

METHOD AND SYSTEM FOR STARTING UP A DISTILLATION TOWER

CROSS REFERENCE TO RELATED APPLICATIONS

- 5 **[0001]** This application claims the priority benefit of United States patent application number 61/982,689 filed April 22, 2014 entitled METHOD AND SYSTEM FOR STARTING UP A DISTILLATION TOWER, the entirety of which is incorporated by reference herein.

BACKGROUND

10 Fields of Disclosure

[0002] The disclosure relates generally to the field of fluid separation in a distillation tower. More specifically, the disclosure relates to the startup of a distillation tower.

Description of Related Art

- 15 **[0003]** This section is intended to introduce various aspects of the art, which may be associated with the present disclosure. This discussion is intended to provide a framework to facilitate a better understanding of particular aspects of the present disclosure. Accordingly, it should be understood that this section should be read in this light, and not necessarily as admissions of prior art.

- 20 **[0004]** The production of natural gas hydrocarbons, such as methane and ethane, from a reservoir oftentimes carries with it the incidental production of non-hydrocarbon gases. Such gases include contaminants, such as at least one of carbon dioxide (“CO₂”), hydrogen sulfide (“H₂S”), carbonyl sulfide, carbon disulfide, and various mercaptans. When a feed stream being produced from a reservoir includes these contaminants mixed with hydrocarbons, the stream is oftentimes referred to as “sour gas.”

- 25 **[0005]** Many natural gas reservoirs have relatively low percentages of hydrocarbons and relatively high percentages of contaminants. Contaminants may act as a diluent and lower the heat content of hydrocarbons. Additionally, in the presence of water some contaminants can become quite corrosive.

- 30 **[0006]** It is desirable to remove contaminants from a stream containing hydrocarbons to produce sweet and concentrated hydrocarbons. Specifications for pipeline quality natural gas typically call for a maximum of 2 – 4% CO₂ and ¼ grain H₂S per 100 scf (4 ppmv) or 5 mg/Nm³ H₂S. Specifications for lower temperature processes such as natural gas

liquefaction plants or nitrogen rejection units typically require less than 50 ppm CO₂.

[0007] The separation of contaminants from hydrocarbons is difficult and consequently significant work has been applied to the development of hydrocarbon/contaminant separation methods. These methods can be placed into three general classes: absorption by solvents
5 (physical, chemical, and hybrids), adsorption by solids, and distillation.

[0008] Separation by distillation of some mixtures can be relatively simple and, as such, is widely used in the natural gas industry. However, distillation of mixtures of natural gas hydrocarbons, primarily methane, and one of the most common contaminants in natural gas, carbon dioxide, can present significant difficulties. Conventional distillation principles and
10 conventional distillation equipment are predicated on the presence of only vapor and liquid phases throughout the distillation tower. The separation of CO₂ from methane by distillation involves temperature and pressure conditions that result in solidification of CO₂ if a pipeline or better quality hydrocarbon product is desired. The required temperatures are cold temperatures typically referred to as cryogenic temperatures.

15 [0009] Certain cryogenic distillations can overcome the above mentioned difficulties. These cryogenic distillations provide the appropriate mechanism to handle the formation and subsequent melting of solids during the separation of solid-forming contaminants from hydrocarbons. The formation of solid contaminants in equilibrium with vapor-liquid mixtures of hydrocarbons and contaminants at particular conditions of temperature and
20 pressure takes place in a controlled freeze zone section. A stripper section may also help separate the contaminants from the hydrocarbons but the stripper section is operated at a temperature and pressure that does not form solid.

[0010] Disadvantages may arise when using cryogenic distillations in a distillation tower if the appropriate temperature and/or composition profiles are not achieved by the end of
25 startup of the distillation tower. The appropriate temperature and composition profiles may vary depending on the section of the distillation tower. Disadvantages may include the formation of solids within the distillation tower but outside of the controlled freeze zone section. Disadvantages may also include undue accumulation of solids in the controlled freeze zone section. Either of these two disadvantages may interfere with the proper
30 operation of the controlled freeze zone section and/or the effective separation of methane from contaminants.

[0011] A need exists for improved technology for starting-up the distillation tower so as

to achieve appropriate temperature and/or composition profiles in the distillation tower by the end of startup (i.e., by normal operation) of the distillation tower.

SUMMARY

5 **[0012]** The present disclosure provides a system and method for starting-up a distillation tower, among other things.

10 **[0013]** A method for startup of a distillation tower may comprise maintaining a rectifier section in the distillation tower, maintaining a lower section in the distillation tower that is configured to form solids from a contaminant within a stream that enters the distillation tower, feeding the stream to the lower section, directly feeding methane to at least one of the rectifier section and a rectifier section outlet line of the rectifier section when a contaminant concentration of the contaminant exiting as a vapor in an upper portion of the lower section is outside of a predetermined concentration, and introducing the vapor from the lower section to the rectifier section when the contaminant concentration exiting the upper portion of the lower section is within the predetermined concentration.

15 **[0014]** A method for startup of a distillation tower may comprise maintaining a rectifier section in the distillation tower, maintaining a lower section in the distillation tower that is configured to form solids from a contaminant within a stream that enters the distillation tower, feeding the stream to the lower section, directly feeding methane to at least one of the rectifier section and a rectifier section outlet line of the rectifier section when a contaminant concentration of the contaminant exiting as a vapor in an upper portion of the lower section is outside of a predetermined concentration, introducing the vapor from the lower section to the rectifier section when the contaminant concentration exiting the upper portion of the lower section is within the predetermined concentration, and producing hydrocarbons from the distillation tower.

25 **[0015]** A distillation tower for startup may comprise a rectifier section, a lower section configured to form solid from contaminant within a stream, and a storage unit holding methane that fluidly connects to at least one of the rectifier section and a rectifier section outlet line of the rectifier section, wherein the lower section introduces the contaminant exiting as a vapor from an upper portion of the lower section to the rectifier section when a contaminant concentration of the vapor exiting the upper portion of the lower section is within a predetermined concentration and wherein the lower section does not introduce the vapor from the lower section to the rectifier section when the contaminant concentration

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exiting the upper portion of the lower section is outside of the predetermined concentration.

