

**METHOD AND DEVICE FOR SEPARATING HYDROCARBONS AND
CONTAMINANTS WITH A SURFACE TREATMENT MECHANISM**

CROSS REFERENCE TO RELATED APPLICATIONS

- 5 **[0001]** This application claims the priority benefit of both United States Provisional patent application number 61/912,987 filed on December 6, 2013 entitled METHOD AND DEVICE FOR SEPARATING HYDROCARBONS AND CONTAMINANTS WITH A SURFACE TREATMENT MECHANISM, the entirety of which is incorporated by reference herein.
- 10 **[0002]** This application is related to but does not claim priority to U.S. Provisional patent application numbers: 61/912,957 filed on December 6, 2013 entitled METHOD AND DEVICE FOR SEPARATING HYDROCARBONS AND CONTAMINANTS WITH A SPRAY ASSEMBLY; 62/044,770 filed on September 2, 2014 entitled METHOD AND DEVICE FOR SEPARATING HYDROCARBONS AND CONTAMINANTS WITH A
- 15 SPRAY ASSEMBLY; 61/912,959 filed on December 6, 2013 entitled METHOD AND SYSTEM OF MAINTAINING A LIQUID LEVEL IN A DISTILLATION TOWER; 61/912,964 filed on December 6, 2013 entitled METHOD AND DEVICE FOR SEPARATING A FEED STREAM USING RADIATION DETECTORS; 61/912,970 filed on December 6, 2013 entitled METHOD AND SYSTEM OF DEHYDRATING A FEED
- 20 STREAM PROCESSED IN A DISTILLATION TOWER; 61/912,975 filed on December 6, 2013 entitled METHOD AND SYSTEM FOR SEPARATING A FEED STREAM WITH A FEED STREAM DISTRIBUTION MECHANISM; 61/912,978 filed on December 6, 2013 entitled METHOD AND SYSTEM FOR PREVENTING ACCUMULATION OF SOLIDS IN A DISTILLATION TOWER; 61/912,983 filed on December 6, 2013 entitled METHOD
- 25 OF REMOVING SOLIDS BY MODIFYING A LIQUID LEVEL IN A DISTILLATION TOWER; 61/912,984 filed on December 6, 2013 entitled METHOD AND SYSTEM OF MODIFYING A LIQUID LEVEL DURING START-UP OPERATIONS; 61/912,986 filed on December 6, 2013 entitled METHOD AND DEVICE FOR SEPARATING HYDROCARBONS AND CONTAMINANTS WITH A HEATING MECHANISM TO
- 30 DESTABILIZE AND/OR PREVENT ADHESION OF SOLIDS.

BACKGROUND

Fields of Disclosure

[0001] The disclosure relates generally to the field of fluid separation. More specifically, the disclosure relates to the cryogenic separation of contaminants, such as acid gas, from a hydrocarbon.

Description of Related Art

[0002] 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.

[0003] 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.”

[0004] 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. Some contaminants, like sulfur-bearing compounds, are noxious and may even be lethal. Additionally, in the presence of water some contaminants can become quite corrosive.

[0005] 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.

[0006] 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 (physical, chemical and hybrids), adsorption by solids, and distillation.

[0007] 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 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.

[0008] 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 pressure takes place in a controlled freeze zone section.

[0009] Sometimes solids can adhere to an internal (e.g., controlled freeze zone wall) of the controlled freeze zone section rather than falling to the bottom of the controlled freeze zone section.

[0010] The adherence is disadvantageous. The adherence, if uncontrolled, can interfere with the proper operation of the controlled freeze zone and the effective separation of methane from the contaminants.

[0011] A need exists for improved technology to prevent and/or destabilize any adhesion of solids to surface(s) in the controlled freeze zone section.

SUMMARY

[0012] The present disclosure provides a device and method for separating contaminants from hydrocarbons and preventing and/or destabilizing the adhesion of solids to surface(s) in the controlled freeze zone section, among other things.

[0013] A method for separating a feed stream in a distillation tower may comprise maintaining a controlled freeze zone section in the distillation tower that forms solids from a feed stream, wherein the controlled freeze zone section includes one or more internally disposed elements and a controlled freeze zone wall having an internal wall surface inside of

the distillation tower, modifying at least one of the internally disposed elements, the internal wall surface, or both with a treatment mechanism that includes at least one of (a) removing portions of the internal wall surface and (b) applying a coating surface, introducing the feed stream into the controlled freeze zone section, forming the solids from the feed stream in the controlled freeze zone section, and at least one of preventing and destabilizing adhesion of the solids to the internal wall surface with the treatment mechanism.

[0014] A method for producing hydrocarbons may comprise maintaining a controlled freeze zone section in the distillation tower that forms solids from a feed stream, wherein the controlled freeze zone section includes internally disposed elements and a controlled freeze zone wall having an internal wall surface inside of the distillation tower, modifying at least one of the elements, the internal wall surface, or both with a treatment mechanism that includes at least one of (a) removing portions of the internal wall surface and (b) applying a coating surface, introducing the feed stream into the controlled freeze zone section, forming solids from the feed stream in the controlled freeze zone section, at least one of preventing and destabilizing adhesion of the solids to the internal wall surface with the treatment mechanism, and producing hydrocarbons in the feed stream from the distillation tower.

