CLAIMS

What is claimed is:

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

an acid gas removal system for receiving the sour gas stream, wherein the acid gas removal system utilizes a cryogenic distillation tower that separates the sour gas stream into an overhead gas stream comprised primarily of methane, and a liquefied bottom acid gas stream comprised primarily of carbon dioxide; and

a sulfurous components removal system upstream of the acid gas removal system, wherein the sulfurous components removal system receives a raw gas stream and generally separates the raw gas stream into a hydrogen sulfide stream and the sour gas stream.

2. The system of claim 1, wherein the raw gas stream contains between about 4 ppm and 100 ppm sulfurous components.

3. The system of claim 2, wherein the cryogenic acid gas removal system further comprises a heat exchanger for chilling the sour gas stream before entry into the cryogenic distillation tower.

4. The system of claim 3, wherein:

the cryogenic distillation tower comprises a lower distillation zone and an intermediate controlled freezing zone that receives a cold liquid spray comprised primarily of methane, the tower receiving and then separating the sour gas stream into an overhead methane stream and the bottom acid gas stream; and

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 spray.

5. The system of claim 2, wherein the acid gas removal system is a bulk fractionation system.

6. The system of claim 2, wherein the sulfurous components removal system comprises a chemical solvent system.

7. The system of claim 6, wherein the chemical solvent comprises methyl diethanol amine (MDEA), a selective amine from a Flexsorb® family of solvents, or combinations thereof.

8. The system of claim 6, wherein the chemical solvent system utilizes a plurality of co-current contactors.

9. The system of claim 8, wherein the co-current contactors of the chemical solvent system comprise:

a first co-current contactor configured to receive (i) the raw gas stream and (ii) a second liquid solvent, the first co-current contactor also being configured to release (iii) a first partially-sweetened gas stream comprised primarily of methane and (iv) a first partially-loaded gas-treating solution;

a second co-current contactor configured to receive (i) the first partially-sweetened gas stream and (ii) a third liquid solvent, and is configured to release (iii) a second partially-sweetened gas stream and (iv) a second partially-loaded gas-treating solution; and

a final co-current contactor configured to receive (i) a previous partially-sweetened gas stream, and (ii) a regenerated liquid solvent, and configured to release (iii) a final sweetened gas stream comprised primarily of methane, and (iv) a final lightly-loaded gas-treating solution;

wherein:

the hydrogen sulfide stream is comprised at least in part of the first partially-loaded gas-treating solution and the second partially-loaded gas-treating solution; and

the regenerated liquid solvent is comprised at least in part of a regenerated solvent stream whereby the hydrogen sulfide has been substantially removed from at least the first partially-loaded gas-treating solution and the second partially-loaded gas-treating solution.

10. The chemical solvent system of claim 9, further comprising:

a liquid solvent regenerator configured to receive at least the first partially-loaded gas-treating solution, and to produce the regenerated liquid solvent.

11. The gas processing facility of claim 9, wherein:

the liquid solvent and the regenerated liquid solvent comprise a hindered amine, a tertiary amine, or combinations thereof.

12. The system of claim 8, wherein the co-current contactors of the chemical solvent system comprise:

a first co-current contactor, a second co-current contactor and a final co-current contactor, each of these co-current contactors being configured (i) to receive the raw gas stream and a liquid solvent, and (ii) to release a sweetened gas stream and a separate loaded gas-treating solution;

the first co-current contactor, the second co-current contactor and the final co-current contactor being configured to deliver the respective sweetened gas streams as progressively sweetened gas streams in series; and

the final co-current contactor, the second co-current contactor and the first co-current contactor being arranged to deliver the respective gas-treating solutions as progressively richer gas-treating solutions in series.

13. The method of claim 12, wherein:

the first co-current contactor receives (i) the initial gas stream and a (ii) second liquid solvent, and releases (iii) a first partially-sweetened gas stream and (iv) a first partially-loaded gas-treating solution;

the second co-current contactor receives (i) the first partially-sweetened gas stream from the first co-current contactor and (ii) a third liquid solvent, and releases (iii) a second partially-sweetened gas stream and (iv) a second partially-loaded gas-treating solution, and

the final co-current contactor receives (i) a previous partially-sweetened gas stream and (ii) a regenerated liquid solvent, and releases (iii) a final sweetened gas stream and (iv) a final lightly-loaded gas-treating solution.

14. The system of claim 2, wherein the sulfurous components removal system comprises a physical solvent system that utilizes a physical solvent.

15. The system of claim 14, wherein the physical solvent comprises N-methyl pyrollidone, propylene carbonate, methyl cyanoacetate, refrigerated methanol, tetramethylene sulfone, Selexol™, or combinations thereof.

16. The system of claim 14, wherein the physical solvent system comprises:

an absorber for receiving the raw gas stream and separating the raw gas stream into the sour gas stream and the hydrogen sulfide stream, the hydrogen sulfide stream comprising hydrogen sulfide and a liquid physical solvent;

at least two separators for processing the hydrogen sulfide stream so as to separate hydrogen sulfide from physical solvent; and

a regenerator for regenerating the physical solvent and returning at least a part of the physical solvent to the absorber.

