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(54) **Title**: METHOD AND SYSTEM FOR SEPARATING A FEED STREAM WITH A FEED STREAM DISTRIBUTION MECHANISM

(57) **Abstract**: The present disclosure provides a distillation tower for separating a feed stream. The distillation tower includes a controlled freeze zone section having a controlled freeze zone upper section and a controlled freeze zone lower section below the controlled freeze zone upper section. The controlled freeze zone section includes: (a) a spray assembly in the controlled freeze zone upper section; (b) a melt tray assembly in the controlled freeze zone lower section; (c) a feed stream distribution mechanism between the spray assembly and the melt tray assembly. The feed stream distribution mechanism is constructed and arranged to uniformly distribute the feed stream in the controlled freeze zone section.

METHOD AND SYSTEM FOR SEPARATING A FEED STREAM WITH A FEED STREAM DISTRIBUTION MECHANISM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority benefit of both United States Provisional patent application number 61/912,975 filed December 6, 2013 entitled METHOD AND SYSTEM FOR SEPARATING A FEED STREAM WITH A FEED STREAM DISTRIBUTION MECHANISM, the entirety of which is incorporated by reference herein.

[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 SPRAY ASSEMBLY; 61/912,959 filed on December 6, 2013 entitled METHOD AND SYSTEM OF MAINTAING 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 STREAM PROCESSED IN A DISTILLATION TOWER; 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 OF REMOVING SOLDS 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 DESTABILIZE AND/OR PREVENT ADHESION OF SOLIDS; 61/912,987 filed on December 6, 2013 entitled METHOD AND DEVICE FOR SEPARATING HYDROCARBONS AND CONTAMINANTS WITH A SURFACE TREATMENT MECHANISM.

BACKGROUND

Fields of Disclosure

[0003] 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

[0004] 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.

[0005] 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 ("CO_2"), hydrogen sulfide ("H_2S"), 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."

[0006] 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.

[0007] 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% CO_2 and ¼ grain H_2S per 100 scf (4 ppmv) or 5 mg/Nm3 H_2S. Specifications for lower temperature processes such as natural gas liquefaction plants or nitrogen rejection units typically require less than 50 ppm CO_2.

[0008] 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.

[0009] 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 CO_2 from methane by distillation involves temperature and pressure conditions that result in solidification of CO_2 if a pipeline or better quality hydrocarbon product is desired. The required temperatures are cold temperatures typically referred to as cryogenic temperatures.

[0010] 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. A lower section may also help separate the contaminants from the hydrocarbons but the lower section is operated at a temperature and pressure that does not form solid.

[0011] Often times the feed stream separated in a distillation tower having a controlled freeze zone section is first introduced into the distillation tower via the lower section regardless of the amount of CO_2 in the feed stream.

[0012] Disadvantages may arise when the feed stream is first introduced into the lower section regardless of the amount of CO_2 in the feed stream. Disadvantages may include a distillation tower that is not optimally sized. Disadvantages may include a distillation tower that does not use energy efficiently. These disadvantages may arise because the distillation tower may be using more energy and/or space than necessary to process a feed stream when the amount of CO_2 in the feed stream is not properly considered before introducing the feed stream into the distillation tower.

[0013] Disadvantages may arise because solids may adhere to an internal (e.g. the controlled freeze zone wall) of the controlled freeze zone section rather than falling to the bottom of the controlled freeze zone section. The adherence, if uncontrolled, can interfere with the proper operation of the controlled freeze zone section and the effective separation of methane from contaminants.

[0014] A need exists for improved technology for separating a feed stream that optimally matches where the feed stream should enter the distillation tower based on the concentrations of components in the feed stream so as to optimize energy efficiency and/or the size of the distillation tower.

SUMMARY

[0015] The present disclosure provides a device and method for separating contaminants from hydrocarbons, among other things.

[0016] A distillation tower for separating a feed stream may comprise a controlled freeze zone section having a controlled freeze zone upper section and a controlled freeze zone lower section below the controlled freeze zone upper section, wherein the controlled freeze zone section is constructed and arranged to form a solid from a feed stream and the controlled freeze zone section comprises: (a) a spray assembly in the controlled freeze zone upper section; (b) a melt tray assembly in the controlled freeze zone lower section; (c) a feed stream distribution mechanism between the spray assembly and the melt tray assembly. The feed stream distribution mechanism may be constructed and arranged to uniformly distribute the feed stream in the controlled freeze zone section.

[0017] A method of separating a feed stream in a distillation tower may comprise directly introducing a feed stream into a distillation tower via a controlled freeze zone section of the distillation tower; operating the controlled freeze zone section at a temperature and pressure at which the feed stream forms a solid in the controlled freeze zone section; uniformly distributing the feed stream introduced into the controlled freeze zone section with a feed stream distribution mechanism that is below a spray assembly of the controlled freeze zone section; and forming a solid from the feed stream in the controlled freeze zone section.

[0018] A method of producing hydrocarbons in a distillation tower may comprise directly introducing a feed stream into a distillation tower via a controlled freeze zone section of the distillation tower; operating the controlled freeze zone section at a temperature and pressure at which the feed stream forms a solid in the controlled freeze zone section; uniformly distributing the feed stream introduced into the controlled freeze zone section with a feed stream distribution mechanism that is below a spray assembly of the controlled freeze zone section; and producing a hydrocarbon from the feed stream.

[0019] The foregoing has broadly outlined the features of the present disclosure in order

that the detailed description that follows may be better understood. Additional features will also be described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] 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.

[0021] Figure 1 is a schematic diagram of a tower with sections within a single vessel.

[0022] Figure 2 is a schematic diagram of a tower with sections within multiple vessels.

[0023] Figure 3 is a schematic diagram of a tower with sections within a single vessel.

[0024] Figure 4 is a schematic diagram of a tower with sections within multiple vessels.

[0025] Figure 5 is a side view of a middle controlled freeze zone section of a distillation tower.

[0026] Figure 6 is a cross-section of a feed stream distribution mechanism of Figure 3 along line 4-4.

[0027] Figure 7 is a cross-section of a feed stream distribution mechanism of Figure 3 along line 5-5.

[0028] Figure 8 is a cross-section of a feed stream distribution mechanism of Figure 3 along line 6-6.

[0029] Figure 9 is a flowchart of a method within the scope of the present disclosure.

