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(54) **Title:** METHOD AND DEVICE FOR SEPARATING A FEED STREAM USING RADIATION DETECTORS

(57) **Abstract:** The present disclosure provides a method for separating a feed stream in a distillation tower. The method may include forming solids in a controlled freeze zone section of the distillation tower; emitting radiation from a first radiation source in the controlled freeze zone section while the controlled freeze zone section forms no solids; detecting radiation emitted by the first radiation source as a first radiation level; detecting radiation emitted by the first radiation source as a second radiation level after detecting the first radiation level; and determining whether the solids adhered to at least one of on and around a first mechanical component included in the controlled freeze zone section based on the first radiation level and the second radiation level.



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**METHOD AND DEVICE FOR SEPARATING A FEED STREAM USING
RADIATION DETECTORS**

CROSS REFERENCE TO RELATED APPLICATIONS

5 **[0001]** This application claims the priority benefit of both United States Provisional patent application number 61/912,964 filed December 6, 2013 entitled METHOD AND DEVICE FOR SEPARATING A FEED STREAM USING RADIATION DETECTORS, the entirety of which is incorporated by reference herein.

10 **[0002]** This application is related to but does not claim priority to U.S. Provisional patent application numbers: 61/912,957 filed on December 6, 2013 entitled METHOD AND DEVICE FOR SEPARATING HYDROCARBONS AND CONTAMINANTS WITH A SPRAY ASSEMBLY; 62/044,770 filed on September 2, 2014 entitled METHOD AND DEVICE FOR SEPARATING HYDROCARBONS AND CONTAMINANTS WITH A SPRAY ASSEMBLY; 61/912,959 filed on December 6, 2013 entitled METHOD AND
15 SYSTEM OF MAINTAINING A LIQUID LEVEL IN A DISTILLATION TOWER; 61/912,970 filed on December 6, 2013 entitled METHOD AND SYSTEM OF DEHYDRATING A FEED STREAM PROCESSED IN A DISTILLATION TOWER; 61/912,975 filed on December 6, 2013 entitled METHOD AND SYSTEM FOR SEPARATING A FEED STREAM WITH A FEED STREAM DISTRIBUTION
20 MECHANISM; 61/912,978 filed on December 6, 2013 entitled METHOD AND SYSTEM FOR PREVENTING ACCUMULATION OF SOLIDS IN A DISTILLATION TOWER; 61/912,983 filed on December 6, 2013 entitled METHOD OF REMOVING SOLIDS BY MODIFYING A LIQUID LEVEL IN A DISTILLATION TOWER; 61/912,984 filed on December 6, 2013 entitled METHOD AND SYSTEM OF MODIFYING A LIQUID LEVEL
25 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
30 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 (“CO₂”), hydrogen sulfide (“H₂S”), carbonyl sulfide, carbon disulfide and various mercaptans. When a feed stream being produced from a reservoir includes these contaminants mixed with hydrocarbons, the stream is oftentimes referred to as “sour gas.”

[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% 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.

[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
5 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.

10 **[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
15 pressure takes place in a controlled freeze zone section.

[0011] Sometimes solids can adhere to an internal (e.g., controlled freeze zone wall) of the controlled freeze zone section rather than falling to the bottom of the controlled freeze zone section.

[0012] The adherence is disadvantageous. The adherence, if uncontrolled, can interfere
20 with the proper operation of the controlled freeze zone and the effective separation of methane from the contaminants.

[0013] A need exists for improved technology, including technology that may address one or more of the above described disadvantages.

SUMMARY

25 **[0014]** The present disclosure provides a device and method for separating contaminants from hydrocarbons, among other things.

[0015] A method for separating a feed stream in a distillation tower may comprise forming solids in a controlled freeze zone section of the distillation tower; emitting radiation from a first radiation source in the controlled freeze zone section while the controlled freeze
30 zone section forms no solids; detecting radiation emitted by the first radiation source as a first radiation level; detecting radiation emitted by the first radiation source as a second radiation

level after detecting the first radiation level; and determining whether the solids adhered to at least one of on and around a first mechanical component included in the controlled freeze zone section based on the first radiation level and the second radiation level.

[0016] A distillation tower for separating a feed stream may comprise a controlled freeze zone section constructed and arranged to separate the feed stream at a temperature and pressure at which solids form; a radiation source coupled to a first mechanical component included in the controlled freeze zone section, wherein the radiation source emits radiation; and a radiation detector coupled to a second mechanical component included in the controlled freeze zone section, wherein the radiation detector detects a first radiation level emitted from the radiation source in an absence of solid formation and a second radiation level emitted from the radiation source while solids form and after the radiation detector detects the first radiation level.