[0016] The foregoing has broadly outlined the features of the present disclosure in order that the detailed description that follows may be better understood. Additional features will also be described herein.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0017] These and other features, aspects and advantages of the disclosure will become apparent from the following description, appending claims and the accompanying drawings, which are briefly described below.

[0018] Figure 1 is a schematic diagram of a distillation tower.

10 [0019] Figure 2 is a schematic diagram of a distillation tower.

[0020] Figure 3 is a schematic diagram of a distillation tower during startup.

[0021] Figure 4 is a flowchart of a method within the present disclosure.

[0022] It should be noted that the figures are merely examples and no limitations on the scope of the present disclosure are intended thereby. Further, the figures are generally not
15 drawn to scale, but are drafted for purposes of convenience and clarity in illustrating various aspects of the disclosure.

DETAILED DESCRIPTION

[0023] For the purpose of promoting an understanding of the principles of the disclosure, reference will now be made to the features illustrated in the drawings and specific language
20 will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the disclosure is thereby intended. Any alterations and further modifications, and any further applications of the principles of the disclosure as described herein are contemplated as would normally occur to one skilled in the art to which the disclosure relates. It will be apparent to those skilled in the relevant art that some features that are not relevant
25 to the present disclosure may not be shown in the drawings for the sake of clarity.

[0024] As referenced in this application, the terms “stream,” “gas stream,” “vapor stream,” and “liquid stream” refer to different stages of a feed stream as the feed stream is processed in a distillation tower that separates methane, the primary hydrocarbon in natural gas, from contaminants. Although the phrases “gas stream,” “vapor stream,” and “liquid
30 stream,” refer to situations where a gas, vapor, and liquid is mainly present in the stream,

respectively, there may be other phases also present within the stream. For example, a gas may also be present in a “liquid stream.” In some instances, the terms “gas stream” and “vapor stream” may be used interchangeably. As referenced in this application, the term “stream” may be interchangeably referred to as a “feed stream.”

5 **[0025]** The disclosure relates to a system and method for startup of a distillation tower. The system and method helps optimally connect a lower section of the distillation tower to an upper section of the distillation tower during startup of the distillation tower such that the distillation tower achieves the appropriate temperature and/or composition profiles for the stream in the lower and upper sections of the distillation tower at the end of startup. The
10 system and method helps optimally connect the lower section and the upper section without allowing migration of solids outside of a middle controlled freeze zone section of the distillation tower and/or without undue accumulation of solids within the middle controlled freeze zone section. Figures 1-4 of the disclosure display various aspects of the system and method.

15 **[0026]** The system comprises a distillation tower **204** (Figures 1-3). The distillation tower **204** may separate contaminants in a feed stream **10** from methane in a feed stream **10**.

[0027] The distillation tower **204** may comprise an upper section **254** and a lower section **264**. The upper section **254** may comprise a rectifier section **110**. The lower section **264** may comprise a middle controlled freeze zone section **108** and a stripper section **106**. The
20 middle controlled freeze zone section **108** may comprise an upper portion of the lower section **264**. The stripper section **106** may comprise a lower portion **106** (Figure 3) of the lower section **264**. The lower section **264** may be configured to form solids from contaminants within a stream that enters the distillation tower **204**.

[0028] The distillation tower **204** may be referred to as a split-tower configuration
25 because it comprises the upper section **254** and the lower section **264**. The split-tower configuration may be beneficial in situations where, for example, the height of the distillation tower, motion considerations, and/or transportation issues, such as for remote locations, need to be considered. The split-tower configuration allows for the independent operation of the upper section **254** from the lower section **264** during startup of the distillation tower or during
30 normal operation of the distillation tower. Normal operation of the distillation tower occurs after startup of the distillation tower.

[0029] The stripper section **106** is constructed and arranged to separate the feed stream **10**

into an enriched contaminant bottom liquid stream (i.e., liquid stream) and a freezing zone vapor stream (i.e., vapor stream). The stripper section **106** separates the feed stream at a temperature and pressure at which no solids form. The liquid stream may comprise a greater quantity of contaminants than of methane. The vapor stream may comprise a greater quantity of methane than of contaminants. In any case, the vapor stream is lighter than the liquid stream. As a result, the vapor stream rises within the stripper section **106** (i.e., rises toward the top of the stripper section **106**) and the liquid stream falls within the stripper section **106** (i.e., falls toward the bottom of the stripper section **106**). The top of the stripper section **106** is the part of the stripper section **106** closest to the middle controlled freeze zone section **108**.

10 **[0030]** The stripper section **106** may include and/or connect to equipment that separates the feed stream. The equipment may comprise any suitable equipment for separating methane from contaminants, such as one or more packed sections **181**, or one or more distillation trays with perforations downcomers and weirs, and/or one or more chimney assemblies **135** (Figures 1-3). The equipment may comprise components that apply heat to the stream to form the vapor stream and the liquid stream. For example, the equipment may comprise at least one of a first reboiler **112** and a second reboiler **172** that apply heat to the stream. Each of the first reboiler **112** and the second reboiler **172** may be located outside of the distillation tower **204**. The first reboiler **112** may comprise a plurality of first reboilers. The second reboiler **172** may comprise a plurality of second reboilers.

20 **[0031]** The first reboiler **112** may apply heat to the liquid stream that exits the stripper section **106** through a liquid outlet **160** of the stripper section **106**. The liquid stream may travel from the liquid outlet **160** through line **28** to reach the first reboiler **112** (Figures 1-3). The amount of heat applied to the liquid stream by the first reboiler **112** can be increased to separate more methane from contaminants. The more heat applied by the reboiler **112** to the stream, the more methane separated from the liquid contaminants, though more contaminants will also be vaporized.

