CLAIMS

We claim:

1. A method for removing a solidifiable gas component from a process gas stream, the method comprising:

(a) contacting a process gas stream containing a solidifiable gas component with a cold liquid at a contacting temperature and a contacting pressure to form a liquid-solid slurry containing the cold liquid and solids formed by solidifying the solidifiable gas at least a portion of the solidfiable component in the process gas stream;

wherein:

the contacting further forms a treated gas stream containing a portion of the process gas stream that was not solidified by the contacting with the cold liquid;

the cold liquid is at a temperature at which the solidifiable gas component within the process gas stream will transition to a solid phase;

the cold liquid has a different composition than the solidifiable gas component; and

the process gas stream includes at least one gas component that remains in a gas phase at the contacting temperature and the contacting pressure; and

(b) removing at least a portion of the solids from the slurry

2. The method of claim 1, wherein the solidifiable gas component is selected from the group consisting of carbon dioxide, hydrogen sulfide, sulfur dioxide, or carbonyl sulfide.

3. The method of claim 1, wherein the solidifiable gas component is carbon dioxide.

4. The method of claim 1, wherein the process gas stream contains a plurality of solidifiable gas components.

5. The method of claim 1, wherein the process gas stream includes water at a concentration equal to a water saturation at a temperature above the freezing point of water.

6. The method of claim 5, wherein the method includes removing at least a portion of the water from the process gas stream prior to the contacting.

7. The method of claim 1, wherein the process gas stream includes an exhaust stream from a combustion process.

8. The method of claim 1, wherein the cold liquid has a temperature that is below the temperature at which solid carbon dioxide will precipitate from the process gas stream.

9. The method claim 1, wherein the cold liquid has a solidifiable gas component solubility of less than 10 mol% at the contacting pressure and the contacting temperature.

10. The method of claim 1, wherein the cold liquid has a different composition than the process gas stream.

11. The method of claim 1, wherein the cold liquid is a liquid at a temperature of 20° C and a pressure of 1 atmosphere, and further wherein the cold liquid has a freezing point of less than -100° C.

12. The method of claim 1, wherein the cold liquid comprises an isoalkane, an isoalkene, an alcohol, or combinations thereof.

13. The method of claim 1, wherein the cold liquid comprises a mixture of two or more components.

14. The method of claim 12, wherein the cold liquid comprises an isohexane, an isohexene, or combination thereof.

15. The method of claim 1, wherein the cold liquid comprises an ethanol, a methanol, or combinations thereof.

16. The method of claim 1, wherein the contacting pressure is less than 100 psia, and further wherein the contacting temperature is less than -80° C.

17. The method of claim 1, wherein the contacting comprises spraying the process gas stream with the cold liquid.

18. The method claim 1, wherein the contacting includes bubbling the process gas stream through the cold liquid.

19. The method of claim 1, wherein the method includes repeating the contacting with the cold liquid at a different contacting temperature.

20. The method of claim 1, wherein the cold liquid is a first cold liquid, and further wherein the method includes repeating the contacting with a second cold liquid having a different composition than the first cold liquid.

21. The method of claim 1, wherein the method includes repeating the contacting with a second cold liquid at a different contacting temperature.

22. The method of claim 1, wherein the removing includes heating the slurry to a temperature at which at least a portion of the solids are no longer in a solid phase.

23. The method of claim 1, wherein prior to the removing, the method includes pressurizing the slurry to a pressure that is greater than the contacting pressure.

24. The method of claim 23, wherein the pressurization is achieved by heating the solid in a sealed container.

25. The method of claim 1, wherein prior to the removing, the method includes increasing the concentration of the solids in the slurry by removing a portion of the cold liquid from the slurry.

26. The method of claim 22, wherein the solids that are no longer in a solid phase are transformed solids, and further wherein the method includes separating at least a portion of the transformed solids to form an outlet stream.

27. The method of claim 26, wherein the outlet stream is pumped into a subsurface formation for disposal.

28. The method of claim 1, wherein the removing produces a resultant liquid stream from which the solids were removed, and further wherein the methods includes recycling the resultant liquid to form at least a portion of the cold liquid.

29. The method of claim 28, wherein the method includes cooling the resultant liquid stream by heat exchange with at least a portion of the treated gas stream.

30. The method of claim 1, wherein the contacting step is performed in a countercurrent manner.

31. The method of claim 1, wherein the contacting step is performed in two or more stages.

32. The method of claim 1, wherein the removing step is performed mechanically and removal occurs between at least one set of adjacent stages.

33. A system for removing a solidifiable gas component from a process gas stream by direct contact with a cold liquid, the system comprising:

a cold liquid supply containing cold liquid having a cold liquid temperature;

a process gas source containing process gas containing gases that include a solidifiable gas component having a freezing point and at least one other gas component having a freezing point that is lower than the freezing point of the solidifiable gas component;

a contacting assembly adapted to receive a cold liquid stream containing cold liquid from the cold liquid supply, a process gas stream containing process gas from the process gas source, and to directly contact the cold liquid with the process gas at a contacting temperature and a contacting pressure to produce a liquid-solid slurry and a treated gas stream, wherein the slurry contains the cold liquid and solids formed from the solidifiable gas component, and further wherein the treated gas stream contains the at least one other gas component; and

a separation assembly adapted to remove the solids from the slurry to produce a removed stream containing the solidifiable gas component that was removed from the process gas stream.

