

LIQUID COLLECTION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application 62/080,452, filed November 17, 2014, entitled LIQUID COLLECTION SYSTEM, the
5 entirety of which is incorporated by reference herein.

BACKGROUND

Fields of Disclosure

[0002] 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
10 hydrocarbon.

Description of Related Art

[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,
15 it should be understood that this section should be read in this light, and not necessarily as admissions of prior art.

[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
20 (“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.”

[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
25 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.

[0006] It is desirable to remove contaminants from a stream containing hydrocarbons to produce sweet and concentrated hydrocarbons. Specifications for pipeline quality natural gas
30 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 (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 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.

[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 pressure takes place in a controlled freeze zone section.

[0010] Some cryogenic distillation methods include a process to collect a liquid stream in a tray, heat the liquid stream to form a vapor, and re-introduce the vapor into the distillation process. Figures 1 and 2 show a portion of a fractionation column **1** designed to perform such a process. A heated vapor stream is introduced into the column **1** via inlets **2**. The vapor rises through risers or chimneys **3** and heats other portions of the cryogenic distillation process. Cooled vapor descends as liquid between chimneys **3** and falls on a draw tray deck, otherwise known as a chimney tray **4**. All or part of the liquid may be collected. Liquid on the chimney tray **4** is directed to a centralized collection trough **5** that equalizes the flow of the collected liquid to a collection sump(s) **6** through outlet nozzles **7** that are cut into the wall **8** of the fractionation column **1**. Outlet nozzles allow the liquid to transfer from the sump(s) **6** to the downcomer piping **9** and thereby exit the fractionation column **1**.

[0011] Conventional design practice limits the chimney tray 4 to accommodate either one or two outlet nozzles 7 through which the collected liquid passes out of the column and into the downcomer piping. If two outlet nozzles 7 are used, the outlet nozzles almost always are oriented at 180 degrees from each other, as shown in Figures 1 and 2. The outlet nozzles 7 may be positioned several feet above ground to provide a liquid static head, or pressure, in the downcomer piping 9 for required pump performance and / or desired heat exchanger operation. However, a constant head in the downcomer piping may not be possible if more than two outlet nozzles are used. Additionally, as sump extends into the fractionation column 1, the available diameter for fluid and vapor flow inside the fractionation column is reduced.

[0012] A need exists for improved technology that permits more than two outlet nozzles to be employed in a chimney tray assembly.

[0013] A need also exists for improved technology that reduces or eliminates the constriction or reduced diameter for fluid and/or vapor flow in a fractionation column due to a sump.

SUMMARY

[0014] The present disclosure provides an improved chimney tray assembly for use in a fractionation column.

[0015] In one aspect, an apparatus is disclosed for maintaining constant fluid pressure and equalized fluid flow among a plurality of downcomer lines through which liquid from a substantially cylindrical tower is directed. A substantially annular fluid distribution belt is disposed at the circumference of the tower. The fluid distribution belt collects liquid from the tower. At least two outlets direct liquid from the fluid distribution belt out of the tower and into a corresponding number of downcomer lines disposed external to the tower.

[0016] In another aspect, a method is disclosed for maintaining constant fluid pressure and equalized fluid flow among a plurality of downcomer lines through which liquid from a substantially cylindrical tower is directed. A substantially annular fluid distribution belt is disposed at the circumference of the tower. Liquid from the tower is collected in the fluid distribution belt. The liquid is directed from the fluid distribution belt out of the tower and into a corresponding number of downcomer lines disposed external to the tower.

[0017] In another aspect, a method of producing hydrocarbons is disclosed. Constant fluid pressure and equalized fluid flow is maintained among a plurality of downcomer lines

through which liquid from a substantially cylindrical tower is directed. A substantially annular fluid distribution belt is disposed at the circumference of the tower. Liquid from the tower is collected in the fluid distribution belt. Liquid is directed from the fluid distribution belt out of the tower and into a corresponding number of downcomer lines disposed external
5 to the tower. Hydrocarbons from the tower are produced.