[0032] The first reboiler **112** may apply heat to the stream within the distillation tower **204**. Specifically, the heat applied by the first reboiler **112** warms up the stripper section **106**. This heat travels up the stripper section **106** and supplies heat to warm solids entering a melt tray assembly **139** (Figures 1-3) of the middle controlled freeze zone section **108** so that the solids form a liquid and/or slurry mix.

[0033] The second reboiler **172** applies heat to the stream within the stripper section **106**.

This heat is applied closer to the middle controlled freeze zone section **108** than the heat applied by the first reboiler **112**. As a result, the heat applied by the second reboiler **172** reaches the middle controlled freeze zone section **108** faster than the heat applied by the first reboiler **112**. The second reboiler **172** also helps with energy integration. Line **17** may lead
5 from the distillation tower to the second reboiler **172**. Line **117** may lead from the second reboiler **172** to the distillation tower.

[0034] While falling to the bottom of the stripper section **106**, the liquid stream may encounter one or more of the chimney assemblies **135**.

[0035] Each chimney assembly **135** may include a chimney tray **131**. A liquid stream
10 falling to the bottom of the stripper section **106**, may encounter a chimney assembly **135**. The liquid stream may collect on the chimney tray **131**. The liquid stream that collects on the chimney tray **131** may be fed to the second reboiler **172**. After the liquid stream is heated in the second reboiler **172**, the stream may return to the middle controlled freeze zone section **108** to supply heat to the middle controlled freeze zone section **108** and/or the melt tray
15 assembly **139** in the middle controlled freeze zone section **108**. Unvaporized stream exiting the second reboiler **172** may be fed back to the distillation tower **204** below the chimney tray **131**. Vapor stream exiting the second reboiler **172** may be routed under or above the chimney tray **131** when the vapor stream enters the distillation tower **204**.

[0036] The chimney tray **131** may include one or more chimneys **137**. Each chimney **137**
20 serves as a channel that the vapor stream in the stripper section **106** traverses. The vapor stream travels through an opening in the chimney tray **131** at the bottom of the chimney **137** to the top of the chimney **137**. The opening of the chimney tray **131** is closer to the bottom of the stripper section **106** than it is to the bottom of the middle controlled freeze zone section **108**. The top of the chimney tray **131** is closer to the bottom of the middle controlled freeze
25 zone section **108** than it is to the bottom of the stripper section **106**.

[0037] Each chimney **137** has attached to it a chimney cap **133**. The chimney cap **133** covers a chimney top opening **138** of the chimney **137**. The chimney cap **133** prevents the liquid stream from entering the chimney **137**. The vapor stream exits the chimney assembly **135** via the chimney top opening **138**.

[0038] After falling to the bottom of the stripper section **106**, the liquid stream exits the
30 distillation tower **204** through the liquid outlet **160**. The liquid outlet **160** is within the stripper section **106** (Figures 1-3). The liquid outlet **160** may be located at the bottom of the

stripper section **106**.

[0039] After exiting through the liquid outlet **160**, the feed stream may travel via line **28** to the first reboiler **112**. The feed stream may be heated by the first reboiler **112** and vapor may then re-enter the lower section **106** through line **30**. The feed stream not vaporized by the first reboiler **112** (i.e., the unvaporized liquid) may continue out of the distillation process via line **24**. The unvaporized liquid may not re-enter the distillation tower **204**.

[0040] The middle controlled freeze zone section **108** is constructed and arranged to separate the stream introduced into the middle controlled freeze zone section into solids and a vapor stream. The middle controlled freeze zone section **108** forms the solids. The solids may be comprised more of contaminants than of methane. The vapor stream (i.e., methane-enriched vapor stream) may comprise more methane than contaminants. The middle controlled freeze zone section **108** may receive the vapor stream that rises from the stripper section **106**.

[0041] The middle controlled freeze zone section **108** may comprise the melt tray assembly **139**. The melt tray assembly **139** may be constructed and arranged to melt solids formed in the middle controlled freeze zone section **108**. When the vapor stream rises from the stripper section **106** to the middle controlled freeze zone section **108**, the vapor stream immediately encounters the melt tray assembly **139** and supplies heat to melt the solids. The melt tray assembly **139** may comprise at least one of a melt tray **118**, a bubble cap **132**, a liquid **130** and heat mechanism **134**.

[0042] The melt tray **118** may collect a liquid **130** that helps melt the solids formed in the middle controlled freeze zone section **108**. The melt tray **118** divides at least a portion of the middle controlled freeze zone section **108** from the stripper section **106**. The melt tray **118** is at the bottom **45** of the middle controlled freeze zone section **108** (Figures 1-3).

[0043] The bubble cap **132** may act as a channel for the vapor stream rising from the stripper section **106** to the middle controlled freeze zone section **108**. The bubble cap **132** may provide a path for the vapor stream that forces the vapor stream up a riser **140** and then down and around the riser **140** to the melt tray **118**. The riser **140** is covered by a cap **141**. The cap **141** prevents the liquid **130** from travelling into the riser and it also helps prevent solids from travelling into the riser **140**. The vapor stream's traversal through the bubble cap **132** allows the vapor stream to transfer heat to the liquid **130** within the melt tray assembly **139**.

[0044] The heat mechanism **134** may heat up the liquid **130** within the melt tray assembly **139** to facilitate melting of the solids into a liquid and/or slurry mix. The heat mechanism **134** may be located anywhere within the melt tray assembly **139**. For example, as shown in Figures 1-3, a heat mechanism **134** may be located around the bubble caps **132**. The heat
5 mechanism **134** may be any suitable mechanism, such as a heat coil. The heat source of the heat mechanism **134** may be any suitable heat source.

[0045] The liquid **130** in the melt tray assembly is heated by the vapor stream rising from the stripper section **106**. The liquid **130** may also be heated by the heat mechanism **134**. The heat transferred by the vapor stream and/or the heat mechanism heats up the liquid, thereby
10 enabling the heat to melt the solids.