[0030] 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

[0031] 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. 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.

[0032] 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, 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.

[0033] The disclosure relates to a system and method for separating a feed stream in a distillation tower. The system and method helps optimally match where the feed stream should enter the distillation tower based on the concentrations of components in the feed stream so as to improve energy efficiency and/or optimally size the distillation tower. The system and method may also help prevent the undesired accumulation of solids in the controlled freeze zone section of the distillation tower. Figures 1-9 of the disclosure display various aspects of the system and method.

[0034] The system and method may separate a feed stream having methane and contaminants. The system may comprise a distillation tower **104**, **204** (Figures 1-2). The distillation tower **104**, **204** may separate the contaminants from the methane.

[0035] The distillation tower **104**, **204** may be separated into three functional sections: a 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.

[0036] 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 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 vapors to the condenser **122**.

[0037] 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.

[0038] The sections of the distillation tower **104** may be housed within a single vessel (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**.

[0039] The sections of the distillation tower **204** may be housed within a plurality of vessels to form a split-tower configuration (Figures 2 and 4). 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 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.

[0040] 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 1 and 3.

[0041] The system may also include a heat exchanger **100** (Figures 1-4). 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**.

[0042] 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 **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.

[0043] 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**. 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**.

[0044] 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.

[0045] 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 **100**.

[0046] The system may include lines **12**. Each of the lines may be referred to as an inlet channel **12**. The feed stream is introduced into the distillation tower **104**, **204** through one of the lines **12**. One or more lines **12** may extend to the lower section **106** or the middle controlled freeze zone section **108** of the distillation tower **104**, **204** to another of the lines **12**. For example, the line **12** 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). Each line **12** may directly or indirectly extend to the lower section **106** or the middle controlled freeze zone section **108**. Each line **12** may extend to an outer surface of the distillation tower **104**,

204 before entering the distillation tower.

[0047] 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**.

[0048] Before entering the distillation tower **104**, **204**, a sample of the feed stream **10** may enter an analyzer (not shown). The sample of the feed stream **10** may be a small sample of the feed stream **10**. The feed stream **10** may comprise feed from multiple feed sources or feed from a single feed source. Each feed source may comprise, for example, a separate reservoir, one or more wellbores within one or more reservoirs, etc. The analyzer may determine the percentage of CO_2 in the sample of the feed stream **10** and, therefore, the content of CO_2 in the feed stream **10**. The analyzer may connect to multiple lines **12** so that the feed stream **10** can be sent to one or more sections **106**, **108** of the distillation tower **104**, **204** after the sample of the feed stream **10** exits the analyzer. If the analyze determines that the percentage of CO_2 is greater than about 20% or greater than 20%, the analyzer may direct the feed stream to the line **12** extending from the lower section **106**. If the analyzer determines that the percentage of CO_2 is less than about 20% or less than 20%, the analyzer may direct the feed stream to the line **12** extending from the middle controlled freeze zone section **108**. The analyzer may be any suitable analyzer. For example, the analyzer may be a gas chromatograph or an IR analyzer. The analyzer may be positioned before the feed stream **10** enters the heat exchanger **100**. The feed stream **10** entering the analyzer may be a single phase.

[0049] While the feed stream **10** may be introduced into any section of the distillation tower **104**, **204** regardless of the percentage of CO_2 in the feed stream **10**, it is more efficient to introduce the feed stream **10** into the section of the distillation tower **104**, **204** that will employ the best use of energy. For this reason, it is preferable to introduce the feed stream to the lower section **106** when the percentage of CO_2 in the feed stream is greater than any percentage about 20% or greater than 20% and to the middle controlled freeze zone section **108** when the percentage of CO_2 in the feed stream is any percentage less than about 20% or less than 20%.

[0050] The feed stream may be directly or indirectly fed to one of the sections **106**, **108**, **301**. Thus, for the best use of energy it is best to introduce the feed stream into the distillation tower **104**, **204** at the point in the distillation process of the distillation tower **104**,

204 that matches the relevant percentage or content of CO_2 in the feed stream.

[0051] The feed stream **10** may enter a separator **208** (Figure 5). The separator **208** separates a feed stream vapor portion from a feed stream liquid portion before the feed stream is introduced into the distillation tower **104**, **204**. The feed stream vapor portion may be fed to a different section or portion within a section of the distillation tower **104**, **204** than the feed stream liquid portion. For example, the feed stream vapor portion may be fed to an upper controlled freeze zone section **39** of the middle controlled freeze zone section **108** and/or the feed stream liquid portion may be fed to a lower controlled freeze zone section **40** of the middle controlled freeze zone section **108** or to the lower section **106** of the distillation tower.

[0052] 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 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**.

[0053] 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).

[0054] 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.

[0055] 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.

[0056] The first reboiler **112** may 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.

[0057] 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.

[0058] The equipment may include one or more chimney assemblies **135** (Figures 1-4). While falling to the bottom of the lower section **106**, the liquid stream may encounter one or more of the chimney assemblies **135**.

[0059] 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 **106** to supply heat to the middle controlled freeze zone section **106** 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**.

[0060] 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**.

[0061] 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**.

[0062] 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 1-4). The liquid outlet **160** may be located at the bottom of the lower section **106**.

[0063] 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**.

[0064] The systems 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.

[0065] 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.

[0066] 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 middle controlled freeze zone section **108** forms the solid, **304** (Figure 9). 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.

[0067] 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**.

[0068] 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 1-4). 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**.

[0069] The melt tray assembly **139** is constructed and arranged to melt solids 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 solids. The melt tray assembly **139** may comprise at least one of a melt tray **118**, a bubble cap **132**, a liquid **130** and heat mechanism(s) **134**.

[0070] 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**.

[0071] 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**.

[0072] 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.

[0073] 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.

[0074] 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**.

[0075] 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. Instead of a spray pump **128**, gravity may induce flow in the liquid.

[0076] 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**.

[0077] 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 tend to condense or solidify with the colder temperatures and fall to the bottom of the middle controlled freeze zone section **108**.

[0078] 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 line may extend to the lower section **106**. The line **22** may extend from an outer surface of the distillation tower **104**, **204**.