[0017] A method for separating a feed stream in a distillation tower may comprise forming solids in a controlled freeze zone section of the distillation tower; emitting radiation from a first radiation source in the controlled freeze zone section while the controlled freeze zone section forms no solids; detecting radiation emitted by the first radiation source as a first radiation level; detecting radiation emitted by the first radiation source as a second radiation level after detecting the first radiation level; and determining whether the solids adhered to at least one of on and around a first mechanical component included in the controlled freeze zone section based on the first radiation level and the second radiation level.

[0018] 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

[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 schematic diagram of a tower with sections within a single vessel.

[0021] Figure 2 is a schematic diagram of a tower with sections within multiple vessels.

[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 portion of a middle controlled freeze zone section and a lower section of a distillation tower showing some of the components of these sections.

5 [0025] Figure 6 is a flowchart of a method within the scope of the present disclosure.

[0026] 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.

10 DETAILED DESCRIPTION

[0027] 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
15 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.

[0028] As referenced in this application, the terms “stream,” “gas stream,” “vapor
20 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
25 may also be present in a “liquid stream.” In some instances, the terms “gas stream” and “vapor stream” may be used interchangeably.

[0029] The disclosure relates to a system and method for separating a feed stream in a distillation tower. The system and method helps detect the presence of accumulated solids in the controlled freeze zone section. Figures 1-6 of the disclosure display various aspects of
30 the system and method.

[0030] The system and method may separate a feed stream having methane and

contaminants. The system may comprise a distillation tower **104, 204** (Figures 1-4). The distillation tower **104, 204** may separate the contaminants from the methane.

[0031] 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.

[0032] 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**.

[0033] 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.

[0034] 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**.

[0035] 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.

5 **[0036]** 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
10 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
15 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
20 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,
25 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.

[0037] The system may also include a heat exchanger **100** (Figures 1-4). The feed stream
30 **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**.

[0038] 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.

[0039] 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**.

[0040] 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.

[0041] 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**.

[0042] The system may include a line **12** (Figures 1-4). The line may also be referred to as an inlet channel **12**. The feed stream **10** may be introduced into the distillation tower **104, 204** through the line **12**. The line **12** may extend to the lower section **106** or the middle controlled freeze zone section **108** of the distillation tower **104, 204**. For example, the line **12** may extend to the lower section **106** such that the feed stream **10** may enter the lower section **106** of the distillation tower **104, 204** (Figures 1-4). The line **12** may directly or indirectly extend to the lower section **106** or the middle controlled freeze zone section **108**. The line **12** may extend to an outer surface of the distillation tower **104, 204** before entering the distillation tower.

[0043] 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**.

[0044] 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**.

[0045] 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).

[0046] 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**.
5 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.

[0047] 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).
10 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.

[0048] The first reboiler **112** may also apply heat to the stream within the distillation
15 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.

[0049] The second reboiler **172** applies heat to the stream within the lower section **106**.
20 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.

[0050] The equipment may include a chimney assembly **135** (Figures 1-4). While falling
25 to the bottom of the lower section **106**, the liquid stream may encounter one or more of the chimney assemblies **135**.

[0051] 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
30 **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**.

5 **[0052]** 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**.

10 **[0053]** 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**.

15 **[0054]** 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**.

20 **[0055]** 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**.

25 **[0056]** 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.

30 **[0057]** 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.

30 **[0058]** The vapor stream in the lower section **106** rises from the lower section **106** to the middle controlled freeze zone section **108**. The middle controlled freeze zone section **108** is constructed and arranged to separate the feed stream **10** introduced into the middle controlled

freeze zone section, or into the top of lower section **106**, into a solid and a vapor stream. The solid may be comprised more of contaminants than of methane. The vapor stream (i.e., methane-enriched vapor stream) may comprise more methane than contaminants.

[0059] 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**.

[0060] The middle controlled freeze zone section **108** may comprise a melt tray assembly **139** that is maintained in the middle controlled freeze zone section **108** (Figures 1-5). The melt tray assembly **139** is within the lower section **40** of the middle controlled freeze zone section **108**. The melt tray assembly **139** is not within the upper section **39** of the middle controlled freeze zone section **108**.