17. The system of claim 2, wherein:

the sulfurous components removal system comprises at least one solid adsorbent bed for substantially adsorbing sulfurous components, the sulfurous components being released as the hydrogen sulfide stream when the at least one solid adsorbent bed is regenerated; and

the at least one solid adsorbent bed substantially passes methane and CO_2 as the sour gas stream.

18. The system of claim 17, wherein the solid adsorbent bed (i) is fabricated from a zeolite material, or (ii) comprises at least one molecular sieve.

19. The system of claim 18, wherein the sulfurous components removal system further comprises a separator for separating carbon dioxide from sulfurous components in the hydrogen sulfide stream.

20. The system of claim 17, wherein the regeneration is part of a pressure-swing adsorption process.

21. The system of claim 20, wherein the at least one solid adsorbent bed comprises at least three adsorbent beds, with:

a first of the at least three adsorbent beds being in service for adsorbing hydrogen sulfide;

a second of the at least three adsorbent beds undergoes regeneration; and

a third of the at least three adsorbent beds is held in reserve to replace the first of the at least three adsorbent beds.

22. The system of claim 21, wherein the sulfurous components removal system further comprises a vacuum for applying negative relative pressure to the first of the at least three adsorbent beds to aid in desorbing hydrogen sulfide from the first of the at least three adsorbent beds before the hydrogen sulfide stream enters the separator.

23. The system of claim 17, wherein the regeneration is part of a thermal-swing adsorption process.

24. The system of claim 23, wherein the at least one solid adsorbent bed comprises at least three adsorbent beds, with:

a first of the at least three adsorbent beds being in service for adsorbing hydrogen sulfide;

a second of the at least three adsorbent beds undergoes regeneration; and

a third of the at least three adsorbent beds is held in reserve to replace the first of the at least three adsorbent beds.

25. The system of claim 24, wherein:

the sulfurous components removal system further comprises a regeneration gas heater for (i) receiving a regenerating gas, (ii) heating the regenerated gas, and (iii) desorbing hydrogen sulfide from the second adsorbent bed by applying heat from the heated regenerated gas to the second adsorbent bed;

the regeneration gas heater releases a gas stream to the first solid adsorbent bed for separation of the gas stream into the hydrogen sulfide stream and the sour gas stream; and

the sulfurous components removal system further comprises a separator for separating out any methane from the hydrogen sulfide stream.

26. The system of claim 25, wherein the sulfurous components removal system further comprises a cooler for receiving the hydrogen sulfide stream and chilling the hydrogen sulfide fluid stream before it enters the separator.

27. The system of claim 2, wherein:

the sulfurous components removal system comprises at least one solid adsorbent bed for substantially adsorbing hydrogen sulfide, the hydrogen sulfide being released as the hydrogen sulfide stream when the at least one solid adsorbent bed is regenerated; and

the at least one solid adsorbent bed substantially passes methane and carbon dioxide as the sour gas stream.

28. The system of claim 27, wherein the at least one solid adsorbent bed is an adsorptive kinetic separations bed.

29. The system of claim 2, wherein the sulfurous components removal system comprises a redox system.

30. The system of claim 29, wherein the redox system comprises:

a contactor for receiving the raw gas stream and a chelated oxidized metal, the chelated oxidized metal mixing with the raw gas stream so as to cause a reduction-oxidation reaction and to release (i) a bottom aqueous solution comprising a chelated reduced metal and elemental sulfur, and (ii) an overhead gas stream comprised of methane and carbon dioxide;

an oxidizer for receiving the bottom aqueous solution along with air, and providing a chamber for an oxidation reaction, the oxidizer releasing an aqueous chelated metal mixture with elemental sulfur;

a separator for receiving the aqueous chelated metal mixture with elemental sulfur, and separating the aqueous chelated metal mixture with elemental sulfur into a regenerated chelated metal catalyst solution and elemental sulfur; and

a line for directing at least a portion of the regenerated chelated metal catalyst solution back into the contactor.

31. The system of claim 2, wherein the sulfurous components removal system comprises a scavenger system.

32. The system of claim 31, wherein the scavenger system comprises:

a line wherein a liquid scavenging agent is mixed with the raw gas stream;

a separating vessel for separating the raw gas stream into the sour gas stream and a spent scavenger stream, the spent scavenger stream comprising hydrogen sulfide and the liquid scavenging agent.

33. The system of claim 2, wherein the overhead gas stream comprises not only methane, but also helium, nitrogen, or combinations thereof.

34. The system of claim 2, wherein the sulfurous components removal system comprises a system for implementing a CrystaSulf process.