[0018] 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

10 [0019] 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.

[0020] Figure 1 is a side elevational view of a portion of a distillation column or tower.

[0021] Figure 2 is a top plan view of the portion shown in Figure 1.

15 [0022] Figure 3 is a schematic diagram of a tower with sections within a single vessel.

[0023] Figure 4 is a schematic diagram of a tower with sections within multiple vessels.

[0024] Figure 5 is a schematic diagram of a tower with sections within a single vessel.

[0025] Figure 6 is a schematic diagram of a tower with sections within multiple vessels.

20 [0026] Figure 7 is a side elevational view of another portion of the distillation column or tower.

[0027] Figure 8 is a top plan view of a fluid distribution system according to the disclosure.

[0028] Figure 9 is a side elevational view of the fluid distribution system shown in Figure 8.

25 [0029] Figure 10 is a top plan view of another fluid distribution system according to the disclosure.

[0030] Figure 11 is a side elevational view of the fluid distribution system shown in Figure 10.

[0031] Figure 12 is a detail view of the fluid distribution system shown in Figures 10-11.

[0032] Figure 13 is a top plan view of another fluid distribution system according to the disclosure.

[0033] Figure 14 is a side elevational view of the fluid distribution system shown in Figure 13.

5 [0034] Figure 15 is a flowchart of a method according to the disclosure.

[0035] Figure 16 is a flowchart of another method according to the disclosure.

[0036] 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
10 aspects of the disclosure.

DETAILED DESCRIPTION

[0037] 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
15 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 to the present disclosure may not be shown in the drawings for the sake of clarity.

20 [0038] 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 stream,” refer to situations where a gas, vapor, and liquid is mainly present in the stream,
25 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.

[0039] The disclosure relates to a system and method for maintaining constant fluid pressure and equalized fluid flow among a plurality of downcomer lines through which liquid
30 from a substantially cylindrical tower is directed. Figures 3-16 of the disclosure display various aspects of the system and method. The disclosure demonstrates how such system and

method may be used beneficially in an application in a hydrocarbon distillation tower, and specifically in a distillation tower implementing a controlled freeze zone method as disclosed herein. However, it is to be understood that the system and method of the disclosure may be used in other types of towers where maintaining constant fluid pressure and and equalized
5 fluid flow is desired.

[0040] The system and method may separate a feed stream having methane and contaminants. The system may comprise a distillation tower **104**, **204** (Figures 3-6). The distillation tower **104**, **204** may separate the contaminants from the methane.

[0041] The distillation tower **104**, **204** may be separated into three functional sections: a
10 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.

[0042] The distillation tower **104**, **204** may incorporate only two functional sections when the upper section **110** is not needed and/or desired. When the distillation tower does not
15 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
20 vapors to the condenser **122**.

[0043] 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.

[0044] The sections of the distillation tower **104** may be housed within a single vessel
25 (Figures 3 and 5). 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**.

[0045] The sections of the distillation tower **204** may be housed within a plurality of vessels to form a split-tower configuration (Figures 4 and 6). Each of the vessels may be separate from the other vessels. Piping and/or another suitable mechanism may connect one
30 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 Figures 2 and 4, 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.

[0046] 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 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 3 and 5.

[0047] The system may also include a heat exchanger **100** (Figures 3-6). 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** helps drop the temperature of the feed stream **10** to a level suitable for introduction into the distillation tower **104**, **204**.

[0048] The system may include an expander device **102** (Figures 3-6). 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 **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-T) valve.

[0049] The system may include a feed separator **103** (Figures 5-6). 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**. 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 expander devices **102** such that each line **12** has an expander device **102**.

[0050] The system may include a dehydration unit **261** (Figures 3-6). 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 will 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.

5 **[0051]** The system 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
10 **100**.

[0052] The systems may include a line **12** (Figures 3-6). 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**
15 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 3-6). 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 **104, 204**.

20 **[0053]** If the system includes the feed separator **103** (Figures 5-6), 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**.