[0061] 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**.

[0062] 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**.

[0063] 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**.

[0064] 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,
5 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.

[0065] 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
10 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.

[0066] 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
15 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**.

[0067] 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
20 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.

[0068] The liquid sprayed by the spray assembly **129** contacts the vapor stream at a
25 temperature and pressure at which solids form. Solids, containing mainly contaminants, form when the sprayed liquid contacts the vapor stream, **301** (Figure 6). The solids fall toward the melt tray assembly **139**.

[0069] 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
30 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**.

[0070] 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**.

[0071] 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**.

[0072] 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**.

[0073] 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.

[0074] 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**.

[0075] 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.

5 **[0076]** 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.

10 **[0077]** 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.

[0078] 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).

15 **[0079]** 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
20 **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**.

[0080] 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
25 freeze zone section **110**.

[0081] 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
30 **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 1-4) or gravity. The holding vessel **126** may be needed when there is not a sufficient amount of liquid stream at the bottom of the upper section **110** to feed the spray nozzles **120**.

- 5 **[0082]** The system may also include a radiation source **202** and a radiation detector **201** (Figure 5). The radiation source **202** emits radiation. The radiation detector **201** detects radiation emitted from the radiation source.

- 10 **[0083]** The radiation source **202** may be coupled to a first mechanical component. The first mechanical component may be the distillation tower **104**, **204** and/or included in the distillation tower **104**, **204**. For example, the first mechanical component may comprise one of the controlled freeze zone wall **46** and a support of the middle controlled freeze zone section **108**. If the first mechanical component is the controlled freeze zone wall **46**, the radiation source **202** may be coupled to the external surface **47** of the controlled freeze zone wall **46** (Figure 5). If the first mechanical component is the middle controlled freeze zone section **108**, or included in the middle controlled freeze zone section **108**, the radiation source **202** may emit radiation in the middle controlled freeze zone section **108**. If the first mechanical component is a support of the middle controlled freeze zone section **108**, the support may extend from the middle controlled freeze zone section **108**. The support may be a bracket on the outside of the distillation tower **104**, **204** supporting the radiation source that includes radiation shielding. The support may not protrude into the middle controlled freeze zone section **108**.

- 25 **[0084]** The radiation source **202** may comprise a plurality of radiation sources (Figure 5). Each radiation source **202** may be coupled to the same and/or a different first mechanical component. For example, a first of the radiation sources **202** may be coupled to the controlled freeze zone wall **46**, and a second of the radiation sources **202** may be coupled to the support that extends from the middle controlled freeze zone section **108**. The first radiation source of the radiation sources **202** may not be the same radiation source as the second radiation source of the radiation sources **202**.

- 30 **[0085]** The radiation detector **201** may be coupled to a second mechanical component. The second mechanical component may be the distillation tower **104**, **204** and/or included in the distillation tower **104**, **204**. For example, the second mechanical component may comprise one of the controlled freeze zone wall **46** and the support of the middle controlled

freeze zone section **108**. If the second mechanical component is the controlled freeze zone wall **46**, the radiation source **202** may be coupled to the external surface **47** of the controlled freeze zone wall **46** (Figure 5). If the first mechanical component is the support of the middle controlled freeze zone section **108**, the support may extend from the middle controlled freeze zone section **108**. The support may be a bracket on the outside of the distillation tower **104**, **204** that includes radiation shielding. The support may not protrude into the middle controlled freeze zone section **108**.

[0086] The second mechanical component may be the same mechanical component as the first mechanical component, or a different mechanical component from the first mechanical component. For example, both the first and second mechanical components may be the controlled freeze zone wall **46**. If the first and second mechanical components are the same mechanical component, the first and second mechanical components are at different locations of this mechanical component.