[0079] The middle controlled freeze zone section **108** may include a feed stream distribution mechanism **207** (Figures 5-8). The feed stream distribution mechanism **207** receives the feed stream introduced via inlet channel **12** to the middle controlled freeze zone section **108**. The feed stream distribution mechanism **207** is constructed and arranged to uniformly distribute feed stream in the middle controlled freeze zone section **108**. The feed stream distribution mechanism **207** is below the spray assembly **129**. The feed stream distribution mechanism **207** is above the melt tray assembly **139**. The feed stream distribution mechanism **207** is separate and distinct from the spray assembly **129** and the melt tray assembly **139**.

[0080] The feed stream distribution mechanism **207** may comprise any mechanism that uniformly distributes feed stream introduced into the middle controlled freeze zone section **108**, **303** (Figure 9). For example, as shown in Figures 5-8, the feed stream distribution mechanism **207** may comprise a pipe header **209**. Feed stream entering the feed stream distribution mechanism **207** may enter the feed stream distribution mechanism **207** through one (Figures 7-8) or more inlets **311**.

[0081] The pipe header **209** includes orifices **206**. The orifices **206** are closer to the melt tray assembly **139** than the spray assembly **129**. The orifices **206** are angled downwards toward a controlled freeze zone section bottom **210** (Figure 5) of the middle controlled freeze zone section **108**. The orifices **206** may also be on a lower half **209a** of the pipe header **209** (Figure 6). The orifices **206** may not be on an upper half **209b** of the pipe header **209** (Figure 6). The lower half **209a** of the pipe header **209** is a lower half in the sense that it is closer to the bottom of the middle controlled freeze zone section **108** than the upper half **209b**. The orientation of the orifices **206** forces the feed stream **10** that exits the pipe header **209** through the orifices **206** to flow in a direction that promotes uniform distribution of the feed stream.

The feed stream vapor portion flows downward when it first exits the orifices and then changes direction and flows upward in the middle controlled freeze zone section **108** toward the spray assembly **129**. In other words, the feed stream vapor portion is directed toward the spray assembly **129** from the feed stream distribution mechanism **207**. The feed stream vapor portion may be indirectly directed toward the spray assembly **129**. The feed stream liquid portion flows downward when it first exits the orifices and continues to flow downward toward the melt tray assembly **139**. In other words, the feed stream liquid portion is fed toward the melt tray assembly **139**. The feed stream liquid portion may be directly fed toward the melt tray assembly **139**.

[0082] To enhance the ability of the feed stream distribution mechanism **207** to uniformly distribute the feed stream introduced into the middle controlled freeze zone section **108**, the feed stream distribution mechanism **207** may be shaped to promote uniform distribution.

[0083] The feed stream distribution mechanism **207** may comprise one of an H-shape and an X-shape (Figure 7). The X-shaped feed stream distribution mechanism **207** of Figure 7 includes a first pipe **211** and a second pipe **212**. The first pipe **211** intersects the second pipe **212**. The first pipe **211** extends from near to or a controlled freeze zone first side **213** of the controlled freeze zone wall **46** to near to or a controlled freeze zone second side **214** of the controlled freeze zone wall **46**. As shown in Figure 7, the first pipe **211** extends from the controlled freeze zone first side **213** to near to the controlled freeze zone second side **214**. The first pipe **211** may connect to or include the inlet **311** to the feed stream distribution mechanism **207**. The second pipe **212** extends from or near to a controlled freeze zone third side **215** of the controlled freeze zone wall **46** to near to or a controlled freeze zone fourth side **216** of the controlled freeze zone wall **46**.

[0084] Other shapes of the feed stream distribution mechanism **207** are also possible. For example, as shown in Figure 8 the feed stream distribution mechanism **207** may include a first pipe **211** and a second pipe **212**. The first pipe **211** may intersect the second pipe **212**. The feed stream distribution mechanism **207** may also include a third pipe **223** and a fourth pipe **224**. The third pipe **223** may intersect the second pipe **212**. The fourth pipe **224** may intersect the second pipe **212**. The fourth pipe **224** may be parallel to the third pipe **223**. The first pipe **211**, third pipe **223**, and/or fourth pipe **224** may extend from a controlled freeze zone first side **213** of the controlled freeze zone wall **46** to near to or a controlled freeze zone second side **214** of the controlled freeze zone wall **46**. The first pipe **211** may connect to or include the inlet **311** to the feed stream distribution mechanism **207**. The second pipe **212** may extend from the third pipe **223** to the fourth pipe **224**.

[0085] The controlled freeze zone first side **213** is directly adjacent to the controlled freeze zone third side **215**. The controlled freeze zone third side **215** is directly adjacent to the controlled freeze zone second side **214**. The controlled freeze zone second side **214** is directly adjacent to the controlled freeze zone fourth side **216**. The controlled freeze zone fourth side **216** is directly adjacent to the controlled freeze zone first side **213**. If a pipe extends near to one of the sides **213**, **214**, **215**, **216**, the pipe may not connect to the side **213**, **214**, **215**, **216**. If a pipe extends from one of the sides **213**, **214**, **215**, **216**, the pipe connects to the side **213**, **214**, **215**, **216**. One or more of the pipes connect to or include the inlet **311** to the feed stream distribution mechanism **207**. When a pipe connects to or includes the inlet **311** the inlet protrudes from the middle controlled freeze zone section **108** such that at least a portion of the inlet **311** is outside of the middle controlled freeze zone section **108**.

[0086] The feed stream distribution mechanism **207** may also be a shape that minimizes the size and and/or cross-section, along a lateral axis 5,6 – 5,6 of the controlled freeze zone section **108**, that the feed stream distribution mechanism **207** occupies in the middle controlled freeze zone section **108**. The minimal size and/or cross-section of the feed stream distribution mechanism **207** and the relative warmth of the feed stream helps prevent undesired accumulation of the solid on the feed stream distribution mechanism **207**.

[0087] The temperature of the feed stream that flows through the feed stream distribution mechanism **207** is warmer than the solid formed in the middle controlled freeze zone section **108**. The feed stream is warmer because the feed stream introduced into the distillation tower **104**, **204** is warmer than the solid formed in the middle controlled freeze zone section **108**. The warmer temperature may prevent the feed stream from forming a solid inside of the feed stream distribution mechanism **207** and/or as the feed stream exits the feed stream distribution mechanism **207** and/or on an outer surface of the feed stream distribution mechanism **207**.

[0088] As shown in Figures 1-2, 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**.

[0089] 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**.

[0090] 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.

[0091] 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**.