34. The system of claim 33, wherein the contacting assembly includes a plurality of contacting stages in which the process gas stream is directly contacted with the cold liquid.

35. The system of claim 33, wherein the contacting assembly includes a plurality of contacting assemblies, wherein the cold liquid supply is a first cold liquid supply, the cold liquid stream is a first cold liquid stream, the cold liquid is a first cold liquid, and further wherein the system includes a second cold liquid supply that is adapted to deliver a second cold liquid stream containing a second cold liquid into direct contact with the process gas stream.

36. The system of claim 35, wherein the first cold liquid and the second cold liquid have at least one of different compositions and different temperatures.

37. The system of claim 33, wherein the separation assembly includes a heat source adapted to heat the slurry to a temperature that is above the freezing point of the solidifiable gas component.

38. The system of claim 33, wherein the system includes a solid-liquid separator that is adapted to receive a slurry stream containing the slurry from the contacting assembly and to separate the slurry stream into a concentrated slurry stream and a resultant cold liquid stream, wherein the concentrated slurry stream contains a greater concentration of the solids than the slurry stream, and further wherein the resultant cold liquid stream does not include all of the cold liquid present in the slurry stream.

39. The system of claim 38, wherein the solid-liquid separator comprises a filter.

40. The system of claim 33, wherein the solid-liquid separator comprises a mechanical moving scraper.

41. The system of claim 38, wherein the solid-liquid separator is utilized in a batch, semi-batch, or continuous mode of operation to separate the slurry stream into the concentrated slurry stream and the resultant cold liquid stream.

42. The system of claim 33, wherein the solidifiable gas component is selected from the group consisting of carbon dioxide, hydrogen sulfide, sulfur dioxide, or carbonyl sulfide.

43. The system of claim 33, wherein the solidifiable gas component is not water.

44. The system of claim 33, wherein the contacting pressure is less than 100 psia and that contacting temperature is less than -80° C.

45. The system of claim 44, wherein the contacting pressure is less than 35 psia.

46. The system of claim 33, wherein the cold liquid has a freezing point that is less than -100° C, and further wherein the cold liquid is a liquid at a temperature of 20° C and a pressure of 1 atm.

47. The system of claim 33, wherein the cold liquid has a solidifiable gas component solubility of less than 10 mol% at the contacting pressure and the contacting temperature.

48. The system of claim 33, wherein the cold liquid has a different composition than the process gas stream.

49. A system for removing a solidifiable gas component from a process gas stream, the system comprising:

means for providing a cold liquid and a process gas stream; wherein the process gas stream includes a solidifiable gas component having a freezing point and at least one other gas component having a freezing point that is lower than the freezing point of the solidifiable gas component; and further wherein the cold liquid has a freezing point that is lower than a temperature at which the solidifable gas component within the process gas stream will transition to a solid phase, is liquid at a temperature of 20° C and a pressure of 1 atm, and has a different composition than the process gas stream;

means for directly contacting the cold liquid with the process gas stream to solidify the solidifiable gas component and to form a liquid-solid slurry and a treated gas stream; wherein the slurry contains the cold liquid and the solidified solidifiable gas component; and further wherein the treated gas stream contains a portion of the process gas stream that was not solidified to form the slurry; and

means for removing the solidified solidifiable gas component from the slurry.

50. The system of claim 49, wherein the solidifiable gas component is carbon dioxide, and the other gas component is nitrogen gas.

51. The system of claim 49, wherein the means for directly contacting includes at least one spray tower, bubble column, bubble contactor, tank, or combination thereof.

52. The system of claim 49 wherein the means for directly contacting includes at least one spray tower.

53. The system of claim 49, wherein the cold liquid includes at least one isoalkane, isoalkene, alcohol, or combination thereof.

54. The system of claim 49, wherein the means for directly contacting contacts the cold liquid with the process gas stream in a countercurrent manner.

55. The system of claim 49, wherein the means for directly contacting contacts the cold liquid with the process gas stream in two or more stages.

56. The system of claim 49, wherein the means for removing mechanically removes the solidified solidifiable gas component between at least one set of adjacent stages.

Claims:

1. A system for removing a solidifiable gas component from a process gas stream, the system comprising:

means for providing a cold liquid and a process gas stream; wherein the process gas stream includes a solidifiable gas component having a freezing point and at least one other gas component having a freezing point that is lower than the freezing point of the solidifiable gas component; and further wherein the cold liquid has a freezing point that is lower than a temperature at which the solidifable gas component within the process gas stream will transition to a solid phase, is liquid at a temperature of 20° C and a pressure of 1 atm, and has a different composition than the process gas stream;

means for directly contacting the cold liquid with the process gas stream to solidify the solidifiable gas component and to form a liquid-solid slurry and a treated gas stream; wherein the slurry contains the cold liquid and the solidified solidifiable gas component; and further wherein the treated gas stream contains a portion of the process gas stream that was not solidified to form the slurry; and

means for removing the solidified solidifiable gas component from the slurry.