[0046] The middle controlled freeze zone section **108** may comprise a spray assembly **129** (Figures 1-3). The spray assembly **129** cools the vapor stream that rises from a lower middle controlled freeze zone section **312** (Figure 3) of the middle controlled freeze zone section **108**. The lower middle controlled freeze zone section **312** is below an upper middle
15 controlled freeze zone section **313** (Figure 3) of the middle controlled freeze zone section **108**. The spray assembly **129** sprays liquid, which is cooler than the vapor stream, on the vapor stream to cool the vapor stream. A portion of the spray assembly **129** may be within the upper middle controlled freeze zone section **313**. The spray assembly **129** is not within the lower middle controlled freeze zone section **312**. The spray assembly **129** is above the
20 melt tray assembly **139**. The melt tray assembly **139** is below the spray assembly **129**. The temperature in the middle controlled freeze zone section **108** cools down as the vapor stream travels from the lower middle controlled freeze zone section **312** to the upper middle controlled freeze zone section **313**.

[0047] The spray assembly **129** may include a spray nozzle **120** (Figures 1-3). The spray
25 nozzle **120** sprays liquid on the rising vapor stream. The spray assembly **129** may include a spraying mechanism. The spraying mechanism may include a spray pump **128** (Figures 1-3) to pump the liquid or gravity to induce flow in the liquid. The spray pump **128** may be outside of the distillation tower **204**.

[0048] The liquid sprayed by the spray assembly **129** contacts the vapor stream rising in
30 the middle controlled freeze zone section **108** at a temperature and pressure at which solids form. Solids, containing mainly contaminants, form when the liquid sprayed contacts the vapor stream. The solids formed, fall toward the melt tray assembly **139** to interact with the

liquid **130**.

[0049] The solids form the liquid and/or slurry mix when in the liquid **130**. The liquid and/or slurry mix flows from the middle controlled freeze zone section **108** to the stripper section **106**. The liquid and/or slurry mix flows from the lower middle controlled freeze zone section **312** to the top of the stripper section **106** via a line **22** (Figures 1-3). The line **22** may be an exterior line. The line **22** may extend from the distillation tower **204**. The line **22** may extend from the middle controlled freeze zone section **108**. The line may extend to the stripper section **106**. The line **22** may extend from an outer surface of the distillation tower **204**.

[0050] The rectifier section **110** operates at a temperature and pressure and contaminant concentration at which no solids form. The rectifier section **110** is constructed and arranged to cool a vapor stream introduced into the rectifier section **110**. The cooling of the stream separates any contaminants in the vapor stream from methane in the vapor stream. Reflux in the rectifier section **110** cools the vapor stream. The reflux is introduced into the rectifier section **110** via line **18** (Figures 1-3). Line **18** may extend to the rectifier section **110**. Line **18** may extend from an outer surface of the distillation tower **204**.

[0051] After contacting the reflux in the rectifier section **110**, the feed stream forms a vapor stream and a liquid stream. The vapor stream comprises more methane than contaminants. The vapor stream rises in the rectifier section **110** and the liquid stream falls to a bottom of the rectifier section **110**.

[0052] The rectifier section **110** may include a mass transfer device **176** (Figures 1-3). The mass transfer device may facilitate separation of the methane from the contaminants when the stream contacts the reflux. The mass transfer device **176** helps separate the methane from the contaminants. The mass transfer device **176** may comprise any suitable separation device, such as a tray with perforations, or a section of random or structured packing **176** to facilitate contact of the vapor and liquid phases.

[0053] After rising to a top portion of the rectifier section **110**, the vapor stream may exit the rectifier section **110** of the distillation tower **204** via the rectifier section outlet **401** (Figures 1-3) through outlet line **14** (Figures 1-3). The line **14** (i.e., rectifier section outlet line) may emanate from an upper part of the rectifier section **110**. The line **14** may extend from an outer surface of the rectifier section **110**.

[0054] From line **14**, the vapor stream may enter a condenser **122** (Figures 1-3). The

condenser **122** cools the vapor stream to form a cooled stream. The condenser **122** at least partially condenses the stream.

[0055] After exiting the condenser **122**, the cooled stream may enter a separator **124** (Figures 1-3). The separator **124** separates the cooled stream into a liquid stream and a vapor stream. The separator may be any suitable separator that can separate a stream into a liquid stream and a vapor stream, such as a reflux drum.

[0056] Once separated, the vapor stream may exit the separator **124** as sales product. The sales product may travel through line **16** (Figures 1-3) for subsequent sale to a pipeline and/or condensation to be liquefied natural gas. The vapor stream only exits the separator **124** as sales product if the contaminants within the vapor stream are below a certain amount such as, for example, less than 2% of the stream.

[0057] Once separated, the liquid stream may return to the rectifier section **110** through line **18** as the reflux. The reflux may travel to the rectifier section **110** via any suitable mechanism, such as a reflux pump **150** (Figures 1 and 3) or gravity.

[0058] The liquid stream (i.e., freezing zone liquid stream) that falls to the bottom of the rectifier section **110** collects at the bottom of the rectifier section **110** as liquid **330** (Figures 1-3). The liquid **330** may collect at the bottommost portion of the rectifier section **110**.

[0059] During startup within the distillation tower **204**, the rectifier section **110** does not connect to the lower section **264** of the distillation tower **204**. The rectifier section **110** connects to the lower section **264** when (1) the amount of liquid **130** in the melt tray assembly **139** is greater than or equal to a predetermined melt tray amount and (2) the amount of contaminants within the vapor stream exiting the upper portion of the lower section **264** is within a predetermined concentration. Once the rectifier section **110** connects to the lower section **264**, the distillation tower **204** operates under normal operation. In other words, during normal operation, the rectifier section **110** connects to the lower section **264**.

[0060] During startup, the rectifier section **110** and the lower section **264** are maintained, **401** (Figure 4), **402** (Figure 4). During startup, stream **10** is fed to the lower section **264** of the distillation tower **204**, **403** (Figure 4). The middle controlled freeze zone section **108** may also be maintained.