[0087] The radiation detector **201** may or may not be in-line with the radiation source **202**. The radiation detector **201** is 180 degrees or about 180 degrees from the radiation source **202** relative to the central axis of the tower. The radiation detector **201** has a radiation detector lateral axis **211-211**. The radiation source **202** has a radiation source lateral axis **212-212**. The radiation detector lateral axis **211-211** is 180 degrees or about 180 degrees from the radiation source lateral axis **212-212**. Those of skill in the art will appreciate that alternate embodiments may maintain a 180 degree or about 180 degree orientation between the radiation detector lateral axis **211-211** and the radiation source lateral axis **212-212** without passing through the central axis of the tower. For example, the 180 degree or about 180 degree orientation between the radiation detector lateral axis **211-211** and the radiation source lateral axis **212-212** may be maintained with the radiation detector **201** and the radiation source **202** disposed about 120 degrees and about 240 degrees relative to the external surface **47** depending in part on wall thickness and column diameter. In all such embodiments, if the radiation detector lateral axis **211-211** is 180 degrees or about 180 degrees from the radiation source lateral axis **212-212**, and the radiation detector **201** and the radiation source **202** are at substantially the same elevation on the distillation tower, the radiation detector **201** is substantially in-line with the radiation source **202**. The radiation detector **201** and radiation source **202** may not be at substantially the same elevation. The radiation detector **201** and radiation source **202** may not be at substantially the same elevation

to get a better indication of whether solids have adhered and/or to accommodate a situation where mechanical components prevent the radiation detector **201** and radiation source **202** from being substantially at the same elevation. If the radiation detector **201** and the radiation source **202** are not at the same elevation, the radiation detector **201** and the radiation source **202** may not be in-line.

[0088] The radiation detector **201** may comprise a plurality of radiation detectors (Figure 5). Each radiation detector **201** may be coupled to the same and/or a different second mechanical component. For example, a first of the radiation detectors **201** may be coupled to the controlled freeze zone wall **46**, and a second of the radiation detectors **201** may be coupled to the support. Each of the radiation detectors **201** may detect radiation emitted from one or more radiation sources **202**. For example, when there are multiple radiation detectors **201**, each of the radiation detectors **201** may detect the radiation emitted from a single radiation source **202** with which it is paired, or each of the radiation detectors **201** may detect the radiation emitted from the same radiation source **202**. There may be cases where some sources and detectors are paired, while other detectors receive radiation from a single source at a different height or lateral angle on the distillation tower.

[0089] To detect that solids have adhered, a radiation source **202** must first emit radiation **302** (Figure 6) while the distillation tower is operating but not generating solids. When the distillation tower is operating and not generating solids the distillation tower may generate vapor. The distillation tower may also generate liquids. The radiation source **202** must first emit radiation **302** while the distillation tower is operating but not generating solids to ensure that a baseline amount of radiation in the middle controlled freeze zone section is generated. The baseline amount of radiation indicates the level of radiation in the middle controlled freeze zone section in the absence of solid formation.

[0090] The radiation emitted by the radiation source **202** while the distillation tower is operating but not generating solids is detected by at least one of the radiation detectors **201**. The radiation detected by the radiation detector(s) **201** is a first radiation level, **303** (Figure 6). The radiation emitted by the radiation source(s) **202** may be emitted at least one of when there is (a) vapor in the middle controlled freeze zone section **108** and (b) when there is vapor and liquid in the middle controlled freeze zone section **108**. When (a) occurs, there may be no liquid in the middle controlled freeze zone section **108**. Radiation may be emitted by the radiation source(s) **202** multiple times so that multiple first radiation levels may be detected

by one or more of the radiation detectors **201**.

[0091] The first radiation level(s) detected by the radiation detector(s) **202** is used to determine a radiation deviation range. The first radiation level is used to generate the baseline amount of radiation in the middle controlled freeze zone section **108**. The baseline amount of radiation is indicative of no solids in the middle controlled freeze zone section **108**. The baseline amount of radiation is used to calibrate the baseline amount of radiation within the middle controlled freeze zone section **108**. Once solids form in the middle controlled freeze zone section, the amount of radiation detected will likely be less than the baseline amount of radiation because the interaction of the radiation emitted with the solids will reduce the amount of radiation detected by the radiation detector **202**.

[0092] After using the first radiation level to generate the baseline radiation amount, a radiation deviation range from the baseline radiation amount may be determined and/or established. The radiation deviation range may comprise a normal radiation deviation range and an abnormal radiation deviation range. When a radiation level falls within the normal radiation deviation range, solids are forming in the middle controlled freeze zone section **108** but the solids have not adhered or it is unlikely that the solids have adhered in the middle controlled freeze zone section **108**. When a radiation level falls within the abnormal radiation deviation range, solids are forming in the middle controlled freeze zone section **108** and solids have adhered in the middle controlled freeze zone section **108**.