[0092] 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.

[0093] 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.

[0094] 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.

[0095] 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).

[0096] 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**.

[0097] 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 **110**.

[0098] 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 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 1 and 3). 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 1-2) 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**.

[0099] It is important to note that the steps depicted in Figure 7 are provided for illustrative purposes only and a particular step may not be required to perform the inventive methodology. The claims, and only the claims, define the inventive system and methodology.

[0100] Disclosed aspects may be used in hydrocarbon management activities. As used herein, “hydrocarbon management” or “managing hydrocarbons” includes hydrocarbon extraction, hydrocarbon production, hydrocarbon exploration, identifying potential hydrocarbon resources, identifying well locations, determining well injection and/or extraction rates, identifying reservoir connectivity, acquiring, disposing of and/ or abandoning hydrocarbon resources, reviewing prior hydrocarbon management decisions, and any other hydrocarbon-related acts or activities. The term "hydrocarbon management" is also used for the injection or storage of hydrocarbons or CO_2, for example the sequestration of

CO_2, such as reservoir evaluation, development planning, and reservoir management. The disclosed methodologies and techniques may be used to produce hydrocarbons in a feed stream extracted from, for example, a subsurface region. The feed stream extracted may be processed in the distillation tower **104**, **204** and separated into hydrocarbons and contaminants. The separated hydrocarbons exit the middle controlled freeze zone section **108** or the upper section **110** of the distillation tower. Some or all of the hydrocarbons that exit are produced, **307** (Figure 9). Hydrocarbon extraction may be conducted to remove the feed stream from for example, the subsurface region, which may be accomplished by drilling a well using oil well drilling equipment. The equipment and techniques used to drill a well and/or extract the hydrocarbons are well known by those skilled in the relevant art. Other hydrocarbon extraction activities and, more generally, other hydrocarbon management activities, may be performed according to known principles.

[0101] 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 are considered to be within the scope of the disclosure.

[0102] It should be understood that numerous changes, modifications, and alternatives to the preceding disclosure can be made without departing from the scope of the disclosure. The preceding description, therefore, is not meant to limit the scope of the disclosure. Rather, the scope of the disclosure is to be determined only by the appended claims and their equivalents. It is also contemplated that structures and features in the present examples can be altered, rearranged, substituted, deleted, duplicated, combined, or added to each other.

[0103] The articles “the”, “a” and “an” are not necessarily limited to mean only one, but rather are inclusive and open ended so as to include, optionally, multiple such elements.

CLAIMS

What is claimed is:

1. A distillation tower for separating a feed stream, the distillation tower comprising:

a controlled freeze zone section having a controlled freeze zone upper section and a controlled freeze zone lower section below the controlled freeze zone upper section, wherein the controlled freeze zone section is constructed and arranged to form a solid from a feed stream and the controlled freeze zone section comprises:

(a) a spray assembly in the controlled freeze zone upper section;

(b) a melt tray assembly in the controlled freeze zone lower section;

(c) a feed stream distribution mechanism between the spray assembly and the melt tray assembly,

wherein the feed stream distribution mechanism is constructed and arranged to uniformly distribute at least a portion of the feed stream in the controlled freeze zone section.

2. The distillation tower of claim 1, wherein the feed stream distribution mechanism is separate and distinct from the spray assembly and the melt tray assembly.

3. The distillation tower of any one of claim 1-2, wherein the feed stream distribution mechanism comprises a pipe header having orifices that are closer to the melt tray assembly than the spray assembly.

4. The distillation tower of claim 3, wherein the orifices are oriented towards a controlled freeze zone bottom of the controlled freeze zone section.

5. The distillation tower of claim 3, wherein the pipe header is one of H-shaped and X-shaped.

6. The distillation tower of claim 3, wherein the pipe header includes a first pipe and a second pipe that intersects the first pipe.

7. The distillation tower of claim 6,

wherein the controlled freeze zone section includes a controlled freeze zone wall,

wherein the first pipe extends from a controlled freeze zone first side of the controlled freeze zone wall to a controlled freeze zone second side of the controlled freeze zone wall, and

wherein the second pipe extends from a controlled freeze zone third side of the controlled freeze zone wall to a controlled freeze zone fourth side of the controlled freeze zone wall.

8. The distillation tower of claim 3, wherein the pipe header includes:

a first pipe,

a second pipe that intersects the first pipe,

a third pipe that intersects the second pipe, and

a fourth pipe that intersects the second pipe and is parallel to the third pipe.

9. The distillation tower of claim 8,

wherein the controlled freeze zone section includes a controlled freeze zone wall, and

wherein the first pipe extends from the controlled freeze zone wall to the second pipe.

10. The distillation tower of any one of claim 1-9, wherein the distillation tower further comprises an inlet channel that extends from the controlled freeze zone section and transports the feed stream into the controlled freeze zone section.

11. The distillation tower of claim 10,

wherein the feed stream comprises a hydrocarbon and a contaminant, and

wherein the feed stream contains less than or equal to 20% contaminant when transported into the controlled freeze zone section from the inlet channel.

12. A method of separating a feed stream in a distillation tower, the method comprising:

directly introducing a feed stream or a portion thereof into a distillation tower via a controlled freeze zone section of the distillation tower;

operating the controlled freeze zone section at a temperature and pressure at which the feed stream forms a solid in the controlled freeze zone section;

uniformly distributing the feed stream introduced into the controlled freeze zone section with a feed stream distribution mechanism that is below a spray assembly of the controlled freeze zone section; and

forming a solid from the feed stream in the controlled freeze zone section.

13. The method of claim 12, wherein uniformly distributing the feed stream comprises at least one of (i) directing a liquid feed stream portion of the feed stream toward a melt tray assembly of the controlled freeze zone section and (ii) directing a vapor feed stream portion of the feed stream toward the spray assembly.

14. The method of claim 13, wherein the internal elements comprise a controlled freeze zone wall of the controlled freeze zone section.

15. The method of claim any one of claim 13-14, wherein the liquid feed stream portion of the feed stream is directly directed toward a melt tray assembly.

16. The method of claim any one of 13-15, wherein the vapor feed stream portion of the feed stream is indirectly directed toward the spray assembly.

17. The method of any one of claim 13-16, further comprising separating the vapor feed stream portion from the liquid feed stream portion before uniformly distributing the vapor feed stream portion and the liquid feed stream portion.