[0061] During startup, methane is directly fed to at least one of the rectifier section **110** and the rectifier section outlet line **14** of the rectifier section **110** when a contaminant

concentration of the contaminant in a vapor stream exiting as a vapor in the upper portion of the lower section **264** is outside of a predetermined concentration, **404** (Figure 4). Methane is fed directly when the contaminant concentration is outside of the predetermined concentration to enable the portions of the distillation tower **204** (stripper section **106**, middle controlled freeze zone section **108** and rectifier section **110**) to have the appropriate amount of contaminant for the distillation tower **204** to operate during normal operations.

[0062] When the methane is directly fed to the rectifier section **110**, the methane may be directly fed to a rectifier section inlet **402** (Figure 3) of the rectifier section **110**. The rectifier section inlet **402** (Figure 3) may connect to line **316** (Figure 3). Line **316** may extend to the rectifier section **110** such that the methane travels to the rectifier section inlet **402** (Figure 3) via line **316**.

[0063] Methane may be fed directly to the rectifier section outlet line **14** of the rectifier section **110** via line **318** (Figure 3). Line **318** may extend to the rectifier section outlet line **14** such that the methane travels to the rectifier section outlet line **14** via line **318**. After being fed to the rectifier section outlet line **14**, the methane may enter the condenser **122** and then the separator **124** and then be fed to the rectifier section **110** via reflux pump **150**.

[0064] Once the contaminant concentration exiting as the vapor stream is within the predetermined concentration, methane need not be directly fed to the rectifier section **110**. The contaminant exiting as the vapor in the upper portion of the lower section **264** is the vapor exiting a top portion of the middle controlled freeze zone section **108**. The contaminant exiting as the vapor in the upper portion of the lower section **264** is not the vapor exiting the stripper section **106** to enter the middle controlled freeze zone section **108** from the stripper section **106**. Directly feeding the methane to the rectifier section **110** may comprise discontinuously directly feeding the methane or continuously feeding the methane.

[0065] The predetermined concentration is any suitable range. For example, the predetermined concentration is between 2 and 7 percent of contaminants within a stream. More specifically, the predetermined concentration may be between 3 and 6 percent of contaminants within a stream. If the contaminant concentration is within the predetermined concentration, the contaminant concentration falls within the suitable range. If the contaminant concentration is outside of the predetermined concentration, the contaminant concentration falls outside of the suitable range. For example, if the predetermined concentration is between 2 and 7 percent, a contaminant concentration equal to 8% falls

outside of the suitable range and a contaminant concentration of 4% falls within the suitable range. The contaminant concentration is the total percentage of contaminant within the vapor stream exiting the upper portion of the lower section **264**. The contaminant comprises carbon dioxide. The predetermined concentration may be any percentage within a range that
5 includes or is bounded by any of the preceding examples.

[0066] The methane fed directly to at least one of the rectifier section **110** via line **316** and the rectifier section outlet line **14** via line **318** may come from any suitable source. For example, the methane may come from a housing mechanism **317** (Figure 3). The housing mechanism **317** may be filled with methane. The methane may be in vapor form. The
10 housing mechanism **317** may be any suitable mechanism. For example, the housing mechanism **317** may comprise one of a storage unit and a pipeline.

[0067] When the methane is fed directly to the rectifier section **110**, the vapor stream rises and exits the rectifier section **108** to line **14**. Regardless of whether the methane is fed directly to at least one of the rectifier section **110** and the rectifier section outlet line **14**, from
15 line **14**, the vapor stream enters the condenser **122** and is cooled. From the condenser **122** the methane enters the separator **124** where the cooled methane is separated into a vapor stream and a liquid stream. The liquid stream reenters the rectifier section via line **18**. After reentering the rectifier section via line **18**, the liquid within the liquid stream falls to the bottom of the rectifier section **110** as liquid **330**. Any vapor within the liquid stream rises and
20 exits the rectifier section **108** via line **14**.

[0068] The liquid stream that falls to the bottom of the rectifier section **110** accumulates as the liquid **330**. The liquid **330** is discontinuously fed from the rectifier section **110** to the lower section **264** while the melt tray amount of liquid **130** in the melt tray assembly **139** is below (i.e., less than) a predetermined melt tray amount. Discontinuously feeding the spray
25 includes discontinuously introducing the spray from the rectifier section **110** to the spray assembly **129** in the lower section **264**. Discontinuously feeding the spray occurs before introducing vapor from the lower section **264** to the rectifier section **110**. The liquid **330** is continuously fed from the rectifier section **110** to the lower section **264** when the amount of liquid **130** is greater than or equal to (i.e., at least) the predetermined melt tray amount.
30 Continuously feeding the spray includes continuously feeding the spray from the rectifier section **110** to the spray assembly **129** in the lower section **264**. Continuously feeding the spray may occur before introducing the vapor from the lower section **264** to the rectifier section **110**.

[0069] The predetermined melt tray amount is an amount sufficient to provide a sufficient warm thermal mass to reliably melt all solids that enter the liquid **130** in the melt tray assembly **139**. When the liquid level of the melt tray amount is at least at this predetermined melt tray amount, it is more likely that the middle controlled freeze zone section **108** will
5 operate properly by forming solids and vapors and melting the solids in the melt tray assembly **139**, such that the methane in the feed stream is separated out from the contaminants in the feed stream.

[0070] The liquid stream exiting the rectifier section **110** may be fed to a line **41** that connects to a flow controlling device **320** and to the spraying mechanism. The liquid stream
10 may exit the rectifier section **110** via outlet **260**. The flow controlling device **320** is configured to open and close. When the flow controlling device **320** is open, the liquid stream is fed to the lower section **264**. When the flow controlling device **320** is open, some of the liquid stream may be fed to the rectifier section **110** via flow back line **331** (Figure 3). When the flow controlling device **320** is closed, the liquid stream is not fed to the lower
15 section **264**. When the flow controlling device **320** is closed, some of the liquid stream may be fed to the rectifier section **110** via flow back line **331**. The flow controlling device **320** may comprise any suitable device. For example, the flow controlling device **320** may comprise a valve.

