CLAIMS

1. A fractionation system for removing heavy hydrocarbons in a gas stream, comprising:

a feed gas inlet through which a feed gas stream is introduced;

a stripping section configured to receive a predominantly liquid phase of the feed gas stream; and

a co-current contacting system configured to receive a predominantly vapor phase of the feed gas stream, the co-current contacting system comprising:

a compact contacting bundle disposed within a vessel that forms a unitary pressure boundary, the compact contacting bundle including a plurality of substantially parallel contacting units, each of the plurality of contacting units having

a droplet generator and a mass transfer section arranged in-line within a pipe, each droplet generator configured to generate droplets from a liquid and to disperse the droplets into a gas stream, and each mass transfer section configured to provide a mixed, two-phase flow having a vapor phase and a liquid phase, and

a separation system configured to separate the vapor phase from the liquid phase; and

an inlet manifold configured to distribute the liquid to each droplet generator of the plurality of contacting units;

wherein a concentration of heavy hydrocarbons in the vapor phase provided by each mass transfer section of the plurality of contacting units is lower than a concentration of heavy hydrocarbons in the liquid phase provided by each mass transfer section of the plurality of contacting units; and further comprising:

a flash separator arranged to receive the predominantly vapor phase of the feed gas stream prior to said predominantly vapor phase being sent through the co-current contacting system, the flash separator configured to separate liquids from the predominantly vapor phase; and

a flash reflux line connected to the flash separator and to the stripping section, the flash reflux line configured to convey liquids separated from the predominantly vapor phase in the flash separator to the stripping section.

2. The fractionation system of claim 1, wherein the co-current contacting system is a first

co-current contacting system in a plurality of co-current contacting systems, the plurality of co-current contacting systems including additional co-current contacting systems arranged in series with the first co-current contacting system, each of the additional co-current contacting systems having a compact contacting bundle disposed within a vessel that forms a unitary pressure boundary, the compact contacting bundle of each of the additional co-current contacting systems including a plurality of substantially parallel contacting units having

a droplet generator and a mass transfer section, each droplet generator configured to generate droplets from a liquid and to disperse the droplets into a gas stream, and each mass transfer section configured to provide a mixed, two-phase flow having a vapor phase and a liquid phase, and

a separation system configured to separate the vapor phase from the liquid phase; and

an inlet manifold configured to distribute the liquid to each droplet generator of the plurality of contacting units;

wherein the vapor phase of the first co-current contacting system comprises the gas stream for a first of the additional co-current contacting systems, and wherein the liquid phase of a second of the additional co-current contacting systems comprises the liquid from which droplets are generated in one of

the first co-current contacting system, and

the first of the additional co-current contacting systems.

3. The fractionation system of claim 2, wherein the additional co-current contacting systems includes a last co-current contacting system; and

a reflux drum configured to receive a vapor phase from the last co-current contacting system and separate a reflux liquid from said vapor phase;

wherein the last co-current contacting system comprises

a compact contacting bundle disposed within a vessel that forms a unitary pressure boundary, the compact contacting bundle of the last co-current contacting system including a plurality of substantially parallel contacting units, each of the plurality of contacting units having a droplet generator and a mass transfer section, the droplet generator configured to generate droplets from the reflux liquid and to disperse the droplets into a gas stream received from one of the plurality of co-current contacting systems arranged previously in series with the last co-current contacting system, and

the mass transfer section configured to provide a mixed, two-phase flow having said vapor phase and a liquid phase; and

a separation system configured to separate said vapor phase from the liquid phase, wherein said vapor phase is sent to the reflux drum and the liquid phase comprises the liquid from which droplets are generated in a co-current contacting system of another of the plurality of co-current contacting systems.

4. The fractionation system of claim 3, further comprising a reflux cooler situated between the last co-current contacting system and the reflux drum, the reflux cooler configured to cool the vapor phase of the last co-current contacting system prior to being sent to the reflux drum.

5. The fractionation system of claim 2, wherein the vessel is a first vessel, and further comprising one or more additional vessel arranged in series or in parallel to the first vessel, each of the one or more additional vessels having disposed therein one or more additional co-current contacting systems being arranged in parallel within the respective vessel.

6. The fractionation system of any of claims 1 to 5, wherein at least one of the droplet generators in the plurality of contacting units in the compact contacting bundle comprises:

an annular support ring securing the droplet generator in-line within the pipe;

a plurality of spokes extending from the annular support ring, the annular support ring having a plurality of liquid channels configured to allow a liquid stream to flow through the plurality of spokes and out of injection orifices disposed on the plurality of spokes; and

a gas entry cone supported by the plurality of spokes and configured to allow

a first portion of a gas stream to flow through a hollow section of the gas entry cone and through gas exit slots included in the plurality of spokes, and

a second portion of the gas stream to flow around the gas entry cone and between the plurality of spokes, wherein the second portion of the gas stream is separate from the first portion of the gas stream.

7. The fractionation system of claim 6, wherein a downstream portion of the gas entry cone comprises a blunt ended cone.

8. The fractionation system of claim 6, wherein a downstream portion of the gas entry

cone comprises a tapered ended cone.

9. The fractionation system of any of claims 1 to 8, wherein the flash separator comprises a cyclonic separator.

10. The fractionation system of any of claims 1 to 9, further comprising an agglomerator situated at an input of the flash separator.