[0054] 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
25 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 from the lower section **106** and the liquid stream
30 falls to the bottom of the lower section **106**.

[0055] 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 3-6).

[0056] 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, set up similarly to the second reboiler described above, may also be used.

[0057] 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 3-6). 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.

[0058] 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 3-6) of the middle controlled freeze zone section **108** so that the solids form a liquid and/or slurry mix.

[0059] 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.

[0060] The equipment may include one or more chimney assemblies **135** (Figures 3-6). While falling to the bottom of the lower section **106**, the liquid stream may encounter one or more of the chimney assemblies **135**.

[0061] 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 **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 tower **104, 204**.

[0062] 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** 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**.

[0063] 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**.

[0064] Figure 8 is a top plan view of a fluid distribution system **300** according to an aspect of the disclosure. Figure 9 is a side elevational view of the fluid distribution system **300** shown in Figure 8. Figures 8-9 show a fluid distribution system **300** according to an aspect of the disclosure. The fluid distribution system **300** may include a collection trough **302** into which liquid on the chimney tray **131** is collected. The collection trough **302** is shown as having two ends **304** and **306** disposed at proximal and distal ends of the collection trough **302** and extending substantially across the inner diameter of the distillation tower **104, 204**. A sump **308**, shown as an annular surface or ledge, may be disposed at a slightly lower elevation than the elevation of the collection trough **302** in some embodiments to aid flowing liquid in the collection trough into the sump **308**. An annular fluid distribution belt **310** is disposed along an inner circumference of the outer wall **312** of the distillation tower **104, 204**. The fluid distribution belt **310** is shown in Figures 8-9 as having a semi-circular or half-

pipe cross-section along an outer circumference. The fluid distribution belt **310** may be positioned no higher than the elevation of the sump **308**. One or more outlets or holes **313** are cut or drilled through the outer wall **312** of the distillation tower **104, 204** to permit liquid in the sump **308** to flow into the fluid distribution belt **310**. At least two outlet nozzles **314** are attached to the fluid distribution belt **310**. Downcomer lines **316**, which may include tubing or piping, or partially enclosed fluid passages, are connected to the outlet nozzles **314**. The number of outlet nozzles **314** used in system **300** may be varied to accommodate the number of downcomer lines **316**. This number is typically more than two with a maximum number limited by mechanical strength considerations of the fluid distribution belt **310**.

10 [0065] The locations of the outlet nozzles **314** around the fluid distribution belt **310** are chosen to distribute liquid flow evenly between the outlet nozzles. Furthermore, the locations of the outlet nozzles **314** around the fluid distribution belt **310** preferably do not coincide with the locations of the holes or openings **313** that permit fluid to flow from the sump **308** into the fluid distribution belt **310**. Additionally, the centerline **318** of the fluid distribution
15 belt **310** may coincide with the center axis **320** of the outlet nozzles **314**.

[0066] Figure 10 is a top plan view of a fluid distribution system **400** according to the disclosure. Figure 11 is a side elevational view of the fluid distribution system **400** shown in Figure 10. The components of the fluid distribution system **400** may be the same as the components of the fluid distribution system **300** of Figures 8-9 except as otherwise noted.
20 Figures 10-11 show another aspect of the disclosure in which a system **400** includes a fluid distribution belt **410** that is not integral with the distillation tower **104, 204**. As shown, the fluid distribution system **400** is at least partially disposed outside of an outer wall **312** of the tower **104, 204**. The fluid distribution belt **410** is depicted as having a generally circular cross-section and is connected to the sump **308** via a short pipe segment or segments **412**.
25 Alternatively, the fluid distribution belt **410** may be arranged at a lower elevation along the distillation tower **104, 204**. The system **400** is otherwise constructed and operates substantially similar to sytem **300**. For example, a plurality of outlet nozzles **314** are disposed in the fluid distribution belt **410** to accommodate the number of required independent downcomer lines **316**. The number of outlet nozzles **314** is typically more than
30 two with a maximum number limited by mechanical strength considerations of the fluid distribution belt **410**.