[0093] The normal deviation range includes radiation levels that are an insignificant departure from the baseline amount of radiation. The abnormal deviation range includes radiation levels that are a significant departure from the baseline amount of radiation. In some instances, a radiation level indicative of a solid accumulation in an amount greater than 0 and less than 1 inch falls within the normal radiation deviation range. For example, a radiation level indicative of a solid accumulation greater than or equal to 1/10 inch and less than or equal to 2/10 of an inch may fall within the normal deviation range. In some instances, a radiation level that is indicative of a solid accumulation in any amount greater than or equal to one inch falls within the abnormal radiation deviation range. The radiation level will likely not be detected in inches. Instead the radiation level may be detected as a certain count of radiation and the specific count of radiation may be transformed/calculated into the inch equivalent of solids.

[0094] To detect that any solid has adhered, a radiation source **201** must continue to emit

radiation while the distillation tower **104, 204** is operating and forming solids in the middle controlled freeze zone section **108**. When the distillation tower **104, 204** is operating and forming solids, solids may form that adhere to the first mechanical component in the middle controlled freeze zone section **108** (Figure 6). Each radiation source **201** is placed at a location in and/or on the middle controlled freeze zone section **108** where solid may adhere/accumulate. Each radiation detector **202** is placed at a location in and/or on the middle controlled freeze zone section **108** where it can detect radiation emitted from a radiation source **201**. When the radiation source **201** emits radiation, the radiation detector **202** in communication (i.e., in a location where it can detect radiation emitted from a particular radiation source **201**) with the radiation source **201** that emitted radiation detects a second radiation level, **304** (Figure 6). The amount of radiation detected by the radiation detector **202** while the distillation tower **104, 204** is operating and forming solids is a second radiation level.

[0095] To determine whether solid adhered to and/or around the first mechanical component in the middle controlled freeze zone section **108**, the first radiation level and the second radiation level are considered, **305** (Figure 6). The baseline amount of radiation in the middle controlled freeze zone section **108** is determined while the middle controlled freeze zone section **108** is operating and forming solids. The second radiation level is compared to the radiation deviation range that is based on the baseline amount of radiation. If the second radiation level falls within the normal radiation range, a determination is made that no solids have adhered. If the second radiation level falls within the abnormal radiation range, a determination is made that solids have adhered.

[0096] Periodic or continuous second radiation level measurements may be taken while the distillation tower **104, 204** is operating and forming solids. The amount of solids that have adhered to a first mechanical component may change over time. For example, the amount of solids may increase or decrease. When the amount of solids decrease, the amount of solids may decrease such that no solids adhere to the first mechanical component. The periodic or continuous measurements can therefore, for example, help determine when, if at all, solids begin to adhere and/or when solids have accumulated.

[0097] If the determination is made that solids have adhered to and/or around the first mechanical component, measures may be undertaken to destabilize the solids from the first mechanical component. Examples of measures that may be undertaken to destabilize the

solids are described in the applications entitled "Method and Device for Separating Hydrocarbons and Contaminants with a Heating Mechanism," "Method and Device for Separating Hydrocarbons and Contaminants with a Spray Assembly," "Method and Device for Separating Hydrocarbon and Contaminants with a Surface Treatment Mechanism," and
5 "Method of Modifying a Liquid Level in a Distillation Tower" by Jaime Valencia et al. and having the same priority date as the present application.

[0098] Persons skilled in the technical field will readily recognize that in practical applications of the disclosed methodology, one or more steps may be performed on a computer, typically a suitably programmed digital computer. Further, some portions of the
10 detailed descriptions which follow are presented in terms of procedures, steps, logic blocks, processing and other symbolic representations of operations on data bits within a computer memory. These descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. In the present application, a procedure, step, logic block, process, or the like, is
15 conceived to be a self-consistent sequence of steps or instructions leading to a desired result. The steps are those requiring physical manipulations of physical quantities. Usually, although not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated in a computer system.

20 **[0099]** It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussions, it is appreciated that throughout the present application, discussions utilizing the terms such as "*processing*," "*computing*," "*calculating*," "*detecting*," "*determining*,"
25 "*displaying*," "*copying*," "*producing*," "*storing*," "*accumulating*," "*adding*," "*applying*," "*identifying*," "*consolidating*," "*waiting*," "*including*," "*executing*," "*maintaining*," "*updating*," "*creating*," "*implementing*," "*generating*," "*transforming*," or the like, may refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities
30 within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[0100] It is important to note that the steps depicted in Figure 6 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.

