CLAIMS

What is claimed is:

1. A system for removing acid gases from a raw gas stream, comprising:

a cryogenic distillation tower, the tower having a controlled freezing zone that receives a cold liquid spray comprised primarily of methane, the tower receiving and then separating the raw gas stream into an overhead methane gas stream and a substantially solid material comprised of precipitated carbon dioxide;

refrigeration equipment downstream of the cryogenic distillation tower for cooling the overhead methane stream and returning a portion of the overhead methane stream to the cryogenic distillation tower as the cold liquid spray;

a collector tray below the controlled freezing zone for receiving the substantially solid material as it is precipitated in the controlled freezing zone and directing the substantially solid material out of the cryogenic distillation tower;

a first filter for receiving the substantially solid material and separating the substantially solid material into a solid component comprised primarily of carbon dioxide, and a non-solid material comprising methane; and

a liquid return line for returning at least a portion of the non-solid material to the cryogenic distillation tower.

2. The system of claim 1, wherein the collector tray comprises a downcomer into which the precipitated substantially solid material falls.

3. The system of claim 1, wherein the collector tray directs the substantially solid material out of the cryogenic distillation tower (i) by gravitational flow, (ii) by operation of a mechanical translation device, (iii) by aid of spraying a portion of the cold liquid spray into the collector tray and against the substantially solid material, or (iv) by combinations thereof.

4. The system of claim 3, wherein:

the collector tray comprises a downcomer into which the precipitated substantially solid material falls;

the mechanical translation device is an auger; and

the auger is disposed within the downcomer.

5. The system of claim 1, wherein:

the cryogenic distillation tower further comprises an upper rectification zone above the controlled freezing zone, and a lower distillation zone below the controlled freezing zone; and

the cryogenic distillation tower is configured to receive the raw gas stream into the lower distillation zone.

6. The system of claim 5, wherein:

the cryogenic distillation tower is configured to release a bottoms stream from the lower distillation zone, the bottoms stream comprising acid gases in liquid phase; and

the liquid return line returns at least a portion of the first liquid material to the lower distillation zone.

7. The system of claim 6, wherein the bottoms feed stream comprises carbon dioxide, ethane, propane, butane, hydrogen sulfide, aromatic hydrocarbons, or combinations thereof, in substantially liquid phase.

8. The system of claim 6, wherein the first filter comprises (i) a porous medium, (ii) one or more filter presses, (iii) one or more belt presses, (iv) a hydrocyclone, (v) a centrifugal separator, or (vi) combinations thereof.

9. The system of claim 6, wherein the collector tray is operated at a temperature of about -70° F to -80° F.

10. The system of claim 8, wherein:

the solid component from the first filter is a first filter cake; and

the liquid material from the first filter is a first filtrate.

11. The system of claim 10, further comprising:

a rinsing vessel for rinsing the first filter cake using a cold carbon dioxide stream, and producing a first solid-liquid slurry.

12. The system of claim 11, wherein the rinsing vessel comprises a mixer for mixing the first filter cake so as to produce the first solid-liquid slurry

13. The system of claim 11, further comprising:

a second filter comprising a porous medium, the second filter receiving the first solid-liquid slurry and producing a second filter cake comprised primarily of solid carbon dioxide, and a second filtrate comprising methane, in liquid phase.

14. The system of claim 13, wherein the system is configured to combine the first filtrate and the second filtrate, and return the combined first filtrate and second filtrate to the lower distillation zone as the liquid material.

15. The system of claim 14, wherein the first filtrate further comprises methane, carbon dioxide, hydrogen sulfide, or combinations thereof.

16. The system of claim 11, further comprising:

a heat exchanger configured to warm substantially solid material taken primarily from a final-stage filter cake to produce a substantially pure carbon dioxide stream, in liquid phase; and

wherein the cold carbon dioxide stream comprises a portion of the substantially pure carbon dioxide stream.

17. The system of claim 16, wherein the final-stage filter cake is produced after the first filter in a second filter or a third filter.

18. The system of claim 5,

wherein the raw gas stream comprises hydrogen sulfide; and

the system further comprises a hydrogen sulfide removal system configured to remove a substantial portion of the hydrogen sulfide from the raw gas stream before the raw gas stream is injected into the cryogenic distillation tower.

19. The system of claim 1, wherein:

the cryogenic distillation tower further comprises an upper rectification zone above the controlled freezing zone; and

the cryogenic distillation tower is configured to receive the raw gas stream into the controlled freezing zone.