[0015] A distillation tower that separates a contaminant in a feed stream from a hydrocarbon in the feed stream may comprise a stripper section constructed and arranged to separate a feed stream, comprising a contaminant and a hydrocarbon, into an enriched contaminant bottom liquid stream, comprising the contaminant, and a freezing zone vapor stream, comprising the hydrocarbon, without forming solids; and a controlled freeze zone comprising: a spray assembly constructed and arranged to form the solid; an internal wall surface, inside of the distillation tower, at least one of having a substantially smooth surface and a coating surface, wherein the coating surface is inside of the distillation tower and is an outermost surface of the internal wall surface.

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

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 tower with sections within a single vessel.

[0019] Figure 2 is a schematic diagram of a tower with sections within multiple vessels.

[0020] Figure 3 is a schematic diagram of a tower with sections within a single vessel.

[0021] Figure 4 is a schematic diagram of a tower with sections within multiple vessels.

5 [0022] Figure 5 is a schematic, cross-sectional diagram of the controlled freeze zone section of a distillation tower with a treatment mechanism.

[0023] Figure 6 is a schematic, cross-sectional diagram of the controlled freeze zone section of a distillation tower with a treatment mechanism.

10 [0024] Figure 7 is a schematic, cross-section diagram of the controlled freeze zone section of a distillation tower with a treatment mechanism and a closing element.

[0025] Figure 8 is a schematic, cross-section diagram of the controlled freeze zone section of a distillation tower with a treatment mechanism and a closing element.

[0026] Figure 9 is a flowchart of a method within the scope of the present disclosure.

15 [0027] 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 drawn to scale, but are drafted for purposes of convenience and clarity in illustrating various aspects of the disclosure.

DETAILED DESCRIPTION

20 [0028] 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 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.

25 It will be apparent to those skilled in the relevant art that some features that are not relevant to the present disclosure may not be shown in the drawings for the sake of clarity.

[0029] 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

30 gas, from contaminants. Although the phrases “gas stream,” “vapor stream,” and “liquid

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.

5 **[0030]** The disclosure relates to a system and method for separating a feed stream in a distillation tower. The system and method helps prevent and/or destabilize adhesion of solids in the controlled freeze zone section of the distillation tower by at least one of (a) removing portions of a surface within the controlled freeze zone section and (b) applying a coating surface to surfaces within the controlled freeze zone section. Figures 1-9 of the disclosure
10 display various aspects of the system and method

[0031] The system and method may separate a feed stream having methane and contaminants. The system may comprise a distillation tower **104, 204** (Figures 1-4). The distillation tower **104, 204** may separate the contaminants from the methane.

[0032] The distillation tower **104, 204** may be separated into three functional sections: a
15 lower section **106**, a middle controlled freeze zone section **108** and an upper section **110**. The distillation tower **104, 204** may incorporate three functional sections when the upper section **110** is needed and/or desired.

[0033] The distillation tower **104, 204** may incorporate only two functional sections when
20 the upper section **110** is not needed and/or desired. When the distillation tower does not include an upper section **110**, a portion of vapor leaving the middle controlled freeze zone section **108** may be condensed in a condenser **122** and returned as a liquid stream via a spray assembly **129**. Moreover, lines **18** and **20** may be eliminated, elements **124** and **126** may be one and the same, and elements **150** and **128** may be one and the same. The stream in line **14**, now taking the vapors leaving the middle controlled freeze section **108**, directs these
25 vapors to the condenser **122**.

[0034] The lower section **106** may also be referred to as a stripper section. The middle controlled freeze zone section **108** may also be referred to as a controlled freeze zone section. The upper section **110** may also be referred to as a rectifier section.

[0035] The sections of the distillation tower **104** may be housed within a single vessel
30 (Figures 1 and 3). For example, the lower section **106**, the middle controlled freeze zone section **108**, and the upper section **110** may be housed within a single vessel **164**.

[0036] The sections of the distillation tower **204** may be housed within a plurality of vessels to form a split-tower configuration (Figure 2). Each of the vessels may be separate from the other vessels. Piping and/or another suitable mechanism may connect one vessel to another vessel. In this instance, the lower section **106**, middle controlled freeze zone section **108** and upper section **110** may be housed within two or more vessels. For example, as shown in Figure 2, the upper section **110** may be housed within a single vessel **254** and the lower and middle controlled freeze zone sections **106**, **108** may be housed within a single vessel **264**. When this is the case, a liquid stream exiting the upper section **110**, may exit through a liquid outlet bottom **260**. The liquid outlet bottom **260** is at the bottom of the upper section **110**. Although not shown, each of the sections may be housed within its own separate vessel, or one or more section may be housed within separate vessels, or the upper and middle controlled freeze zone sections may be housed within a single vessel and the lower section may be housed within a single vessel, etc. When sections of the distillation tower are housed within vessels, the vessels may be side-by-side along a horizontal line and/or above each other along a vertical line.