11. The fractionation system of any of claims 1 to 10, wherein the separation system of the co-current contacting system comprises a cyclonic separator.

12. The fractionation system of any of claims 1 to 13, wherein the feed gas stream comprises a natural gas stream, and wherein the heavy hydrocarbons comprise at least one of propane, butane, hexane, and heptane.

13. A method of removing heavy hydrocarbons in a gas stream, comprising:

introducing a feed gas stream into a feed gas inlet;

receiving a predominantly liquid phase of the feed gas stream into a stripping section;

receiving a predominantly vapor phase of the feed gas stream into a co-current contacting system comprising a compact contacting bundle disposed within a vessel that forms a unitary pressure boundary, the compact contacting bundle including a plurality of substantially parallel contacting units, each of the plurality of contacting units having a droplet generator and a mass transfer section, and a separation system arranged in-line within a pipe;

distributing the liquid to each droplet generator of the plurality of contacting units;

using each droplet generator, generating droplets from a liquid and dispersing the droplets into a gas stream;

in each mass transfer section, providing a mixed, two-phase flow having a vapor phase and a liquid phase; and

in each separation system, separating the vapor phase from the liquid phase;

wherein a concentration of heavy hydrocarbons in the vapor phase provided by each mass transfer section of the plurality of contacting units is lower than a concentration of heavy hydrocarbons in the liquid phase provided by each mass transfer section of the plurality of contacting units;

receiving the predominantly vapor phase of the feed gas stream in a flash separation system prior to sending the predominantly vapor phase through the co-current contacting system;

separating liquids from the predominantly vapor phase in the flash separation system; and

conveying liquids separated from the predominantly vapor phase in the flash separation system to the stripping section via a flash reflux line.

14. The method of claim 13, wherein the co-current contacting system is a first co-current contacting system in a plurality of co-current contacting systems, the plurality of co-current contacting systems including additional co-current contacting systems arranged in series with the first co-current contacting system, the method further comprising:

successively flowing the vapor phase of the first co-current contacting system through each of the additional co-current contacting systems, each of the additional co-current contacting systems having a compact contacting bundle disposed within a vessel that forms a unitary pressure boundary, the compact contacting bundle of each of the additional co-current contacting systems including a plurality of substantially parallel contacting units having

a droplet generator and a mass transfer section, each droplet generator generating droplets from a liquid and to disperse the droplets into a gas stream, and each mass transfer section providing a mixed, two-phase flow having a vapor phase and a liquid phase, and

a separation system that separates the vapor phase from the liquid phase; and

an inlet manifold that distributes the liquid to each droplet generator of the plurality of contacting units;

wherein the vapor phase of the first co-current contacting system comprises the gas stream for a first of the additional co-current contacting systems, and wherein the liquid phase of a second of the additional co-current contacting systems comprises the liquid from which droplets are generated in one of

the first co-current contacting system, and

the first of the additional co-current contacting systems.

15. The method of claim 13 or 14, wherein each droplet generator in the plurality of

contacting units includes an annular support ring securing the droplet generator in-line within the respective pipe, a plurality of spokes extending from the annular support ring, and a gas entry cone supported by the plurality of spokes, the method further comprising:

flowing a liquid stream through liquid channels disposed in the annular support ring, through the plurality of spokes, and out of injection orifices disposed on the plurality of spokes; and

flowing a first portion of a gas stream through a hollow section of the gas entry cone and through gas exit slots included in the plurality of spokes, and

flowing a second portion of the gas stream around the gas entry cone and between the plurality of spokes, wherein the second portion of the gas stream is separate from the first portion of the gas stream.

16. The method of any of claims 13 to 15, further comprising:

feeding the predominantly vapor phase of the feed gas stream into an agglomerator prior to the predominantly vapor phase of the feed gas stream being received by the flash separation system.

17. The method of any of claims 13 to 16, wherein the co-current contacting system is a first co-current contacting system in a plurality of co-current contacting systems arranged in series, the plurality of co-current contacting systems including the first co-current contacting systems and a last co-current contacting system that has a compact contacting bundle disposed within a vessel that forms a unitary pressure boundary, the compact contacting bundle of the last co-current contacting system including a plurality of substantially parallel contacting units, each of the plurality of contacting units of the last co-current contacting system having a droplet generator and a mass transfer section;

in a reflux drum, separating a vapor phase of the last co-current contacting system from a reflux liquid;

generating droplets from the reflux liquid in the droplet generators of the contacting units of the last co-current contacting system;

dispersing said droplets into a gas stream received from a previous co-current contacting system;

in each mass transfer section of the plurality of contacting units of the last co-current contacting system, providing a mixed, two-phase flow having a vapor phase and a liquid phase;

in each separation system of the plurality of contacting units of the last co-current contacting system, separating the vapor phase from the liquid phase of the mixed, two-phase flow;

sending the vapor phase of the mixed, two-phase flow to the reflux drum; and

using the liquid phase of the mixed, two-phase flow to generate droplets in the contacting units of a previous co-current contacting system.

18. The method of claim 17, further comprising:

cooling the vapor phase of the mixed, two-phase flow generated by the separation system of the contacting units of the last co-current contacting system prior to sending said vapor phase to the reflux drum.