5 **[0101]** Aspects of the present disclosure may also relate to an apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general-purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable medium. A computer-readable medium includes any mechanism for
10 storing or transmitting information in a form readable by a machine (e.g., a computer). For example, but not limited to, a computer-readable (e.g., machine-readable) medium includes a machine (e.g., a computer) readable storage medium (e.g., read only memory (“ROM”), random access memory (“RAM”), magnetic disk storage media, optical storage media, flash memory devices, etc.), and a machine (e.g., computer) readable transmission medium
15 (electrical, optical, acoustical or other form of propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.). The computer-readable medium may be non-transitory. The amounts determined may be displayed in the operator’s console.

[0102] Furthermore, as will be apparent to one of ordinary skill in the relevant art, the modules, features, attributes, methodologies, and other aspects of the disclosure can be
20 implemented as software, hardware, firmware or any combination of the three. Of course, wherever a component of the present disclosure is implemented as software, the component can be implemented as a standalone program, as part of a larger program, as a plurality of separate programs, as a statically or dynamically linked library, as a kernel loadable module, as a device driver, and/or in every and any other way known now or in the future to those of
25 skill in the art of computer programming. Additionally, the present disclosure is in no way limited to implementation in any specific operating system or environment.

[0103] 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
30 hydrocarbon resources, identifying well locations, determining well injection and/or extraction rates, identifying reservoir connectivity, acquiring, disposing of and/ or abandoning hydrocarbon resources, reviewing prior hydrocarbon management decisions, and

any other hydrocarbon-related acts or activities. The term “hydrocarbon management” is also used for the injection or storage of hydrocarbons or CO₂, for example the sequestration of CO₂, such as reservoir evaluation, development planning, and reservoir management. The disclosed methodologies and techniques may be used to produce hydrocarbons in a feed stream extracted from, for example, a subsurface region. The extracted feed stream 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, **306**. 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.

[0104] 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.

[0105] For the purpose of this disclosure, the term “coupled” means the joining of two members directly or indirectly to one another. Such joining may be stationary or moveable in nature. Such joining may be achieved with the two members or the two members and any additional intermediate members being integrally formed as a single unitary body with one another or with the two members or the two members and any additional intermediate members being attached to one another. Such joining may be permanent in nature or may be removable or releasable in nature.

[0106] 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.

- 5 **[0107]** The articles “the,” “a” and “an” are not necessarily limited to mean only one, but rather are inclusive and open ended so as to include, optionally, multiple such elements.

CLAIMS

What is claimed is:

1. A method for separating a feed stream in a distillation tower comprising:
forming solids in a controlled freeze zone section of the distillation tower;
5 emitting radiation from a first radiation source in the controlled freeze zone section while the controlled freeze zone section forms no solids;
detecting radiation emitted by the first radiation source as a first radiation level;
detecting radiation emitted by the first radiation source as a second radiation level after detecting the first radiation level; and
10 determining whether the solids adhered to at least one of on and around a first mechanical component included in the controlled freeze zone section based on the first radiation level and the second radiation level.
2. The method of claim 1, wherein the first mechanical component comprises one of: (a)
15 a wall of the controlled freeze zone section and (b) a channel of the controlled freeze zone section.
3. The method of any one of claims 1-2, wherein determining whether the solids adhered comprises: using the first radiation level to generate a baseline radiation level in the
20 controlled freeze zone section and comparing the second radiation level to a radiation deviation range, the radiation deviation range dependent on the baseline radiation level.
4. The method of claim 3, wherein the radiation deviation range comprises a normal radiation deviation range and an abnormal radiation deviation range indicative of solid
25 adhesion, and wherein the method further comprises determining that the solids adhered if the second radiation level is within the abnormal radiation deviation range.
5. The method of any one of claims 1-4, further comprising emitting radiation from a plurality of first radiation sources; detecting radiation emitted from each of the plurality of
30 first radiation sources as first radiation levels; and detecting radiation emitted from each of the plurality of first radiation sources as second radiation levels.
6. A distillation tower for separating a feed stream, the distillation tower comprising:
a controlled freeze zone section constructed and arranged to separate the feed stream

at a temperature and pressure at which solids form;

a radiation source coupled to a first mechanical component included in the controlled freeze zone section, wherein the radiation source emits radiation; and

5 a radiation detector coupled to a second mechanical component included in the controlled freeze zone section, wherein the radiation detector detects a first radiation level emitted from the radiation source in an absence of solids formation and a second radiation level emitted from the radiation source while solids form and after the radiation detector detects the first radiation level.