[0037] The split-tower configuration may be beneficial in situations where the height of the distillation tower, motion considerations, and/or transportation issues, such as for remote locations, need to be considered. This split-tower configuration allows for the independent operation of one or more sections. For example, when the upper section is housed within a single vessel and the lower and middle controlled freeze zone sections are housed within a single vessel, independent generation of reflux liquids using a substantially contaminant-free, largely hydrocarbon stream from a packed gas pipeline or an adjacent hydrocarbon line, may occur in the upper section. And the reflux may be used to cool the upper section, establish an appropriate temperature profile in the upper section, and/or build up liquid inventory at the bottom of the upper section to serve as an initial source of spray liquids for the middle controlled freeze zone section. Moreover, the middle controlled freeze zone and lower sections may be independently prepared by chilling the feed stream, feeding it to the optimal location be that in the lower section or in the middle controlled freeze zone section, generating liquids for the lower and the middle controlled freeze zone sections, and disposing the vapors off the middle controlled freeze zone section while they are off specification with too high a contaminant content. Also, liquid from the upper section may be intermittently or continuously sprayed, building up liquid level in the bottom of the middle controlled freeze zone section and bringing the contaminant content in the middle controlled freeze zone

section down and near steady state level so that the two vessels may be connected to send the vapor stream from the middle controlled freeze zone section to the upper section, continuously spraying liquid from the bottom of the upper section into the middle controlled freeze zone section and stabilizing operations into steady state conditions. The split tower
5 configuration may utilize a sump of the upper section as a liquid receiver for the pump **128**, therefore obviating the need for a liquid receiver **126** in Figures 1 and 3.

[0038] The system may also include a heat exchanger **100** (Figures 1-2). The feed stream **10** may enter the heat exchanger **100** before entering the distillation tower **104**, **204**. The feed stream **10** may be cooled within the heat exchanger **100**. The heat exchanger **100**
10 helps drop the temperature of the feed stream **10** to a level suitable for introduction into the distillation tower **104**, **204**.

[0039] The system may include an expander device **102** (Figures 1-4). The feed stream **10** may enter the expander device **102** before entering the distillation tower **104**, **204**. The feed stream **10** may be expanded in the expander device **102** after exiting the heat exchanger
15 **100**. The expander device **102** helps drop the temperature of the feed stream **10** to a level suitable for introduction into the distillation tower **104**, **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 **104**, **204**. For example, the valve **102** may comprise a Joule-Thompson (J-
20 T) valve.

[0040] The system may include a feed separator **103** (Figures 3-4). The feed stream may enter the feed separator before entering the distillation tower **104**, **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 **104**, **204**.
25 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 sections (i.e. middle controlled freeze zone, and lower sections) of the distillation tower **104**, **204**. The expander device **102** may or may not be downstream of the feed separator **103**. The expander device **102** may comprise a plurality of
30 expander devices **102** such that each line **12** has an expander device **102**.

[0041] The system may include a dehydration unit **261** (Figures 1-4). The feed stream **10** may enter the dehydration unit **261** before entering the distillation tower **104**, **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 **104**, **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.
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- [0042]** The systems may include a filtering unit (not shown). The feed stream **10** may enter the filtering unit before entering the distillation tower **104**, **204**. The filtering unit may remove undesirable contaminants from the feed stream before the feed stream enters the distillation tower **104**, **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
- 15 **100**.
- [0043]** The system may include a line **12** (Figures 1-4). The line may also be referred to as an inlet channel **12**. The feed stream **10** may be introduced into the distillation tower **104**, **204** through the line **12**. The line **12** may extend to the lower section **106** or the middle controlled freeze zone section **108** of the distillation tower **104**, **204**. For example, the line **12**
- 20 may extend to the lower section **106** such that the feed stream **10** may enter the lower section **106** of the distillation tower **104**, **204** (Figures 1-4). The line **12** may directly or indirectly extend to the lower section **106** or the middle controlled freeze zone section **108**. The line **12** may extend to an outer surface of the distillation tower **104**, **204** before entering the distillation tower.
- [0044]** If the system includes the feed separator **103** (Figures 3-4), the line **12** may comprise a plurality of lines **12**. Each line may be the same line as one of the lines that extends from the feed separator to a specific portion of the distillation tower **104**, **204**.
- [0045]** The lower 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 lower 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
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of methane than of contaminants. In any case, the vapor stream is lighter than the liquid stream. As a result, the vapor stream rises from the lower section **106** and the liquid stream falls to the bottom of the lower section **106**.

5 **[0046]** The lower 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 (Figures 1-4).

10 **[0047]** The equipment may include components that apply heat to the stream to form the vapor stream and the liquid stream. For example, the equipment may comprise a first reboiler **112** that applies heat to the stream. The first reboiler **112** may be located outside of the distillation tower **104**, **204**. The equipment may also comprise a second reboiler **172** that applies heat to the stream. The second reboiler **172** may be located outside of the distillation tower **104**, **204**. Line **117** may lead from the distillation tower to the second reboiler **172**. Line **17** may lead from the second reboiler **172** to the distillation tower. Additional reboilers,
15 set up similarly to the second reboiler described above, may also be used.

20 **[0048]** The first reboiler **112** may apply heat to the liquid stream that exits the lower section **106** through a liquid outlet **160** of the lower section **106**. The liquid stream may travel from the liquid outlet **160** through line **28** to reach the first reboiler **112** (Figures 1-4). 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.

25 **[0049]** The first reboiler **112** may also apply heat to the stream within the distillation tower **104**, **204**. Specifically, the heat applied by the first reboiler **112** warms up the lower section **106**. This heat travels up the lower section **106** and supplies heat to warm solids entering a melt tray assembly **139** (Figures 1-4) of the middle controlled freeze zone section **108** so that the solids form a liquid and/or slurry mix.

30 **[0050]** The second reboiler **172** applies heat to the stream within the lower 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.

