CLAIMS

1. A cryogenic distillation tower system for separating acid gases from hydrocarbons in a raw gas stream, comprising:

a controlled freezing zone configured to separate the raw gas stream into an overhead methane gas stream and a substantially solid material comprised of precipitated carbon dioxide;

a lower distillation zone configured to receive a bottoms stream comprising acid gases in liquid phase from the controlled freezing zone, and further configured to pass a vapor separated from the acid gases, wherein the acid gas comprises carbon dioxide, hydrogen sulfide, ethane, propane, butane, aromatic hydrocarbons, or combinations thereof, in substantially liquid phase;

a slurry mix zone below the controlled freezing zone configured to house a liquid bath, and wherein the slurry mix zone is configured to receive the substantially solid material from the controlled freezing zone; and

a tray assembly below the slurry mix zone and above the lower distillation zone, wherein the tray assembly comprises:

a deck at a lower end of the slurry mix zone comprising:

at least one vapor riser, wherein the at least one vapor riser comprises:

a substantially vertical heat transfer section configured to pass the vapor from the lower distillation zone substantially upwards through the slurry mix zone; and

at least one vapor distribution cap that is disposed at an upper end of the vapor riser and comprises a plurality of branching arms, wherein the vapor distribution cap is configured to split the vapor stream into a plurality of branch streams to pass the plurality of branch streams substantially downwards through the slurry mix zone to one or more vapor outlets, wherein the vapor outlets are below the heat transfer section;

wherein the vapor riser and the plurality of branching arms do not share a common wall.

2. The cryogenic distillation tower system of claim 1, wherein each of the plurality of branching arms comprises a plurality of branch vapor outlets.

3. The cryogenic distillation tower system of claim 2, wherein each of the plurality of branching arms comprises a laterally extending sparger section, and wherein the plurality of branch vapor outlets are disposed on the sparger section.

4. The cryogenic distillation tower system of claim 3, wherein the plurality of branch vapor outlets are spaced to create a substantially uniform distribution of vapor with respect to the slurry mix zone.

5. The cryogenic distillation tower system of claim 1, wherein the deck comprises at least one electric heating element.

6. The cryogenic distillation tower system of claim 5, wherein the system further comprises an electric heating element controller operatively coupled to the at least one electric heating element, and where the system is further configured to selectively operate the at least one electric heating element.

7. The cryogenic distillation tower system of claim 1, wherein the vapor outlets are configured to facilitate turbulent flow for the vapor passed through the vapor outlets into the slurry mix zone.

8. The cryogenic distillation tower system of claim 1, wherein the tray assembly comprises a plurality of vapor risers, and wherein at least one vapor outlet of a first vapor riser is disposed at a different height within the slurry mix zone than a vapor outlet of a second vapor riser.

9. A method for separating acid gases from a raw gas feed stream in a cryogenic distillation tower, comprising:

passing a feed stream into a controlled freeze zone section of a distillation tower, the feed stream comprising a hydrocarbon and a contaminant;

contacting the feed stream in the controlled freeze zone section with a freezing zone liquid stream, comprising the hydrocarbon, at a temperature and pressure at which a solid, comprising the contaminant, and a hydrocarbon-enriched vapor stream, comprising the hydrocarbon, form;

passing the solid into a liquid bath section of the distillation tower, wherein the temperature of the liquid bath is higher than the temperature of the solid;

passing a vapor stream from a lower distillation section of the distillation tower into the liquid bath section, wherein the temperature of the vapor stream is higher than the temperature of the liquid bath, and wherein passing the vapor stream from the lower distillation section into the liquid bath section comprises:

passing the vapor stream in a substantially vertically upwards direction through a vapor riser in the liquid bath section, wherein passing comprises exchanging heat from the vapor stream to the liquid bath section;

redirecting the vapor stream from the vapor riser such that it passes in a substantially vertically downwards direction through the liquid bath section, wherein redirecting the vapor

stream comprises splitting the vapor stream into a plurality of branch streams and wherein passing comprises exchanging heat from the plurality of branch streams to the liquid bath section, and wherein the vapor passing through the branching arms does not contact the vapor riser; and

sparging the plurality of branch streams into the liquid bath section at a lower end of the liquid bath section.

10. The method of claim 9, further comprising raising the temperature of the liquid bath section.

11. The method of claim 10, wherein raising the temperature of the liquid bath section comprises turning on at least one electric heating element.

12. The method of claim 11, wherein the at least one electric heating element is one electric heating element among a bank of electric heating elements, and wherein the bank of electric heating elements is energized in unison.

13. The method of claim 9, wherein sparging comprises:

flowing the plurality of branch streams so as to promote a non-linear pattern to the vapor being sparged.

14. The method of claim 9, further comprising splitting each of the plurality of branch streams into at least two sparger streams before sparging the vapor stream into the liquid bath section.

15. A tray assembly for use in a distillation tower, comprising:

a deck configured to support a liquid bath on a top side of the deck and a mixture of a vapor and a liquid on a bottom side of the deck, wherein the deck comprises:

a plurality of electrical heating elements; and

a plurality of vapor risers, wherein each vapor riser comprises:

a vertical trunk configured to pass the vapor from below the deck into an upper end of the liquid bath;

a vapor distribution cap disposed at a top of the vertical trunk;

at least two branches coupled to the vapor distribution cap and configured to pass the vapor from the vapor distribution cap to a lower end of the liquid bath; wherein the at least two branches and the vertical trunk do not share a common wall;

a vapor outlet at a terminal end of each of the at least two branches, wherein each vapor outlet is configured to sparge the vapor into the liquid bath.

16. The tray assembly of claim 15, wherein at least one of the plurality of electrical heating elements is disposed on a first vapor riser of the plurality of vapor rises, a first branch of the at least two branches, or both.

17. The tray assembly of claim 15, wherein each of the at least two branches comprises a sparger section extending away from the branch, wherein each vapor outlet is disposed on a respective sparger section, and wherein the upper end of at least two vapor risers, the vapor outlets, or both are disposed at different heights with respect to the deck.