[0067] Optimal operability of downstream equipment requires equal distribution of the

liquid flowing into the multiple, independent downcomer lines. The design of the systems disclosed herein must assure this equal distribution as it transfers liquid from the chimney tray **131** to the downcomer lines **316**. According to aspects disclosed herein, means are provided to achieve and maintain equal distribution of liquid among the downcomer lines

5 **316**. Figure 12 is a detail view of part of the system **300**, **400** shown in Figures 8-11. Although fluid distribution belt **410** of system **400** (Figures 10-11) is depicted in Figure 12, the aspects disclosed in Figure 12 may also apply to fluid distribution belt **310** of system **300** (Figures 8-9). The top end **322** of each downcomer line **316** extends a certain vertical distance upwardly into the fluid distribution belt **410**. Liquid **324** collects in the sump **308**

10 until it is higher than the top end **322** of the downcomer line **316**. This collected liquid establishes uniform flow of liquid into the downcomer line **316**, and also ensures a constant liquid pressure or head within the fluid distribution belt **410**. The top end **322** of the downcomer line **316** may have a textured surface, e.g., having notches, scallops, grooves, castellations, etc., as shown in Figure 12, to facilitate entry of liquid into the downcomer line.

15 Start-up notches, spouts, or holes **326** may be disposed in the downcomer line **316** where the downcomer line enters the inside of the fluid distribution belt **410**. The start-up holes **326** initiate the beginning of uniform liquid flow into the downcomer line **316** until such time as the level of liquid **324** reaches the top end **322** of the downcomer line. The startup holes **326** encourage a full and even liquid flow to all downcomer lines. Additionally, packing **328** may

20 be placed inside the fluid distribution belt **410** and/or in the sump **308** to act as a calming agent for the liquid **324**, as unsteady, turbulent liquid flow would contribute to uneven liquid distribution to the downcomer lines **316**.

[0068] Figures 13-14 disclose another aspect of the disclosure in which a system **500** includes a fluid distribution belt **510** disposed internal to the distillation tower **104**, **204**, and

25 may be disposed around the inner circumference of the distillation tower **104**, **204**. The fluid distribution belt **510** is positioned to be in fluid connection with the sump **308**. A plurality of outlet nozzles **314** are placed on the outer wall of the distillation tower **104**, **204**, and a plurality of holes (not shown) are cut or drilled through the outer wall so that liquid in the fluid distribution belt **510** flows through the holes into the outlet nozzles. Packing **328** may

30 be placed inside the fluid distribution belt **510** and/or in the sump **308** to act as a calming agent for the liquid contained therein. The design of fluid distribution belt **510** provides uniform flow to multiple, independent downcomer pipe lines and resembles the designs of the fluid distribution belts **310**, **410**.

[0069] Returning to the description of Figures 3-6, 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 3-6). The liquid outlet **160** may be located at the bottom of the lower section **106**.

5 [0070] 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**.

10 [0071] The system may include an expander device **114** (Figures 3-6). 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.

15 [0072] The system may include a heat exchanger **116** (Figures 3-6). 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 and may include a line **26** for an output stream.

20 [0073] 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 maintained to receive a freezing zone liquid stream to form the solid and the vapor stream (i.e., hydrocarbon-enriched vapor stream) in 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 into a solid and a vapor stream. The solid and the vapor stream are formed in the middle controlled freeze zone section **108** when the freezing zone liquid stream is injected into the middle controlled freeze zone section **108** at a temperature and pressure at which the solid and vapor stream form. The solid may be comprised more of contaminants than of methane. The vapor stream may comprise more methane than contaminants.

30 [0074] The middle controlled freeze zone section **108** includes a lower section **40** and an upper section **39** (Figure 7). 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 may not

exclusively be a heating section of the middle controlled freeze zone section **108**. The upper section **39** is primarily but may not exclusively be 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**.