[0051] 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.

[0052] The equipment may include one or more chimney assemblies **135** (Figures 1-4).
5 While falling to the bottom of the lower section **106**, the liquid stream may encounter one or more of the chimney assemblies **135**.

[0053] Each chimney assembly **135** includes a chimney tray **131** that collects the liquid stream within the lower section **106**. 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
10 **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 assembly **139**. Unvaporized stream exiting the second reboiler **172** may be fed back to the distillation tower **104, 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
15 tower **104, 204**.

[0054] The chimney tray **131** may include one or more chimneys **137**. The chimney **137** serves as a channel that the vapor stream in the lower 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 is closer to the bottom of the lower section **106**
20 than it is to the bottom of the middle controlled freeze zone section **108**. The top is closer to the bottom of the middle controlled freeze zone section **108** than it is to the bottom of the lower section **106**.

[0055] 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
25 liquid stream from entering the chimney **137**. The vapor stream exits the chimney assembly **135** via the chimney top opening **138**.

[0056] After falling to the bottom of the lower section **106**, the liquid stream exits the distillation tower **104, 204** through the liquid outlet **160**. The liquid outlet **160** is within the lower section **106** (Figures 1-2). The liquid outlet **160** may be located at the bottom of the
30 lower section **106**.

[0057] 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**. Unvaporized liquid may continue out of the distillation process via line **24**.

[0058] The system may include an expander device **114** (Figures 1-4). After entering 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.

[0059] The system may include a heat exchanger **116** (Figures 1-4). The liquid stream heated by the first reboiler **112** 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.

[0060] The vapor stream in the lower section **106** rises from the lower section **106** to the middle controlled freeze zone section **108**. The middle controlled freeze zone section **108** is constructed and arranged to separate the feed stream **10** introduced into the middle controlled freeze zone section, or into the top of lower section **106**, into a solid and a vapor stream. The solid may be comprised more of contaminants than of methane. The vapor stream (i.e., methane-enriched vapor stream) may comprise more methane than contaminants.

[0061] The middle controlled freeze zone section **108** includes a lower section **40** and an upper section **39** (Figure 5). The lower section **40** is below the upper section **39**. The lower section **40** directly abuts the upper section **39**. The lower section **40** is primarily but not exclusively a heating section of the middle controlled freeze zone section **108**. The upper section **39** is primarily but not exclusively a cooling section of the middle controlled freeze zone section **108**. The temperature and pressure of the upper section **39** are chosen so that the solid can form in the middle controlled freeze zone section **108**.

[0062] As shown in Figures 5-8, the middle controlled freeze zone section **108** may comprise an internal wall surface **31**. The internal wall surface **31** is part of the controlled freeze zone wall **46**.

[0063] The middle controlled freeze zone section **108** may also comprise a spray assembly **129**. The spray assembly **129** cools the vapor stream that rises from the lower section **40**. The spray assembly **129** sprays liquid, which is cooler than the vapor stream, on the vapor stream to cool the vapor stream. The spray assembly **129** is within the upper section **39**. The spray assembly **129** is not within the lower section **40**.

[0064] The spray assembly **129** includes one or more spray nozzles **120** (Figures 1-4). Each spray nozzle **120** sprays liquid on the vapor stream. The spray assembly **129** may also include a spray pump **128** (Figures 1-4) that pumps the liquid. The spray pump **128** pumps the liquid to one or more spray heads of spray assembly **129** and/or spray nozzles. Instead of
5 a spray pump **128**, gravity may induce flow in the liquid.

[0065] The liquid sprayed by the spray assembly **129** contacts the vapor stream at a temperature and pressure at which solids form. Solids, containing mainly contaminants, form when the sprayed liquid contacts the vapor stream. The solids fall toward the melt tray assembly **139**.

10 [0066] The spray assembly **129** includes the one or more spray heads **35**. Each spray nozzle **120** is constructed and arranged to inject the liquid from the spray assembly **129** into the middle controlled freeze zone section **108**. Each spray head **35** is coupled to one of the spray nozzles **120**.

[0067] The temperature in the middle controlled freeze zone section **108** cools down as
15 the vapor stream travels from the bottom of the middle controlled freeze zone section **108** to the top of the middle controlled freeze zone section **108**. The methane in the vapor stream rises from the middle controlled freeze zone section **108** to the upper section **110**. Some contaminants may remain in the methane and also rise. The contaminants in the vapor stream tend to condense or solidify with the colder temperatures and fall to the bottom of the middle
20 controlled freeze zone section **108**.

[0068] As shown in Figures 5-8, the internal wall surface **31** of the middle controlled freeze zone section **108** may be modified with a treatment mechanism **36**, **136**. The treatment mechanism **36**, **136** is constructed and arranged to prevent and/or destabilize adhesion of the solid to the controlled freeze zone wall **46**. The treatment mechanism **36**, **136** prevents
25 and/or destabilizes adhesion of the solid by making a surface of the controlled freeze zone wall **46** substantially smooth such that any solid in the middle controlled freeze zone section **108** cannot adhere to the controlled freeze zone wall **46**. In other words, any protrusions previously on the controlled freeze zone wall **46** that a solid may latch on to are smoothed by the treatment mechanism to a point where it is difficult to impossible for the solid to latch
30 onto the internal wall surface **31**. The treatment mechanism may include at least one of (a) removing portions of the internal wall surface to obtain a substantially smooth surface **36** and (b) modifying the internal wall surface **31** to include a coating surface **136**.