10 7. The distillation tower of claim 6, wherein the first mechanical component comprises one of: (a) a wall of the controlled freeze zone section and (b) a channel of the controlled freeze zone section, and wherein the second mechanical component comprises one of: (a) the wall of the controlled freeze zone section and (b) the channel of the controlled freeze zone section.

15 8. The distillation tower of any one of claims 6-7, wherein the first mechanical component is the second mechanical component.

9. The distillation tower of any one of claims 6-8, wherein the radiation source emits
20 radiation in the controlled freeze zone section.

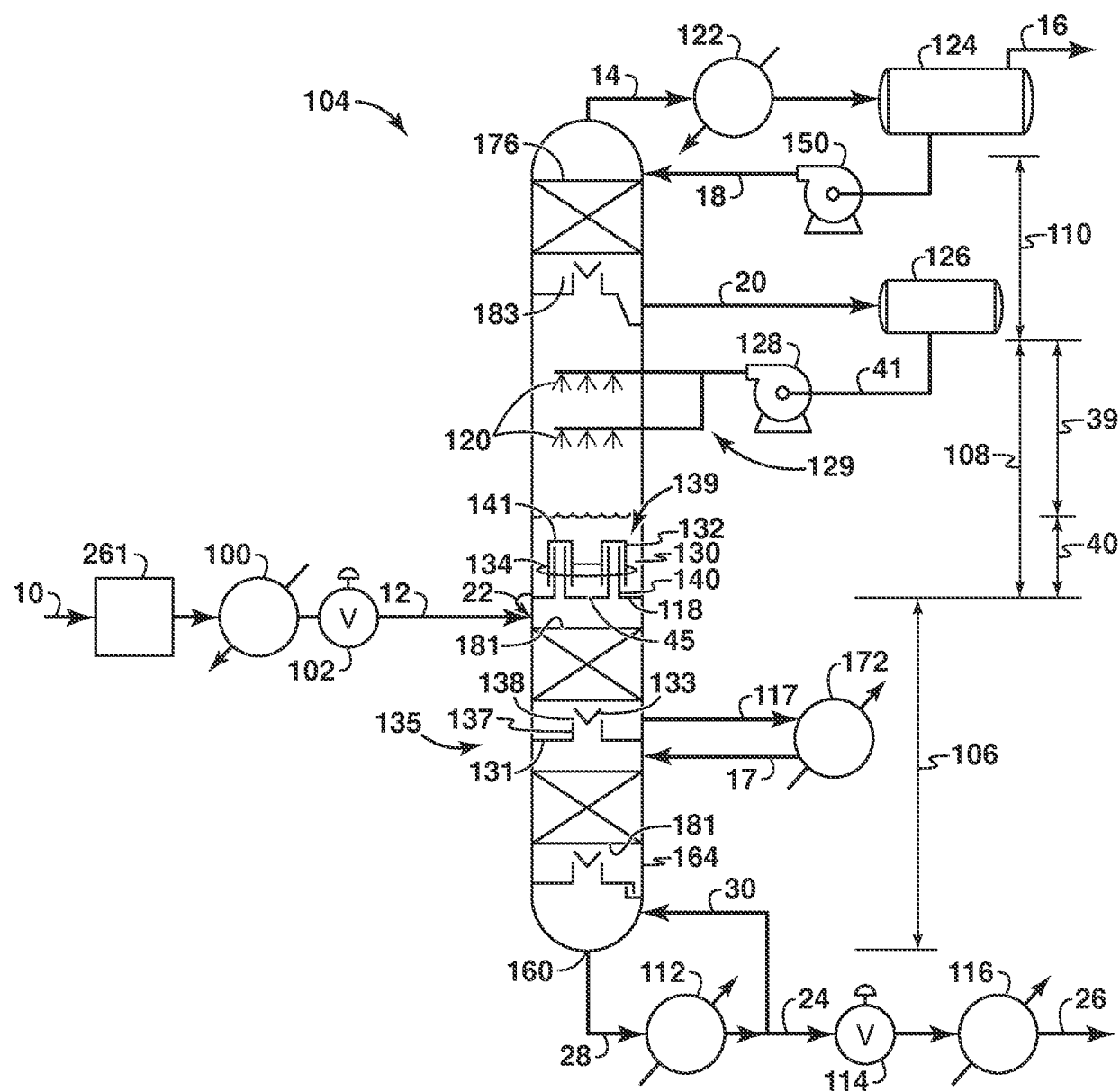
10. The distillation tower of any one of claims 6-9, wherein the radiation source is about 180 degrees from the radiation detector.