5 **[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 3-7). 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**.

10 **[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
15 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**. The melt tray **118** is at the bottom **45** of the middle controlled freeze zone section **108**.

20 **[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 that forces 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 **140**. The cap **141**
25 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
30 located anywhere within the melt tray assembly **139**. For example, as shown in Figures 3-6, a heat mechanism **134** may be located around the 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 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**. The spray assembly **129** is above the melt tray assembly **139**. In other words, the melt tray assembly **139** is below the spray assembly **129**.

15 **[0082]** The temperature in the middle controlled freeze zone section **108** cools down as 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
20 tend to condense or solidify with the colder temperatures and fall to the bottom of the middle controlled freeze zone section **108**.

25 **[0083]** 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 3-6). 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 line may extend to the lower section **106**.

30 **[0084]** 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

5 **110**. Line **18** may extend from an outer surface of the distillation tower **104**, **204**.

[0085] 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**.

10 [0086] 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

15 and liquid phases.

[0087] 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**.

[0088] From line **14**, the vapor stream may enter a condenser **122**. The condenser **122**

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

[0089] 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

25 reflux drum.

[0090] 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.

[0091] Once separated, the liquid stream may return to the upper section **110** through line

30 **18** as the reflux. The reflux may travel to the upper section **110** via any suitable mechanism, such as a reflux pump **150** (Figures 3 and 5) or gravity (Figures 4 and 6).

[0092] The liquid stream (e.g., the 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 3 and 5) or at the bottommost portion of the upper section **110** (Figures 4 and 6). The collected liquid may exit the distillation tower **104, 204** through line **20** (Figures 3 and 5) or outlet **260** (Figures 4 and 6). 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**.

[0093] 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**.

[0094] The line **20** and/or outlet **260** may directly or indirectly (Figures 3-6) connect to the line **41**. When the line **20** and/or outlet **260** directly connect to the line **41**, the liquid spray may be pumped 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 3 and 5). The holding vessel **126** may house at least some of the liquid spray before it is sprayed by the nozzle(s). The liquid spray may be pumped from the holding vessel **126** to the spray nozzle(s) **120** via any suitable mechanism, such as the spray pump **128** (Figures 3-6) 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**.

[0095] Figure 15 is a flowchart showing a method **600** for maintaining constant fluid pressure and equalized fluid flow among a plurality of downcomer lines through which liquid from a substantially cylindrical tower, e.g., the distillation tower **104, 204** of Figures 3-6, is directed. At block **602** a substantially annular fluid distribution belt is disposed at the circumference of the tower. At block **604** liquid from the tower is collected in the fluid distribution belt. At block **606** the liquid is directed from the fluid distribution belt out of the tower and into a corresponding number of downcomer lines disposed external to the tower separating a feed stream in a tower.

[0096] Figure 16 is a flowchart showing a method **700** for producing and/or processing hydrocarbons. At block **702** constant fluid pressure and equalized fluid flow is maintained among a plurality of downcomer lines through which liquid from a hydrocarbon tower is

directed. At block **704** a substantially annular fluid distribution belt is disposed at the circumference of the tower. At block **706** liquid from the tower is collected in the fluid distribution belt. At block **708** liquid is directed from the fluid distribution belt out of the tower and into a corresponding number of downcomer lines disposed external to the tower.

5 At block **710** hydrocarbons from the tower are produced.

[0097] The steps depicted in Figures 15 and 16 are provided for illustrative purposes only and a particular step may not be required to perform the inventive methodology. Moreover, Figures 15 and 16 may not illustrate all the steps that may be performed. The claims, and only the claims, define the inventive system and methodology.

10 [0098] 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
15 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
20 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
25 into the Earth, etc. For example, as shown in Figure 16, the method for producing hydrocarbons may include producing the hydrocarbon-enriched vapor stream extracted from the tower. The method may also include removing the hydrocarbon-enriched vapor stream from the tower before producing the hydrocarbon-enriched vapor stream. The initial hydrocarbon extraction from the reservoir may be accomplished by drilling a well using
30 hydrocarbon drilling equipment. The equipment and techniques used to 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.