18. A method of producing hydrocarbons in a distillation tower, the method comprising:

directly introducing a feed stream into a distillation tower;

operating the controlled freeze zone section at a temperature and pressure at which the feed stream forms a solid in the controlled freeze zone section;

uniformly distributing at least a portion of the feed stream with a feed stream distribution mechanism that is below a spray assembly of the controlled freeze zone section;

forming a solid from the feed stream in the controlled freeze zone section; and

producing a hydrocarbon from the feed stream.

19. The method of claim 18, wherein uniformly distributing the feed stream comprises, at least one of (i) directing a liquid feed stream portion of the feed stream toward a melt tray assembly of the controlled freeze zone section and (ii) directing a vapor feed stream portion of the feed stream toward the spray assembly.

20. The method of claim 19, wherein the internal elements comprise a controlled freeze zone wall of the controlled freeze zone section.

21. The method of any one of claim 19-20, wherein the liquid feed stream portion of the feed stream is directly directed toward a melt tray assembly.

22. The method of any one of claim 19-21, wherein the vapor feed stream portion of the feed stream is indirectly directed toward the spray assembly.

23. The method of any one of claim 19-22, further comprising separating the vapor feed stream portion from the liquid feed stream portion before uniformly distributing the vapor feed stream portion and the liquid feed stream portion.

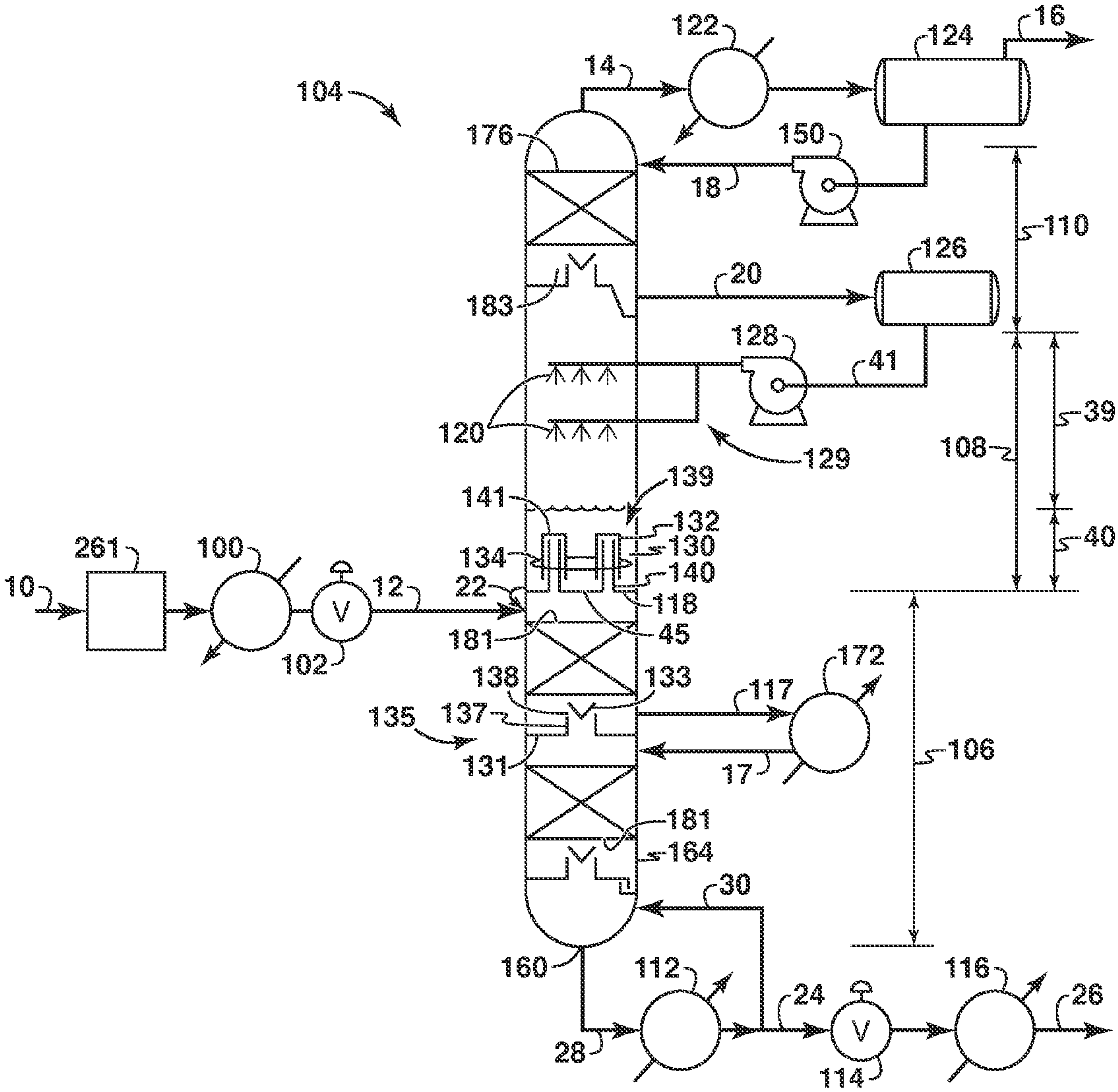
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FIG. 1