[0071] The line **41** may also connect to a holding vessel. The holding vessel may house
20 at least some of the liquid stream before it encounters the spraying mechanism. The holding vessel may be needed when there is not a sufficient amount of the liquid **330** at the bottom of the rectifier section **110** to feed the spraying mechanism.

[0072] Once the liquid stream is fed to the lower section **264** via line **41**, the liquid stream is sprayed on the vapor stream rising in the middle controlled freeze zone section **108** to help
25 form solids and a vapor stream. The solids fall to the bottom of the middle controlled freeze zone section **108** and are melted in the melt tray assembly **139**. The melted solids that turn into liquid increase the amount of liquid **130** in the melt tray assembly **139**. Increasing the amount of liquid **130** helps the liquid **130** be greater than or equal to the predetermined melt tray amount.

[0073] When the amount of liquid **130** in the melt tray assembly is below the predetermined melt tray amount, the liquid stream is discontinuously fed to the lower section **264**; when the amount of liquid **130** in the melt tray assembly is greater than or equal to (i.e.,
30

at least) the predetermined melt tray amount, the liquid stream is continuously fed to the lower section **264**. The flow controlling device **320** is the mechanism by which the liquid stream is discontinuously or continuously fed. When the amount of liquid **130** is below the predetermined melt tray amount (i.e., less than the predetermined melt tray amount), the flow
5 controlling device **320** continuously goes from being open to being closed so that the liquid stream is discontinuously fed to the lower section. In other words, when the flow controlling device **320** is open the liquid stream is fed to the lower section **264** and when the flow controlling device **320** is closed the liquid stream is not fed to the lower section **264**. When the amount of liquid **130** is greater than or equal to the predetermined melt tray amount, the
10 flow controlling device **320** remains open so that the liquid stream is not prevented from being fed to the lower section **264** (i.e., the liquid stream is continuously fed to the lower section **264**). Excess liquid **130** is transferred to the stripper section **106** of the lower section **264** via line **22**.

[0074] The vapor stream formed from the liquid stream sprayed rises to the top of the
15 middle controlled freeze zone section **108** and exits the middle controlled freeze zone section **108** via line **341** (Figures 1-3). Line **341** extends from the middle controlled freeze zone section **108** of the lower section **264** to the rectifier section **110** of the upper section **254**. Line **341** includes a flow controlling device **342**. The flow controlling device **342** is configured to prevent the vapor stream from being fed to the upper section **254** when the
20 contaminant concentration, in the vapor stream, exiting an upper portion of the lower section **264** is outside of the predetermined concentration. The flow controlling device **342** may be any suitable device that is so configured. For example, the flow controlling device **342** may comprise a valve. If the flow controlling device **342** comprises a valve, the valve is open when the contaminant concentration exiting the upper portion of the lower section **264** is
25 within the predetermined concentration. If the flow controlling device **342** comprises a valve, the valve is closed when the contaminant concentration exiting the upper portion of the lower section **264** is outside of the predetermined concentration. Regardless of what the flow controlling device **342** comprises, the flow controlling device **342** is open when the contaminant concentration exiting the upper portion of the lower section **264** is within the
30 predetermined concentration; the flow controlling device is closed when the contaminant concentration exiting the upper portion of the lower section **264** is outside of the predetermined concentration.

[0075] When the contaminant concentration exiting the upper portion of the lower section

264 is outside of the predetermined concentration, the vapor stream in line **341** may be disposed of in any suitable manner via a disposal method. For example, the disposal method could be that the vapor stream is sent to flare. The vapor stream may be disposed of by being fed through line **343** to the disposal method. When the contaminant concentration exiting the upper portion of the lower section **264** is within the predetermined concentration, the vapor from the lower section **264** is fed to the rectifier section **110**, **405** (Figure 4).

[0076] It may take longer for the contaminant concentration to be within the predetermined concentration than for the melt tray amount of liquid **130** in the melt tray assembly **139** to be greater than or equal to the predetermined melt tray amount (i.e., not below the predetermined melt tray amount). When it takes longer, the liquid stream (i.e., spray) is continuously fed to the lower section **264** before the vapor in the vapor stream is introduced (i.e., fed) from the lower section **264** to the rectifier section **110**.

[0077] Before the rectifier section **110** connects to the lower section **264**, feed stream entering the lower section **264** may enter the lower section **264** at a lower rate than the rate at which the feed stream enters the lower section **264** during normal operation. Once the rectifier section **110** connects to the lower section **264**, the feed stream entering can be adjusted to the desired operating rate.

[0078] During startup or normal operation of the distillation tower **204**, the system may include a heat exchanger **100** (Figures 1-3). The feed stream **10** may enter the heat exchanger **100** before entering the distillation tower **204**. The feed stream **10** may be cooled within the heat exchanger **100**. The heat exchanger **100** helps drop the temperature of the feed stream **10** to a level suitable for introduction into the distillation tower **204**.

[0079] During startup or normal operation, the system may include an expander device **102** (Figures 1-3). The feed stream **10** may enter the expander device **102** before entering the distillation tower **204**. The feed stream **10** may be expanded in the expander device **102** after exiting the heat exchanger **100**. The expander device **102** helps drop the temperature of the feed stream **10** to a level suitable for introduction into the distillation tower **204**. The expander device **102** may be any suitable device, such as a valve. If the expander device **102** is a valve, the valve may be any suitable valve that may aid in cooling the feed stream **10** before it enters the distillation tower **204**. For example, the valve **102** may comprise a Joule-Thompson (J-T) valve.

[0080] During startup or normal operation, the system may include a feed separator **103**

(Figure 2). The feed stream may enter the feed separator before entering the distillation tower **204**. The feed separator may separate a feed stream having a mixed liquid and vapor stream into a liquid stream and a vapor stream. Lines **12** may extend from the feed separator to the distillation tower **204**. One of the lines **12** may receive the vapor stream from the feed separator. Another one of the lines **12** may receive the liquid stream from the feed separator. Each of the lines **12** may extend to the same and/or different portions (i.e. middle controlled freeze zone, and stripper section) of the lower section **264**. The expander device **102** may or may not be downstream of the feed separator **103**. The expander device **102** may comprise a plurality of expander devices **102** such that each line **12** has an expander device **102**.