20. The system of claim 19, wherein the first filter comprises a porous medium, one or more filter presses, one or more belt presses, a hydrocyclone, a centrifugal separator, or combinations thereof.

21. The system of claim 19, wherein the collector tray is operated at a temperature of about -70° F to -80° F.

22. The system of claim 19, wherein:

the solid material from the first filter is a first filter cake; and

the liquid material from the first filter is a first filtrate.

23. The system of claim 22, further comprising:

a rinsing vessel for rinsing the first filter cake using a cold carbon dioxide stream, and producing a first solid-liquids slurry.

24. The system of claim 23, wherein the rinsing vessel comprises a mixer for mixing the first filter cake so as to produce the first solid-liquid slurry

25. The system of claim 24, further comprising:

a second filter comprising a porous medium, the second filter receiving the first solids-liquid slurry and producing a second filter cake comprised primarily of solid carbon dioxide, and a second filtrate comprising methane and carbon dioxide, in liquid phase.

26. The system of claim 25, wherein:

the liquid return line merges at least a portion of the second liquid material with the raw gas stream before the raw gas stream is injected into the cryogenic distillation tower.

27. The system of claim 26,

further comprising a distillation separator configured to receive the second filtrate and to produce a bottoms liquid stream comprising carbon dioxide, H_2S, or combinations thereof in liquid phase, and a recovery methane stream; and

wherein the recovery methane stream is combined with the overhead methane stream.

28. The system of claim 27, wherein the first filtrate and the bottoms liquid stream each further comprise hydrogen sulfide.

29. The system of claim 25, further comprising:

a heat exchanger configured to warm substantially solid material taken primarily from a final-stage filter cake to produce a substantially pure carbon dioxide stream, in liquid phase; and

wherein the cold carbon dioxide stream comprises a portion of the substantially pure carbon dioxide stream.

30. The system of claim 29, wherein the final-stage filter cake is produced in the second filter or a third filter.

~~31~~. A method for removing acid gases from a dehydrated raw gas stream, comprising:

providing a cryogenic distillation tower, the tower having a controlled freezing zone that receives a cold liquid spray comprised primarily of methane, and a collector tray below the controlled freezing zone;

injecting the raw gas stream into the cryogenic distillation tower;

chilling the raw gas stream so as to cause carbon dioxide within the raw gas stream to precipitate upon the collector tray as substantially solid material, while allowing methane to substantially vaporize and exit the cryogenic distillation tower as an overhead methane stream;

passing the overhead methane stream through a refrigeration system downstream of the cryogenic distillation tower, the refrigeration system cooling the overhead methane stream;

returning a portion of the cooled overhead methane stream to the cryogenic distillation tower as liquid reflux to serve as the cold liquid spray;

removing the substantially solid material from the cryogenic distillation tower as a slurry;

separating the substantially solid material into a solid material comprised primarily of carbon dioxide, and a liquid material comprising methane; and

returning at least a portion of the liquid material to the cryogenic distillation tower; ~~.~~

32. The method of claim 31, wherein:

the collector tray comprises a downcomer into which the precipitated substantially solid material falls, and a mechanical translation device within the downcomer; and

removing the substantially solid material from the cryogenic distillation tower comprises operating the mechanical translation device to move the substantially solid material from the downcomer out of the cryogenic distillation tower.

33. The method of claim 31, wherein:

the collector tray comprises a downcomer into which the precipitated substantially solid material falls; and

the collector tray directs the substantially solid material out of the cryogenic distillation tower (i) by gravitational flow, (ii) by operation of a mechanical translation device, (iii) by aid of spraying a portion of the cold liquid spray into the collector tray and against the substantially solid material, or (iv) by combinations thereof.

34. The method of claim 31, wherein:

the cryogenic distillation tower further comprises an upper rectification zone above the intermediate controlled freezing zone, and a lower distillation zone below the intermediate controlled freezing zone; and

the raw gas stream is injected into the lower distillation zone.

35. The method of claim 34,

further comprising releasing a bottoms stream from the lower distillation zone, the bottoms stream comprising acid gases in liquid phase; and

wherein returning at least a portion of the liquid material to the cryogenic distillation tower comprises delivering the liquid material to the lower distillation zone.

36. The method of claim 35, wherein the bottoms stream comprises ethane, propane, butane, hydrogen sulfide, carbon dioxide, or combinations thereof, in substantially liquid phase.