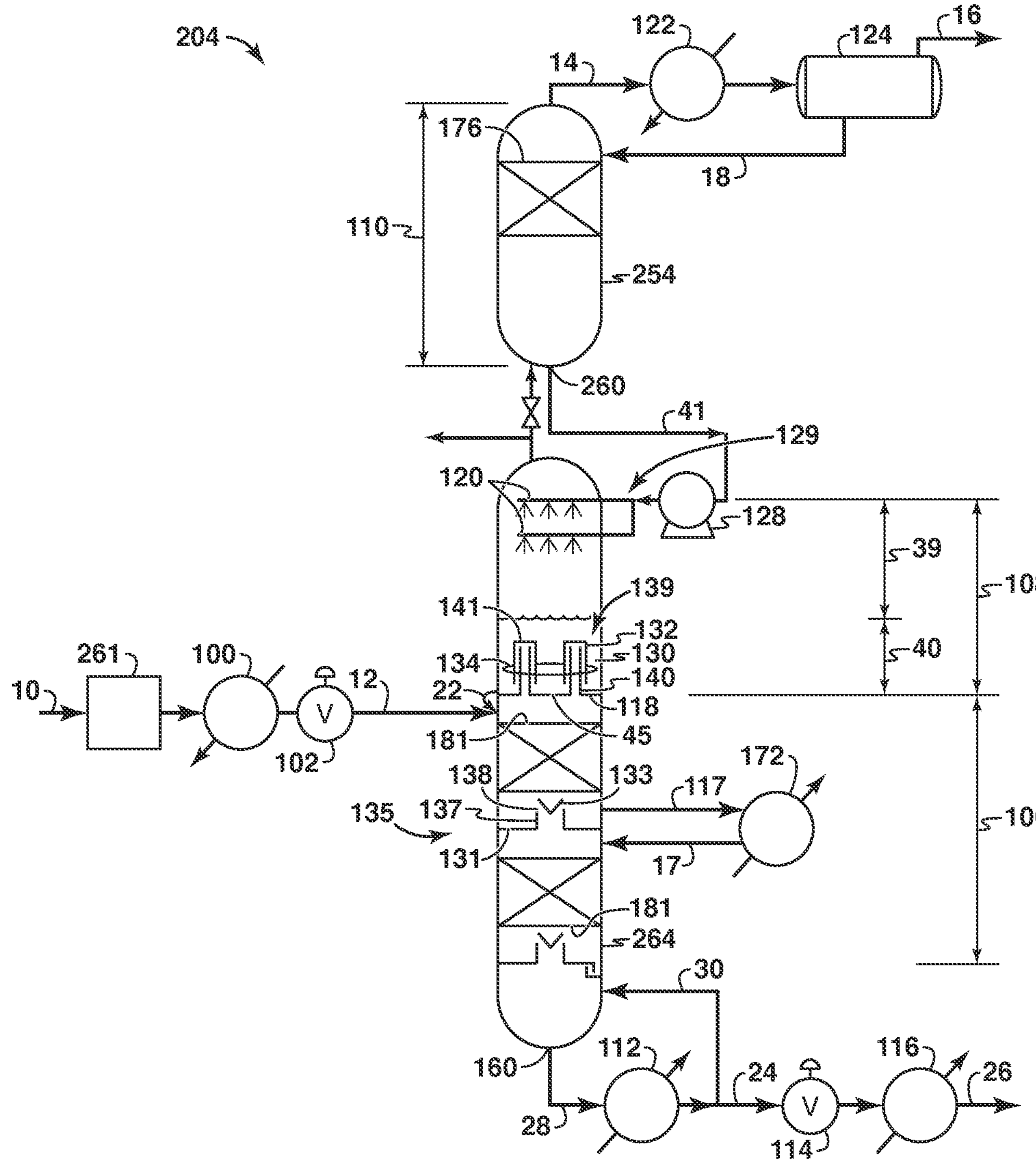
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FIG. 2

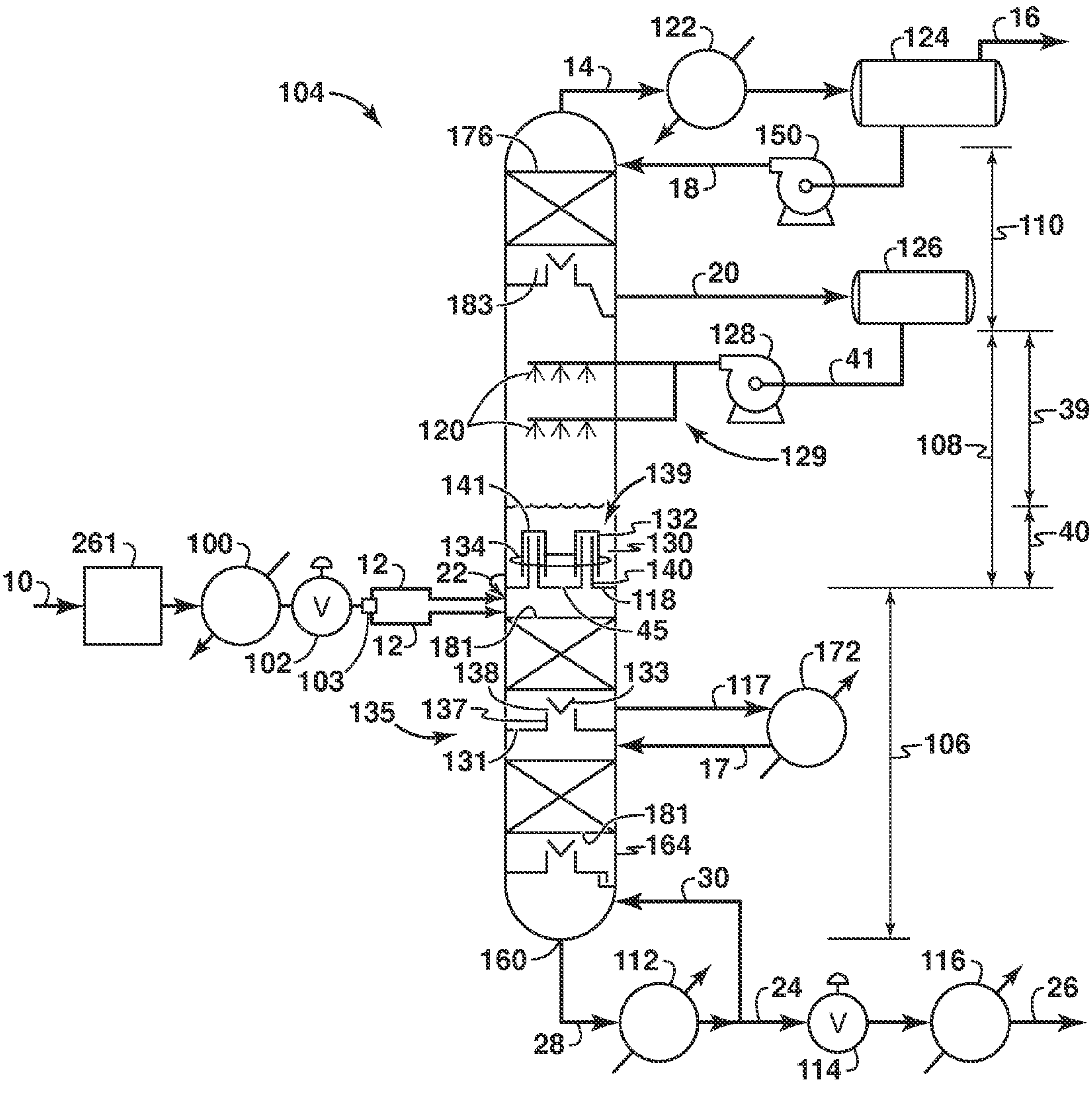
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FIG. 3