[0081] During startup or normal operation, the system may include a dehydration unit **261** (Figures 1-3). The feed stream **10** may enter the dehydration unit **261** before entering the distillation tower **204**. The feed stream **10** enters the dehydration unit **261** before entering the heat exchanger **100** and/or the expander device **102**. The dehydration unit **261** removes water from the feed stream **10** to prevent water from later presenting a problem in the heat exchanger **100**, expander device **102**, feed separator **103**, or distillation tower **204**. The water can present a problem by forming a separate water phase (i.e., ice and/or hydrate) that plugs lines, equipment or negatively affects the distillation process. The dehydration unit **261** dehydrates the feed stream to a dew point sufficiently low to ensure a separate water phase does not form at any point downstream during the rest of the process. The dehydration unit may be any suitable dehydration mechanism, such as a molecular sieve or a glycol dehydration unit.

[0082] During startup or normal operation, the system may include a filtering unit (not shown). The feed stream **10** may enter the filtering unit before entering the distillation tower **204**. The filtering unit may remove undesirable contaminants from the feed stream before the feed stream enters the distillation tower **204**. Depending on what contaminants are to be removed, the filtering unit may be before or after the dehydration unit **261** and/or before or after the heat exchanger **100**.

[0083] During startup or normal operation, the system may include lines **12**. Each of the lines may be referred to as an inlet channel **12**. The feed stream is introduced into the distillation tower **204** through one of the lines **12**. One or more lines **12** may extend to the stripper section **106** or the middle controlled freeze zone section **108** of the lower section **264**. For example, the line **12** may extend to the stripper section **106** such that the feed stream **10** may enter the stripper section **106** (Figures 1-3). Each line **12** may directly or indirectly

extend to the stripper section **106** or the middle controlled freeze zone section **108**. Each line **12** may extend to an outer surface of the lower section **264** before feed stream enters the lower section **264**.

[0084] During startup or normal operation, and before entering the distillation tower **204**,
5 a sample of the feed stream **10** may enter an analyzer (not shown). The sample of the feed stream **10** may be a small sample of the feed stream **10**. The feed stream **10** may comprise feed from multiple feed sources or feed from a single feed source. Each feed source may comprise, for example, a separate reservoir, one or more wellbores within one or more reservoirs, etc. The analyzer may determine the percentage of CO₂ in the sample of the feed
10 stream **10** and, therefore, the content of CO₂ in the feed stream **10**. The analyzer may connect to multiple lines **12** so that the feed stream **10** can be sent to at least one of the stripper section **106** and the middle controlled freeze zone section **108** after the sample of the feed stream **10** exits the analyzer. If the analyzer determines that the percentage of CO₂ is greater than about 20% or greater than 20%, the analyzer may direct the feed stream to the line **12**
15 extending from the stripper section **106**. If the analyzer determines that the percentage of CO₂ is less than about 20% or less than 20%, the analyzer may direct the feed stream to the line **12** extending from the middle controlled freeze zone section **108**. The analyzer may be any suitable analyzer. For example, the analyzer may be a gas chromatograph or an IR analyzer. The analyzer may be positioned before the feed stream **10** enters the heat
20 exchanger **100**. The feed stream **10** entering the analyzer may be a single phase.

[0085] While the feed stream **10** may be introduced into the stripper section **106** or the middle controlled freeze zone section **108** regardless of the percentage of CO₂ in the feed stream **10**, it is more efficient to introduce the feed stream **10** into the section of the distillation tower **204** that will employ the best use of energy. For this reason, it is preferable
25 to introduce the feed stream to the stripper section **106** when the percentage of CO₂ in the feed stream is greater than any percentage about 20% or greater than 20% and to the middle controlled freeze zone section **108** when the percentage of CO₂ in the feed stream is any percentage less than about 20% or less than 20%.

[0086] During startup or normal operation, the system may include an expander device
30 **114** (Figures 1-3). After unvaporized liquid continues out of the distillation process via line **24**, the heated liquid stream may be expanded in the expander device **114**. The expander device **114** may be any suitable device, such as a valve. The valve **114** may be any suitable valve, such as a J-T valve.

[0087] During startup or normal operation, the system may include a heat exchanger **116** (Figures 1-3). The liquid stream expanded in the expander device **114** may be cooled or heated by the heat exchanger **116**. The heat exchanger **116** may be a direct heat exchanger or an indirect heat exchanger. The heat exchanger **116** may comprise any suitable heat exchanger. The liquid stream may exit the heat exchanger **116** through line **26**.

[0088] During normal operation, the methane in the vapor stream that rises to the top of the middle controlled freeze zone section **108** is fed from the middle controlled freeze zone section **108** to the rectifier section **110**. Some contaminants may remain in the methane and also rise. The vapor stream is fed from the middle controlled freeze zone section **108** to the rectifier section **110** because the flow controlling device **342** is open.

[0089] It is important to note that the steps depicted in Figure 4 are provided for illustrative purposes only and a particular step may not be required to perform the inventive methodology. The claims, and only the claims, define the inventive system and methodology.