[0069] Removing portions of the internal wall surface may include any treatment mechanism that can obtain a substantially smooth surface 36. For example, the treatment mechanism may include at least one of mechanically and electrically removing material from the internal wall surface 31. Mechanically removing material from the internal wall surface 31 may, for example, include sanding, grinding, sandblasting, and/or mechanically polishing the internal wall surface 31. Electrically removing material from the internal wall surface 31 may, for example, include electropolishing the internal wall surface 31 and/or laser ablating the internal wall surface 31. When the internal wall surface 31 is electropolished, an electrically-conductive solution may be held against the internal wall surface 31 while electric current passes through the electrically-conductive solution. The electropolishing may remove peaks of internal wall surface 31 from the internal wall surface 31 on a microscopic scale. Electrically removing the material may be preferred to mechanically removing the material because it may be easier to obtain a substantially smooth surface 36 that is a homogenously smooth surface. Regardless of the mechanism, the mechanism involves removing a fine layer of molecules, and particularly protruding molecules, of the internal wall surface 31 to obtain an internal wall surface 31 that is smooth. The obtained internal wall surface 31, such as in the case of electrically removing the material, may also have a nearly mirror-finish surface. The obtained smooth surface is so smooth that it is hard for a solid to adhere to the internal wall surface 31.

[0070] The coating surface 136 is part of the internal wall surface 31. The coating surface 136 may be any suitable coating surface that can withstand cryogenic temperatures. The coating surface 136 may be any suitable coating surface that provides non-stick characteristics. For example, the coating surface 136 may be polytetrafluoroethylene. Polytetrafluoroethylene may be a good coating surface because it's considered to be low energy and can be made very smooth. Specifically, it does not easily attract to other components so it's harder for other components to adhere to it. Once applied, the coating surface 136 may be the innermost surface of the internal wall surface 31 within the inside of the distillation tower 104, 204. The coating surface 136 may be any suitable thickness. For example, the coating thickness 136 may be 100 microns to 300 microns or about 100 microns to 300 microns. Alternatively, the coating thickness 136 may be 100 microns to 1 mm or about 100 microns to 1 mm.

[0071] As shown in Figures 7-8, the controlled freeze zone wall 46 may include a wall opening 57. The wall opening 57 may protrude (i.e., extending away from the longitudinal

axis of the distillation tower **104, 204**) away from the internal wall surface **31**. Solids may build-up in and around the wall opening **57**; solids may latch onto the wall opening **57** and/or the area immediately around the wall opening **57**. To prevent the build-up of solids in and around the wall opening **57**, the middle controlled freeze zone section **108** may include an
5 insert or closing element **55**.

[0072] The closing element **55** may be any suitable shape that can fit within the wall opening **57** and whose closing element inner surface **56** is substantially flush with the internal wall surface **31**. The closing element inner surface **56** is the outermost surface of the closing element **55** within the inside of the distillation tower **104, 204**. The closing element inner
10 surface **56** is smooth enough to prevent and/or destabilize the adhesion of a solid. To be smooth enough, any suitable mechanism may be used on the closing element inner surface **56**. For example, the closing element inner surface **56** may be coated with a coating surface, such as the coating surface previously described, or portions of the closing element inner surface **56** may be removed, such as by using any of the mechanical and electrical surface
15 treatment means previously described.

[0073] In addition to including the internal wall surface **31** modified by the treatment mechanism, one or more internally disposed elements within the middle controlled freeze zone section **108** may be modified with the treatment mechanism. Internally disposed elements within the middle controlled freeze zone section **108** may include the spray
20 assembly **129**, the melt tray assembly **139**, instruments, sensors, etc. Internally disposed elements within the middle controlled freeze zone section **108** are separate components from the internal wall surface **31**. To modify the one or more internally disposed elements, an internally disposed element surface of each internally disposed element may be modified by the treatment mechanism. The internally disposed element surface may be an outer surface
25 of the internally disposed element. Once the internally disposed element surface is modified, the internally disposed element surface may be a substantially smooth surface such that any solids in the middle controlled freeze zone section **108** cannot latch on to the internally disposed element. The substantially smooth surface may be a homogenously smooth surface.

[0074] When the internal wall surface **31** is modified by the treatment mechanism, the
30 middle controlled freeze zone section **108** may or may not include a heating mechanism, such as the heating mechanism described in the application entitled "Method and Device for Separating Hydrocarbons and Contaminants with a Heating Mechanism to Destabilize and/or Prevent Adhesion of Solids" by Jaime Valencia, et al. and filed on the same day as the instant

application. The modified internal wall surface **31** may adequately prevent and/or destabilize the adhesion of solids to the controlled freeze zone wall **46** without the heating mechanism. If the modified internal wall surface **31** is modified by a treatment mechanism that comprises a coating surface, the modified internal wall surface **31** may act as an insulator to the heat being conducted from outside of the distillation tower **104**, **204**. Nevertheless, the heating mechanism, in this instance, may be turned on if the surface modified by the treatment mechanism does not prevent solid build-up.

[0075] The middle controlled freeze zone section **108** may comprise a melt tray assembly **139** that is maintained in the middle controlled freeze zone section **108** (Figures 1-5). The melt tray assembly **139** is within the lower section **40** of the middle controlled freeze zone section **108**. The melt tray assembly **139** is not within the upper section **39** of the middle controlled freeze zone section **108**.