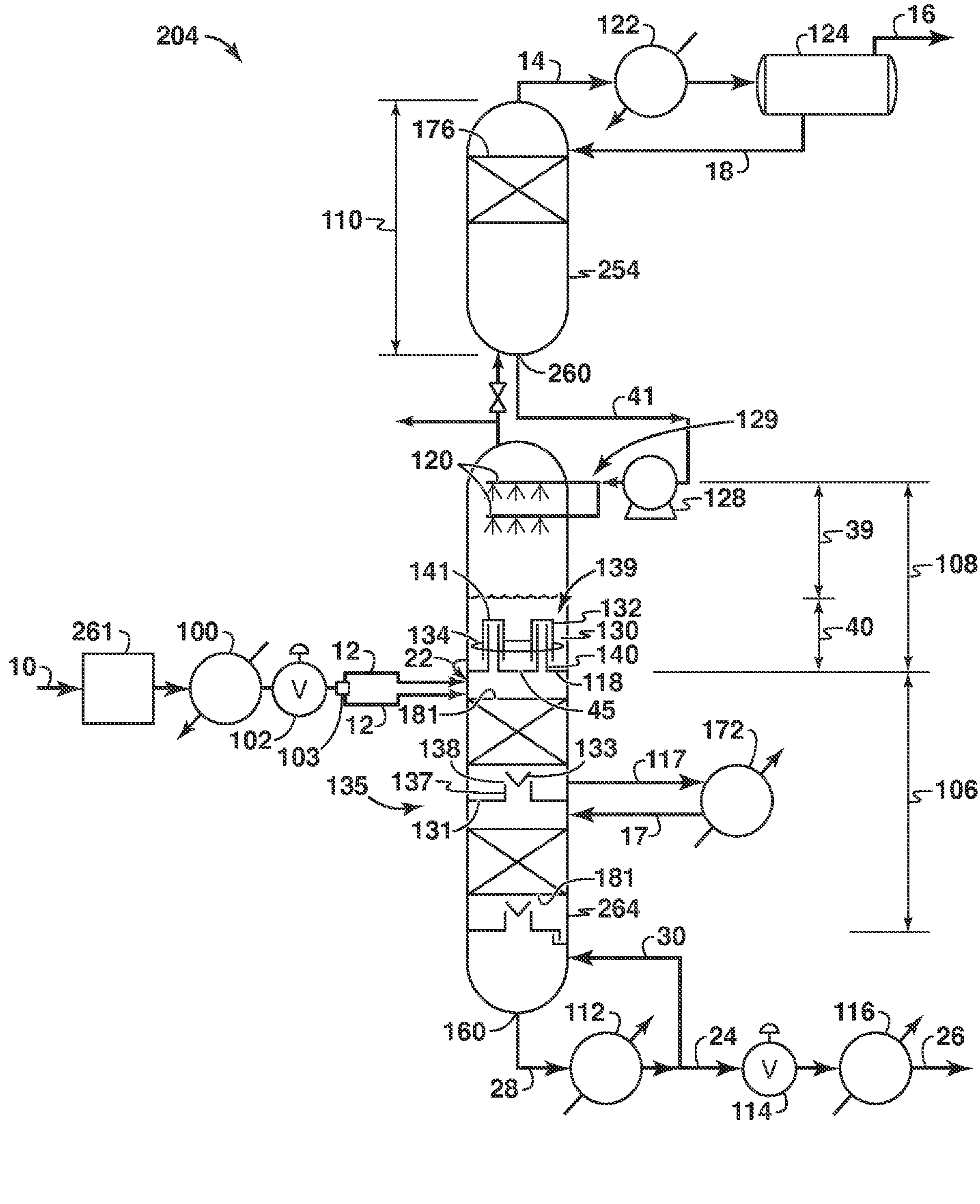
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FIG. 4

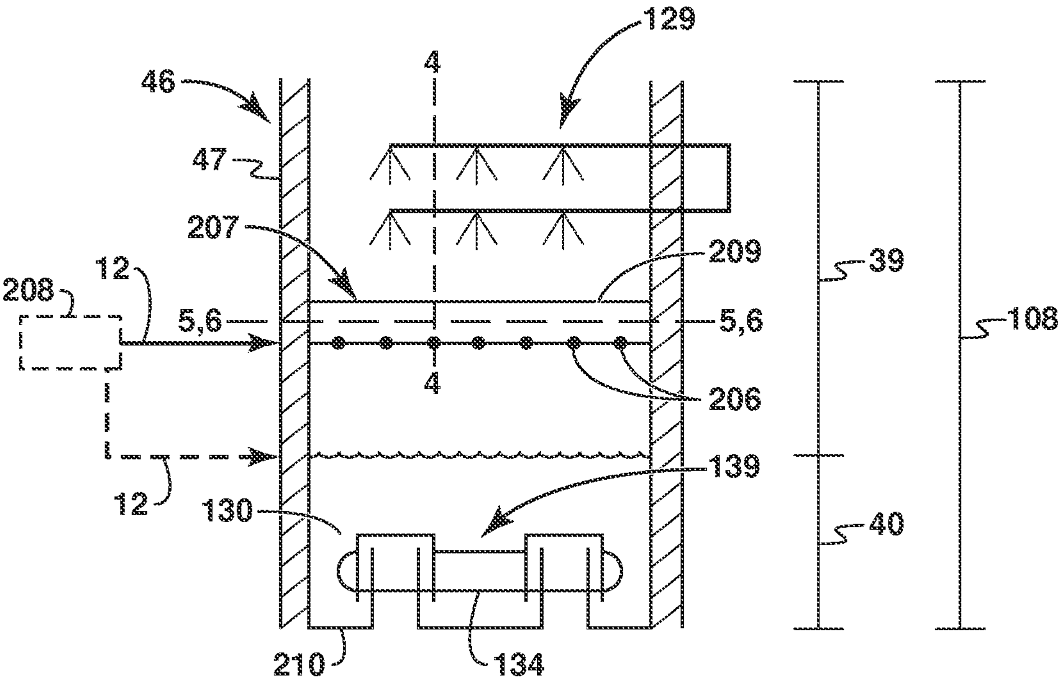
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FIG. 5