[0099] 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. Furthermore, 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.

[0100] It should be understood that the 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.

CLAIMS

1. An apparatus for maintaining constant fluid pressure and equalized fluid flow among a plurality of downcomer lines through which liquid from a substantially cylindrical tower is directed, comprising:

a substantially annular fluid distribution belt positioned about a circumference of the tower, the fluid distribution belt collecting liquid from the tower; and

at least two outlets configured to direct liquid from the fluid distribution belt into a corresponding number of downcomer lines disposed external to the tower; and

a textured surface on a top end of each of the downcomer lines.

2. The apparatus of claim 1, wherein the fluid distribution belt is at least partially disposed outside of an outer wall of the tower, and further comprising a plurality of openings in the outer wall of the tower through which liquid collected inside the tower flows into the fluid distribution belt.

3. The apparatus of claim 2, wherein the plurality of openings are disposed around the fluid distribution belt at different positions from the at least two outlets.

4. The apparatus of claim 1, wherein the fluid distribution belt is at least partially disposed outside of an outer wall of the tower.

5. The apparatus of claim 1, wherein the fluid distribution belt has a cross-section that is substantially semi-circular.

6. The apparatus of claim 1, wherein the fluid distribution belt has a cross-section that is at least substantially circular along an outer circumference.

7. The apparatus of claim 1, comprising at least three outlets.

8. The apparatus of claim 1, wherein an end of each downcomer line extends upwardly into the fluid distribution belt.

9. The apparatus of claim 1, wherein the textured surface comprises one of notches, scallops, grooves, and castellations.

10. The apparatus of claim 1, wherein the fluid distribution belt is disposed at least partially internal to the tower, and wherein the at least two outlets are in fluid communication with the fluid distribution belt via openings in an outer wall of the tower.

11. The apparatus of claim 1, further comprising packing placed inside the fluid distribution belt, the packing as a calming agent for liquid in the fluid distribution belt.

12. An apparatus for maintaining constant fluid pressure and equalized fluid flow among a plurality of downcomer lines through which liquid from a substantially cylindrical tower is directed, comprising:

a substantially annular fluid distribution belt positioned about a circumference of the tower, the fluid distribution belt collecting liquid from the tower;

at least two outlets configured to direct liquid from the fluid distribution belt into a corresponding number of downcomer lines disposed external to the tower, and

at least one opening in each downcomer line at an elevation that is below a top end of said each downcomer line and within the fluid distribution belt, whereby liquid collected in the tower begins to flow through the at least one opening before reaching said top end of said each downcomer line.

13. A method of maintaining constant fluid pressure and equalized fluid flow among a plurality of downcomer lines through which liquid from a substantially cylindrical tower is directed, performed in an apparatus according to claim 1, the method comprising:

collecting liquid from the tower at the substantially annular fluid distribution belt positioned at the circumference of the tower; and

passing liquid from the fluid distribution belt out of the tower and into the corresponding number of downcomer lines disposed external to the tower.

14. The method of claim 13, wherein the fluid distribution belt is disposed at least partially external to the tower.

15. The method of claim 13, wherein the fluid distribution belt is disposed at least partially integral with the tower.

16. The method of claim 13, further comprising:

maintaining a level of liquid in the fluid distribution belt sufficient to melt solids.

17. The method of claim 13, wherein the fluid distribution belt is at least partially internal to the tower.

18. A method of producing hydrocarbons, performed in an apparatus of claim 1, the method comprising:

maintaining constant fluid pressure and equalized fluid flow among the plurality of downcomer lines through which liquid from the substantially cylindrical tower is directed;

collecting liquid from the tower in the substantially annular fluid distribution belt positioned at the circumference of the tower;

passing liquid from the fluid distribution belt out of tower and into the corresponding number of downcomer lines external to the tower; and

passing hydrocarbons from the tower.