[0076] The melt tray assembly **139** is constructed and arranged to melt a solid formed in the middle controlled freeze zone section **108**. When the warm vapor stream rises from the lower 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 solid. 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(s) **134**.

[0077] The melt tray **118** may collect a liquid and/or slurry mix. The melt tray **118** divides at least a portion of the middle controlled freeze zone section **108** from the lower section **106**. Consequently, the melt tray **118** is at the bottom **45** of the middle controlled freeze zone section **108**.

[0078] One or more bubble caps **132** may act as a channel for the vapor stream rising from the lower section **106** to the middle controlled freeze zone section **108**. The bubble cap **132** may provide a path for the vapor stream up the 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**.

[0079] One or more heat mechanisms **134** may further heat up the liquid **130** to facilitate melting of the solids into a liquid and/or slurry mix. The heat mechanism(s) **134** may be located anywhere within the melt tray assembly **139**. For example, as shown in Figures 1-4,

a heat mechanism **134** may be located around bubble caps **132**. The heat 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.

5 **[0080]** The liquid **130** in the melt tray assembly is heated by the vapor stream. The liquid **130** may also be heated by the one or more heat mechanisms **134**. The liquid **130** helps melt the solids formed in the middle controlled freeze zone section **108** into a liquid and/or slurry mix. Specifically, the heat transferred by the vapor stream heats up the liquid, thereby enabling the heat to melt the solids. The liquid **130** is at a level sufficient to melt the solids.

10 **[0081]** 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 lower distillation section **106**. The liquid and/or slurry mix flows from the bottom of the middle controlled freeze zone section **108** to the top of the lower section **106** via a line **22** (Figures 1-4). The line **22** may be an exterior line. The line **22** may extend from the distillation tower **104, 204**. The line **22** may extend from the middle controlled freeze zone section **108**. The
15 line may extend to the lower section **106**. The line **22** may extend from an outer surface of the distillation tower **104, 204**.

20 **[0082]** The vapor stream that rises in the middle controlled freeze zone section **108** and does not form solids or otherwise fall to the bottom of the middle controlled freeze zone section **108**, rises to the upper section **110**. The upper section **110** operates at a temperature and pressure and contaminant concentration at which no solid forms. The upper section **110** is constructed and arranged to cool the vapor stream to separate the methane from the contaminants. Reflux in the upper section **110** cools the vapor stream. The reflux is introduced into the upper section **110** via line **18**. Line **18** may extend to the upper section **110**. Line **18** may extend from an outer surface of the distillation tower **104, 204**.

25 **[0083]** After contacting the reflux in the upper section **110**, the feed stream forms a vapor stream and a liquid stream. The vapor stream mainly comprises methane. The liquid stream comprises relatively more contaminants. The vapor stream rises in the upper section **110** and the liquid falls to a bottom of the upper section **110**.

30 **[0084]** To facilitate separation of the methane from the contaminants when the stream contacts the reflux, the upper section **110** may include one or more mass transfer devices **176**. Each mass transfer device **176** helps separate the methane from the contaminants. Each mass transfer device **176** may comprise any suitable separation device, such as a tray with

perforations, or a section of random or structured packing to facilitate contact of the vapor and liquid phases.

5 [0085] After rising, the vapor stream may exit the distillation tower **104, 204** through line **14**. The line **14** may emanate from an upper part of the upper section **110**. The line **14** may extend from an outer surface of the upper section **110**.

[0086] From line **14**, the vapor stream may enter a condenser **122**. The condenser **122** cools the vapor stream to form a cooled stream. The condenser **122** at least partially condenses the stream.

10 [0087] After exiting the condenser **122**, the cooled stream may enter a separator **124**. The separator **124** separates the vapor stream into liquid and vapor streams. The separator may be any suitable separator that can separate a stream into liquid and vapor streams, such as a reflux drum.

15 [0088] Once separated, the vapor stream may exit the separator **124** as sales product. The sales product may travel through line **16** for subsequent sale to a pipeline and/or condensation to be liquefied natural gas.

[0089] Once separated, the liquid stream may return to the upper section **110** through line **18** as the reflux. The reflux may travel to the upper section **110** via any suitable mechanism, such as a reflux pump **150** (Figures 1 and 3) or gravity (Figures 2 and 4).

20 [0090] The liquid stream (i.e., freezing zone liquid stream) that falls to the bottom of the upper section **110** collects at the bottom of the upper section **110**. The liquid may collect on tray **183** (Figures 1 and 3) or at the bottommost portion of the upper section **110** (Figures 2 and 4). The collected liquid may exit the distillation tower **104, 204** through line **20** (Figures 1 and 3) or outlet **260** (Figures 2 and 4). The line **20** may emanate from the upper section **110**. The line **20** may emanate from a bottom end of the upper section **110**. The line **20** may extend from an outer surface of the upper section **110**.

[0091] The line **20** and/or outlet **260** connect to a line **41**. The line **41** leads to the spray assembly **129** in the middle controlled freeze zone section **108**. The line **41** emanates from the holding vessel **126**. The line **41** may extend to an outer surface of the middle controlled freeze zone section **108**.