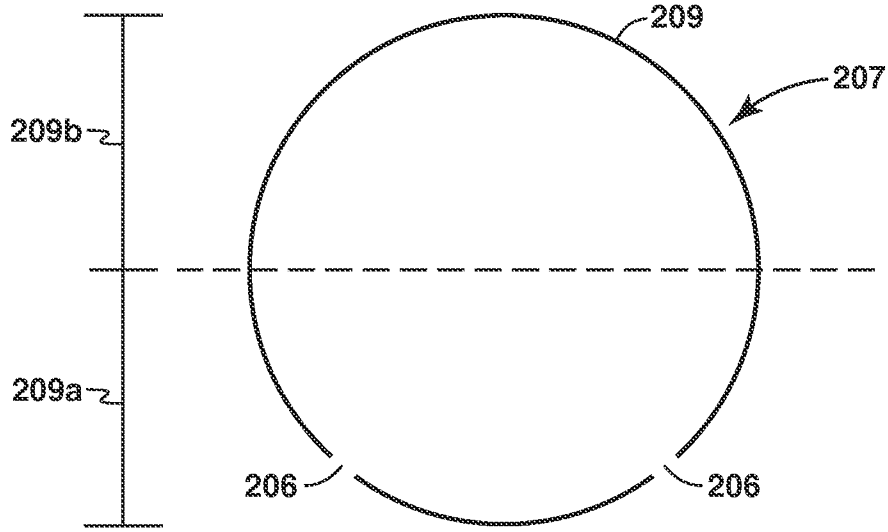
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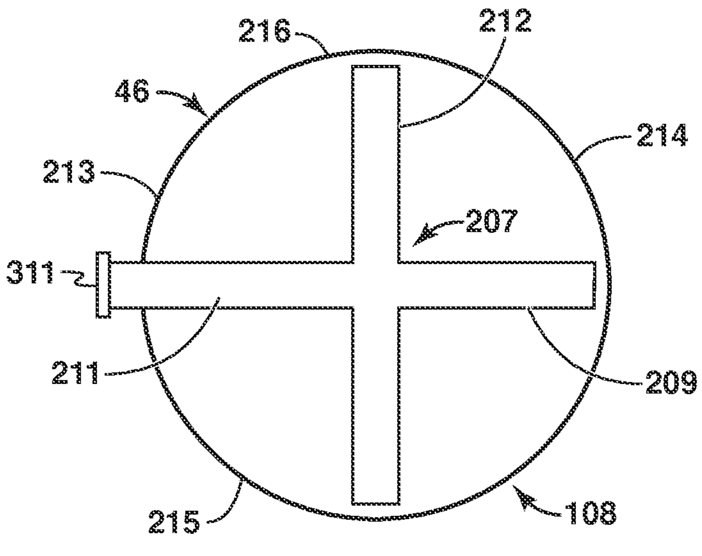
FIG. 6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108

FIG. 7

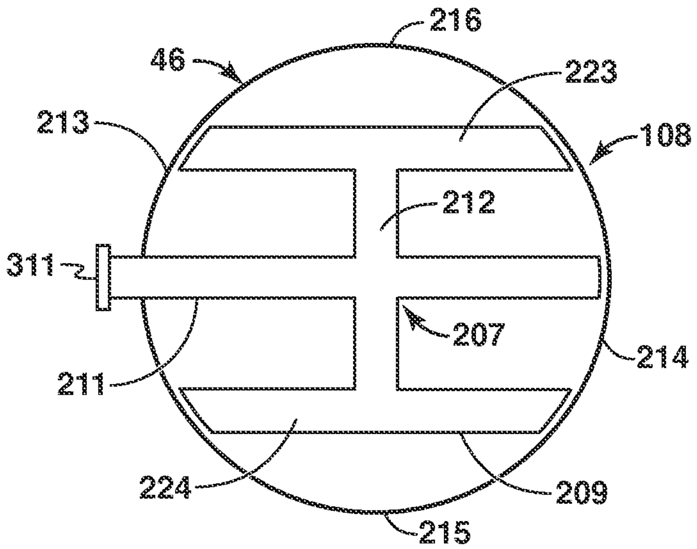
216
46
223
213
108
212
311
207
211
214
224
209
215

FIG. 8

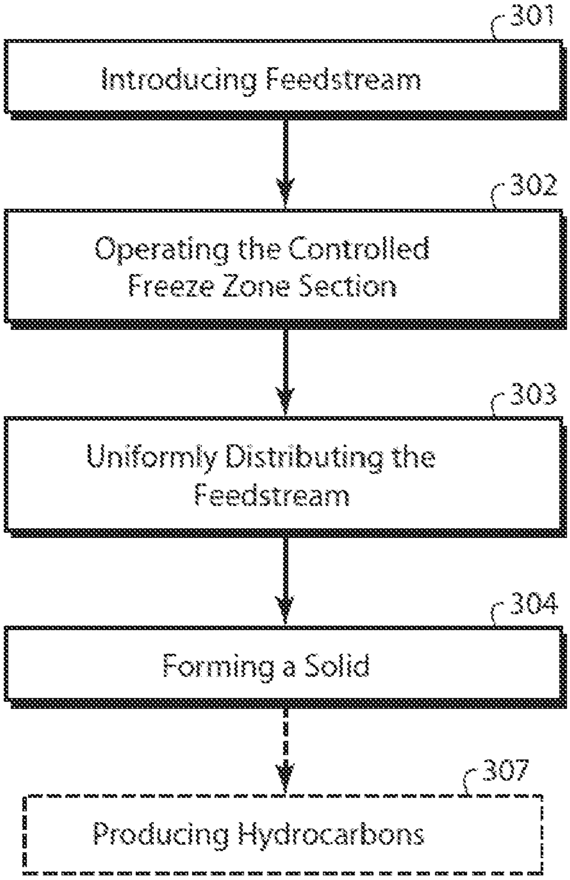
301
Introducing Feedstream
302
Operating the Controlled Freeze Zone Section
303
Uniformly Distributing the Feedstream
304
Forming a Solid
307
Producing Hydrocarbons

FIG. 9