid;

feeding the cooled feed stream to the cryogenic distillation tower; and

mixing an acid-gas-rich liquid stream into a scrubber of the sequential cooling assembly, the scrubber for removing moisture, wherein the acid-gas-rich liquid stream originates at least in part from a bottom section of the cryogenic distillation tower;

wherein the mixing step is part of an upset recovery technique, further comprising temporarily employing the upset recovery technique to recover from or eliminate an upset condition in which ice and/or hydrates have formed in the sequential cooling assembly.

8. The method of claim 7, wherein the first stream comprises carbon dioxide.

9. The method of claim 7 or 8, further comprising cooling the cooled feed stream to a third temperature prior to feeding the cooled feed stream to the cryogenic distillation tower.

10. The method of any one of claims 7-9, wherein the first stream, the second stream, or both are sent to a bottom section of the cryogenic distillation tower.

11. A cryogenic distillation system, comprising:

a progressive conditioning section for a sour gas feed stream, comprising:

a first stage assembly configured to separate the sour gas feed stream into a first stream comprising water and a partially dehydrated feed stream;

a second stage assembly coupled to the first stage assembly and configured to separate the partially dehydrated feed stream into a progressively dehydrated feed stream comprising a hydrocarbon and a second stream comprising an acid gas, and further configured to cool the progressively dehydrated feed stream to a first temperature, wherein the second stage assembly includes a scrubber for removing moisture, and wherein the scrubber is configured to receive an acid-gas-rich recycle stream as part of an upset recovery technique that is temporarily employed to recover from or eliminate an upset condition in which ice and/or hydrates have formed in the progressive conditioning section; and

a third stage assembly coupled to the second stage assembly and further configured to cool the progressively dehydrated feed stream to a second temperature, wherein the second temperature is colder than the first temperature; and

a cryogenic distillation tower comprising a controlled freeze zone, wherein the cryogenic distillation tower is configured to receive the progressively dehydrated feed stream;

wherein the acid-gas-rich recycle stream originates from a bottom section of the cryogenic distillation tower.

12. The system of claim 11, wherein the third stage assembly is further configured to split the progressively dehydrated feed stream into a cooled feed stream comprising a hydrocarbon and a third stream comprising an acid gas, and wherein the second stage assembly, the third stage assembly, or both are coupled to a bottom section of the cryogenic distillation tower.

13. The system of claim 11 or 12, further comprising a fourth stage assembly configured to cool the cooled feed stream to a third temperature, wherein the third temperature is colder than the second temperature.