30 [0092] The line **20** and/or outlet **260** may directly or indirectly (Figures 1-4) connect to the line **41**. When the line **20** and/or outlet **260** directly connect to the line **41**, the liquid

spray may be sent to the spray nozzle(s) **120** via any suitable mechanism, such as the spray pump **128** or gravity. When the line **20** and/or outlet **260** indirectly connect to the line **41**, the lines **20**, **41** and/or outlet **260** and line **41** may directly connect to a holding vessel **126** (Figures 1 and 3). The holding vessel **126** may house at least some of the liquid spray before
5 it is sprayed by the nozzle(s). The liquid spray may be sent from the holding vessel **126** to the spray nozzle(s) **120** via any suitable mechanism, such as the spray pump **128** (Figures 1-4) or gravity. The holding vessel **126** may be needed when there is not a sufficient amount of liquid stream at the bottom of the upper section **110** to feed the spray nozzles **120**.

[0093] A method for separating a feed stream **10** in the distillation tower **104**, **204** and/or
10 producing hydrocarbons may include maintaining the lower section **106** in the distillation tower that separates the feed stream **10** into the enriched contaminant bottom liquid stream and the freezing zone vapor stream; maintaining the middle controlled freeze zone section **108** in the distillation tower **501** that applies the freezing zone liquid stream to form the solid and the hydrocarbon-enriched vapor stream **501** (Figure 9); and modifying the internal wall
15 surface **31** with the treatment mechanism **502** and preventing and/or destabilizing adhesion of the solid to the internal wall surface **31**, **506** (Figure 9). The method may include introducing **503** the feed stream **10** into a section **106**, **108** of the distillation tower **104**, **204** (Figure 9). As previously discussed in the instant application, the feed stream **10** is introduced into one of the sections **106**, **108** via line **12**. The method may include separating the feed stream **10**
20 in the lower section **106** into the enriched contaminant bottom liquid stream and the freezing zone vapor stream at a temperature and pressure at which substantially no solid forms. The lower section **106** operates as previously discussed in the instant application. The method may include forming the solids **504** from the feed stream in the controlled freeze zone section **108**. The solids may form when the freezing zone vapor stream and the freezing zone liquid
25 stream are injected into the middle controlled freeze zone section **108** at a temperature and pressure at which the solid and the hydrocarbon-enriched vapor stream form. The method may include mixing the freezing zone liquid stream with the freezing zone vapor stream in the controlled freeze zone section to form the solid and the hydrocarbon-enriched vapor stream. The middle controlled freeze zone section **108** operates as previously discussed in
30 the instant application. The method may include introducing the feed stream **503** into one of the lower section **106** and the middle controlled freeze zone section **108**. The method may include separating the feed stream **504** in the lower section **106** into the enriched contaminant bottom liquid stream and the freezing zone vapor stream. The method may include injecting

the freezing zone vapor stream **505** into the middle controlled freeze zone section **108** at a temperature and pressure at which the solid and the hydrocarbon-enriched vapor stream form. The method may include preventing and/or destabilizing adhesion of the solid from the middle controlled freeze zone section **506** (Figure 9).

5 **[0094]** The method may include maintaining an upper section **110**. The upper section **110** operates as previously discussed in the instant application. The method may also include separating the feed stream in the upper section **110** as previously discussed in the instant application.

10 **[0095]** The method may include sending the hydrocarbon-enriched stream to a pipeline for sale after it exits the distillation tower **104, 204** via the middle controlled freeze zone section **108** or upper section **110**. The method may include sending the hydrocarbon-enriched stream to an LNG plant after the hydrocarbon-enriched stream is processed to include less than 50 ppm of CO₂ in the distillation tower **104, 204**. This stream may be sent to the LNG plant after exiting the distillation tower **104, 204** via the upper section. The
15 method may include removing the CO₂ enriched stream from the lower section **106** and injecting the CO₂ enriched stream downhole for disposal, or selling the CO₂ enriched stream for EOR purposes assuming this stream does not contain too much H₂S.

20 **[0096]** It is important to note that the steps depicted in Figure 9 are provided for illustrative purposes only and a particular step may not be required to perform the inventive methodology. Moreover, Figure 9 may not illustrate all the steps that may be performed. The claims, and only the claims, define the inventive system and methodology.

25 **[0097]** 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
30 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 in extracting hydrocarbons from a subsurface region and processing the hydrocarbons. Hydrocarbons and contaminants may be

extracted from a reservoir and processed. The hydrocarbons and contaminants may be processed, for example, in the distillation tower previously described. After the hydrocarbons and contaminants are processed, the hydrocarbons may be extracted from the processor, such as the distillation tower, and produced. The contaminants may be discharged
5 into the Earth, etc. For example, the method for producing hydrocarbons may also include removing the hydrocarbon-enriched vapor stream from the distillation tower. The method may also include producing 508 hydrocarbons in the feed stream from the distillation tower (Figure 9). The initial hydrocarbon extraction from the reservoir may be accomplished by drilling a well using hydrocarbon drilling equipment. The equipment and techniques used to
10 drill a well and/or extract these 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.

[0098] As utilized herein, the terms “approximately,” “about,” “substantially,” and similar terms are intended to have a broad meaning in harmony with the common and
15 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
20 inconsequential modifications or alterations of the subject matter described are considered to be within the scope of the disclosure.