35. The system of claim 34, wherein the sulfurous components removal system further comprises:

an absorber for receiving (i) the sour gas stream and (ii) an oxidizing gas as a scrubbing liquor, the oxidizing gas mixing with the raw gas stream so as to cause a chemical reaction such that the absorber (i) releases the sour gas stream and (ii) releases a sorbent comprised of water, hydrogen sulfide and the oxidizing gas;

a flask for separating the liquid sorbent into (i) an overhead vapor stream comprised primarily of hydrocarbon gases and any entrained water vapor, and (ii) a sulfur solution;

a separating vessel for separating water from the hydrocarbon gases and delivering the hydrocarbon gases back to the raw gas stream;

a crystallizer for receiving the sulfur solution, the crystallizer seeding the sulfur solution with sulfur crystals in a settling zone to effect precipitation of dissolved sulfur, the crystallizer (i) releasing a sulfur slurry from a lower portion of the crystallizer, and (ii) directing a liquor from an upper portion of the crystallizer as the oxidizing gas, with a portion of the liquor being directed back to the absorber; and

a filter for separating the sulfur slurry into pure solid sulfur and a clear liquor, the clear liquor being directed back to the crystallizer.

36. The system of claim 2, further comprising:

a dehydration apparatus for receiving the raw gas stream before it passes through the sulfurous components removal system, and separating the raw gas stream into a dehydrated raw gas stream and a stream comprised substantially of an aqueous fluid; and

wherein the raw gas stream received by the sulfurous components removal system is the dehydrated raw gas stream.

37. A system for removing acid gases from a sour gas stream, comprising:

an acid gas removal system for receiving the sour gas stream, the sour gas stream comprising less than about 10% sulfurous components, wherein the acid gas removal system utilizes a cryogenic distillation tower that separates the sour gas stream into an overhead gas stream comprised primarily of methane, and a liquid bottom acid gas stream comprised primarily of carbon dioxide and sulfurous components; and

a sulfurous components removal system downstream of the acid gas removal system, wherein the sulfurous components removal system receives the bottom acid gas stream and generally separates the bottom acid gas stream into a carbon dioxide fluid stream and a hydrogen sulfide stream.

38. The system of claim 37, wherein the acid gas removal system further comprises a heat exchanger for chilling the sour gas stream before entry into the distillation tower.

39. The system of claim 38, wherein the cryogenic distillation tower comprises:

a lower distillation zone and an intermediate controlled freezing zone that receives a cold liquid spray comprised primarily of methane, the tower receiving and then separating the sour gas stream into an overhead methane stream and a bottom liquefied acid gas stream; and

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 liquid reflux.

40. The system of claim 37, wherein the sulfurous components removal system comprises:

at least one solid adsorbent bed for substantially adsorbing hydrogen sulfide from the bottom acid gas stream, the hydrogen sulfide being released as the hydrogen sulfide stream when the at least one solid adsorbent bed is regenerated; and

the at least one solid adsorbent bed substantially passes acid gases comprising carbon dioxide as the carbon dioxide fluid stream.

41. The system of claim 40, wherein the at least one solid adsorbent bed comprises at least one adsorptive kinetic separations bed.

42. The system of claim 37, wherein the sulfurous components removal system comprises an extractive distillation system having at least two extractive distillation columns.

43. The system of claim 42, wherein the extractive distillation system comprises:

a first extractive distillation column that serves as a propane recovery column, the propane recovery column mixing a solvent with the acid gas stream to absorb acid gases, causing the solvent to leave the column as a solvent bottoms stream while separately releasing the carbon dioxide stream;

a second extractive distillation column that serves as a CO_2 removal column, the CO_2 removal column causing solvent and heavy hydrocarbons to leave the acid gas removal column as a second solvent bottoms stream while separately releasing the CO_2; and

a third extractive distillation column that serves as an additive recovery column, the additive recovery column using distillative principles to separate heavy hydrocarbon components, known as "natural gas liquids," from solvent such that a bottom solvent stream is released as a regenerated additive, while natural gas liquids separately exit the column overhead.

44. The system of claim 37 wherein the sour gas stream comprises less than about 1% sulfurous components.

45. The system of claim 37 wherein the sour gas stream comprises between about 4 ppm and 100 ppm sulfurous components.

What is claimed is:

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

an acid gas removal system for receiving the sour gas stream, wherein the acid gas removal system utiltizes a cryogenic distillation tower that separates the sour gas stream into an overhead gas stream comprised primarily of methane, and a liquefied bottom acid gas stream comprised primarily of carbon dioxide; and

a sulfurous components removal system upstream of the acid gas removal system comprising a physical solvent system that utilizes a physical solvent, wherein the sulfurous components removal system receives a raw gas stream and generally separates the raw gas stream into hydrogen sulfide stream and the sour gas stream;

wherein the raw gas stream contains between about 4 ppm and 100 ppm sulfurous components; and

wherein the physical solvent comprises N-methyl pyrollidone, propylene carbonate, methyl cyanoacetate, refrigerated methanol, tetramethylene sulfone, Selexol ^{TM} , or combinations thereof.