37. The method of claim 34, wherein separating the substantially solid material into a solid component comprised primarily of carbon dioxide, and a liquid material comprised primarily of methane, comprises passing the substantially solid material through a first filter, thereby producing a first filter cake comprised primarily of solid carbon dioxide, and a first filtrate comprising methane and carbon dioxide, in liquid phase.

38. The method of claim 37, wherein the separating further comprises:

rinsing the first filter cake using a cold carbon dioxide stream;

mixing the first filter cake to produce a first solid-liquid slurry; and

delivering the first solid-liquid slurry to a second filter, thereby producing a second filter cake comprised primarily of solid carbon dioxide, and a second filtrate comprising methane, in liquid phase.

39. The method of claim 38,

further comprising combining the first filtrate and the second filtrate; and

wherein the second liquid material that is returned to the lower distillation zone comprises the combined first filtrate and second filtrate.

40. The method of claim 39, further comprising:

rinsing the second filter cake using the cold carbon dioxide stream;

mixing the second filter cake to produce a solid-liquid slurry; and

delivering the solid-liquid slurry to a third filter, thereby producing a third filter cake comprised primarily of solid carbon dioxide, and a third filtrate comprising methane, in liquid phase.

41. The method of claim 37, further comprising:

warming substantially solid material taken primarily from a final-stage filter cake to produce a substantially pure carbon dioxide stream, in liquid phase; and

wherein the cold carbon dioxide stream comprises a portion of the substantially pure carbon dioxide stream.

42. The method of claim 41, wherein the warming comprises passing the substantially solid material taken primarily from the final-stage filter cake through a heat exchanger such that heat is exchanged with the raw gas stream.

43. The method of claim 37, wherein the first filter comprises a porous medium or a centrifuge.

44. The method of claim 37,

wherein the dehydrated raw gas stream comprises hydrogen sulfide; and

the method further comprises removing a substantial portion of the hydrogen sulfide from the raw gas stream prior to injecting the raw gas stream into the cryogenic distillation tower.

45. The method of claim 31, wherein:

the cryogenic distillation tower further comprises an upper rectification zone above the intermediate controlled freezing zone; and

the raw gas stream is injected into the controlled freezing zone.

46. The method of claim 45, wherein separating the substantially solid material into a first solid material comprised primarily of carbon dioxide, and a second liquid material comprised primarily of methane, comprises passing the substantially solid material through a first filter, thereby producing a first filter cake comprised primarily of solid carbon dioxide, and a first filtrate comprising methane and carbon dioxide, in liquid phase.

47. The method of claim 46, wherein:

returning at least a portion of the second liquid material to the cryogenic distillation tower comprises (i) injecting the first filtrate directly back into the controlled freezing zone, or (ii) merging the first filtrate with the raw gas stream before the raw gas stream is injected into the cryogenic distillation tower.

48. The method of claim 45, wherein the separating further comprises:

rinsing the first filter cake using a cold carbon dioxide stream;

mixing the first filter cake to produce a first solid-liquids slurry; and

delivering the first solids-liquid slurry to a second filter, thereby producing a second filter cake comprised primarily of solid carbon dioxide, and a second filtrate comprising methane, carbon dioxide and hydrogen sulfide, in liquid phase.

49. The method of claim 48, further comprising:

rinsing the second filter cake using the cold carbon dioxide stream;

mixing the second filter cake to produce a solid-liquids slurry; and

delivering the solids-liquid slurry to a third filter, thereby producing a third filter cake comprised primarily of solid carbon dioxide, and a third filtrate comprising methane, carbon dioxide and hydrogen sulfide, in liquid phase.

50. The method of claim 49, further comprising:

combining the second filtrate and the third filtrate;

injecting the second filtrate and the third filtrate into a distillation separator, thereby producing a bottoms liquid stream comprised primarily of carbon dioxide, in liquid phase, and a recovery methane stream; and

combining the overhead methane stream from the cryogenic distillation tower with the recovery methane stream.

51. The method of claim 46, further comprising:

warming substantially solid material taken primarily from a final-stage filter cake to produce a substantially pure carbon dioxide stream, in liquid phase; and

wherein the cold carbon dioxide stream comprises a portion of the substantially pure carbon dioxide stream.

52. The method of claim 51, wherein the warming comprises passing the substantially solid material taken primarily from the final-stage filter cake through a heat exchanger such that heat is exchanged with the raw gas stream.

~~53. The method of claim 46,~~ wherein the first filter comprises a porous media or a centrifuge.