[0099] For the purpose of this disclosure, the term “coupled” means the joining of two members directly or indirectly to one another. Such joining may be stationary or moveable in nature. Such joining may be achieved with the two members or the two members and any
25 additional intermediate members being integrally formed as a single unitary body with one another or with the two members or the two members and any additional intermediate members being attached to one another. Such joining may be permanent in nature or may be removable or releasable in nature.

[0100] It should be understood that numerous changes, modifications, and alternatives to
30 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.

[0101] 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

1. A method for separating a feed stream in a distillation tower comprising:
 - maintaining a controlled freeze zone section in the distillation tower that forms solids from a feed stream, wherein the controlled freeze zone section includes one or more internally disposed elements and a controlled freeze zone wall having an internal wall surface inside of the distillation tower;
 - modifying at least one of the internally disposed elements, the internal wall surface, or both with a treatment mechanism that includes mechanically removing portions of the internal wall surface wherein mechanically removing material comprises sanding, grinding, sandblasting, or mechanically polishing the internal wall surface;
 - introducing the feed stream into the controlled freeze zone section;
 - forming the solids from the feed stream in the controlled freeze zone section; and
 - at least one of preventing and destabilizing adhesion of the solids to the internal wall surface with the treatment mechanism.
2. The method of claim 1, further comprising:
 - modifying a surface of at least one of at least two internally disposed elements with a treatment mechanism, wherein the two internally disposed elements comprise a melt tray assembly and a spray assembly, and wherein at least one of the melt tray assembly and the spray assembly is separate from the internal wall surface; and
 - at least one of preventing and destabilizing adhesion of the solids to the at least one of the melt tray assembly and the spray assembly with the treatment mechanism.
3. The method of claim 1, further comprising inserting a closing element having a closing element inner surface into a wall opening of the controlled freeze zone wall, wherein the inserted closing element inner surface is substantially flush with the internal wall surface.
4. The method of claim 1 further comprising:
 - producing hydrocarbons in the feed stream from the distillation tower.

5. A distillation tower that separates a contaminant in a feed stream from a hydrocarbon in the feed stream, comprising:

a stripper section constructed and arranged to separate the feed stream, comprising the contaminant and a hydrocarbon, into an enriched contaminant bottom liquid stream, comprising the contaminant, and a freezing zone vapor stream, comprising the hydrocarbon, without forming solids; and

a controlled freeze zone comprising:

a spray assembly constructed and arranged to form the solids;

a melt tray assembly constructed and arranged to melt the solids;

an internal wall surface, inside of the distillation tower, wherein at least one of the spray assembly, melt tray assembly, and internal wall surface has a substantially smooth surface, wherein the substantially smooth surface has been produced by mechanically removing material by sanding, grinding, sandblasting, or mechanically polishing the internal wall surface.

6. The distillation tower of claim 5, wherein the controlled freeze zone wall includes a wall opening that protrudes away from the inside of the distillation tower.

7. The distillation tower of claim 6, further comprising a closing element within the wall opening, wherein the closing element includes a closing element inner surface that is substantially flush with the internal wall surface.

8. The distillation tower of claim 5, wherein the spray assembly includes a spray head and a spray nozzle, and wherein at least one of the spray head and the spray nozzle- have a substantially smooth surface.

9. The distillation tower of claim 5, further comprising a rectifier section constructed and arranged to separate the feedstream without forming solids.

10. The distillation tower of claim 9, wherein at least one of the stripping section, the controlled freeze zone section and the rectifier section are in a first vessel and another of the

at least one of the stripping section, the controlled freeze zone section and the rectifier section are in a second vessel that is separate from the first vessel.

11. The distillation tower of claim 9, wherein the stripping section and the controlled freeze zone section are in a first vessel and the rectifier section is in a second vessel that is separate from the first vessel.

12. A method for separating a feed stream in a distillation tower comprising:

(a) providing a distillation tower that separates a contaminant in a feed stream from a hydrocarbon in the feed stream, wherein the distillation tower comprises:

a stripper section; and

a controlled freeze zone comprising:

a spray assembly constructed and arranged to form the solids;

a melt tray assembly constructed and arranged to melt the solids; and

an internal wall surface, inside of the distillation tower,

wherein at least one of the spray assembly and melt tray assembly have a substantially smooth surface that has been produced by electropolishing at least one of the spray assembly and melt tray assembly; and

wherein the internal wall surface of the controlled freeze zone has a substantially smooth surface that has been produced by mechanically removing material by sanding, grinding, sandblasting, or mechanically polishing the internal wall surface;

(b) introducing the feed stream into the stripper section, wherein the stripper section operates to separate the feed stream and form an enriched contaminant bottom liquid stream and a freezing zone vapor stream and wherein the stripper section operates at a temperature and pressure at which no solids form;

(c) passing the freezing zone vapor stream from the stripper section to the controlled freeze zone;

(d) forming solids comprising the contaminant from the feed stream in the controlled freeze zone section;

wherein the substantially smooth surface of the internal wall surface and the at least one of the spray assembly and melt tray assembly operate to at least prevent or destabilize adhesion of the solids to the internal wall surface and the at least one of the spray assembly and melt tray assembly in the controlled freeze zone.

13. The method of claim 12, wherein the controlled freeze zone further comprises a wall opening that extends away from the internal wall surface of the controlled freeze zone at a longitudinal axis to the distillation tower;

wherein the wall opening comprises a closing element within the wall opening, wherein the closing element includes a closing element inner surface that is substantially flush with the internal wall surface of the controlled freeze zone.