[0090] Disclosed aspects may be used in hydrocarbon management activities. As used herein, “hydrocarbon management” or “managing hydrocarbons” includes hydrocarbon extraction, hydrocarbon production, hydrocarbon exploration, identifying potential hydrocarbon resources, identifying well locations, determining well injection and/or extraction rates, identifying reservoir connectivity, acquiring, disposing of and/ or abandoning hydrocarbon resources, reviewing prior hydrocarbon management decisions, and any other hydrocarbon-related acts or activities. The term “hydrocarbon management” is also used for the injection or storage of hydrocarbons or CO₂, for example the sequestration of CO₂, such as reservoir evaluation, development planning, and reservoir management. The disclosed methodologies and techniques may be used to produce hydrocarbons in a feed stream extracted from, for example, a subsurface region. The feed stream extracted may be processed in the distillation tower **204** and separated into hydrocarbons and contaminants. The separated hydrocarbons exit the middle controlled freeze zone section **108** or the rectifier section **110** of the distillation tower. Some or all of the hydrocarbons that exit may be produced **406** (Figure 4). Hydrocarbon extraction may be conducted to remove the feed stream from for example, the subsurface region, which may be accomplished by drilling a well using oil well drilling equipment. The equipment and techniques used to drill a well and/or extract the hydrocarbons are well known by those skilled in the relevant art. Other hydrocarbon extraction activities and, more generally, other hydrocarbon management

activities, may be performed according to known principles.

[0091] As utilized herein, the terms “approximately,” “about,” “substantially,” and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numeral ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and are considered to be within the scope of the disclosure.

[0092] It should be understood that numerous changes, modifications, and alternatives to the preceding disclosure can be made without departing from the scope of the disclosure. The preceding description, therefore, is not meant to limit the scope of the disclosure. Rather, the scope of the disclosure is to be determined only by the appended claims and their equivalents. It is also contemplated that structures and features in the present examples can be altered, rearranged, substituted, deleted, duplicated, combined, or added to each other.

[0093] The articles “the”, “a” and “an” are not necessarily limited to mean only one, but rather are inclusive and open ended so as to include, optionally, multiple such elements.

CLAIMS

What is claimed is:

1. A method for startup of a distillation tower, the method comprising:
maintaining a rectifier section in the distillation tower;
5 maintaining a lower section in the distillation tower that is configured to form solids from a contaminant within a stream that enters the distillation tower;
feeding the stream to the lower section;
directly feeding methane to at least one of the rectifier section and a rectifier section outlet line of the rectifier section when a contaminant concentration of the contaminant
10 exiting as a vapor in an upper portion of the lower section is outside of a predetermined concentration;
introducing the vapor from the lower section to the rectifier section when the contaminant concentration exiting the upper portion of the lower section is within the predetermined concentration.
- 15 2. The method of claim 1, further comprising:
producing hydrocarbons from the distillation tower.
3. The method of claim 1 or 2, wherein the predetermined concentration is between 2 and 7 percent.
4. The method of any one of claims 1 to 3, wherein the predetermined concentration is
20 between 3 and 6 percent.
5. The method of any one of claims 1 to 4, further comprising discontinuing directly feeding methane to the rectifier section when the contaminant concentration exiting the upper portion of the lower section is within the predetermined concentration.
6. The method of any one of claims 1 to 5, further comprising chilling the stream before
25 the stream enters the lower section.
7. The method of any one of claims 1 to 6, further comprising heating the stream exiting a lower portion of the lower section with a reboiler.
8. The method of any one of claims 1 to 7, further comprising discontinuously feeding spray from the rectifier section to the lower section when a melt tray amount of liquid in a

melt tray assembly of the lower section is below a predetermined melt tray amount.

9. The method of claim 8, wherein discontinuously feeding spray comprises discontinuously introducing the spray from the rectifier section to a spray assembly in the lower section.

5 10. The method of claim 8 or 9, wherein discontinuously feeding spray occurs before the vapor exits the lower section.

11. The method of any one of claims 1 to 7, further comprising continuously feeding spray from the rectifier section to the lower section when the melt tray amount is greater than or equal to the predetermined melt tray amount.

10 12. The method of claim 11, wherein continuously feeding spray comprises continuously introducing the spray from the rectifier section to a spray assembly in the lower section.

13. The method of claim 11 or 12, wherein continuously feeding spray occurs before introducing the vapor from the lower section to the rectifier section.

14. The method of any one of claims 1 to 13, wherein the lower section comprises a
15 middle controlled freeze zone section and a stripper section.

15. The method of claim 14, wherein the middle controlled freeze zone section comprises the upper portion of the lower section.

16. The method of claim 14 or 15, wherein the stripper section comprises the lower portion of the lower section.

20 17. A distillation tower for startup, comprising:

a rectifier section;

a lower section configured to form solid from contaminant within a stream; and

a storage unit holding methane that fluidly connects to at least one of the rectifier section and a rectifier section outlet line of the rectifier section, wherein the lower section
25 introduces the contaminant exiting as a vapor from an upper portion of the lower section to the rectifier section when a contaminant concentration of the vapor exiting the upper portion of the lower section is within a predetermined concentration and wherein the lower section does not introduce the vapor from the lower section to the rectifier section when the contaminant concentration exiting the upper portion of the lower section is outside of the
30 predetermined concentration.

18. The method of claim 17, wherein the predetermined concentration is between 2 and 7 percent.
19. The method of claim 17 or 18, wherein the predetermined concentration is between 3 and 6 percent.
- 5 20. The method of any one of claims 17 to 19, further comprising a chiller that chills the stream before the stream enters the lower section.
21. The method of any one of claims 17 to 20, further comprising a reboiler that heats the stream exiting a lower portion of the lower section.
22. The method of any one of claims 17 to 21, wherein the lower section comprises a
10 spray assembly and a melt tray, wherein the lower section discontinuously receives spray from the rectifier section to the lower section when a melt tray amount of liquid in the melt tray assembly is below a predetermined melt tray amount.
23. The method of any one of claims 17 to 21, wherein the lower section comprises a
15 spray assembly and a melt tray, wherein the lower section continuously receives spray from the rectifier section to the lower section when a melt tray amount of liquid in the melt tray assembly is greater than or equal to a predetermined melt tray amount.
24. The method of any one of claims 17 to 23, wherein the lower section comprises a middle controlled freeze zone section and a stripper section.
25. The method of claim 24, wherein the middle controlled freeze zone section comprises
20 the upper portion of the lower section.
26. The method of claim 24 or 25, wherein the stripper section comprises the lower portion of the lower section.