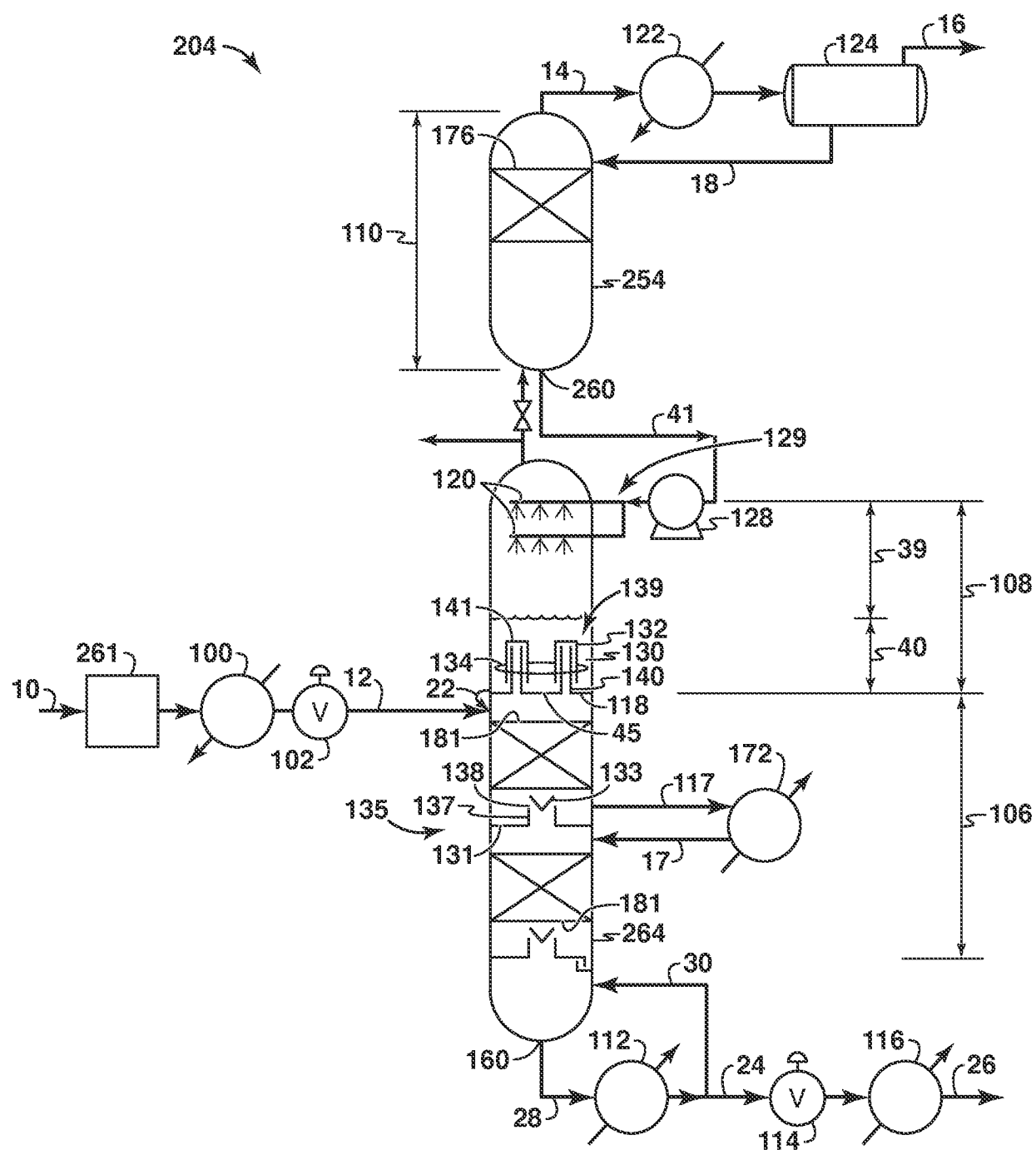
25 11. The distillation tower of any one of claims 6-10, wherein the radiation source is at substantially a same elevation as the radiation detector within the controlled freeze zone section.

30 12. The distillation tower of any one of claim 6-11, wherein the radiation source comprises a radiation source lateral axis and the radiation detector comprises a radiation detector lateral axis that is coaxial with the radiation source lateral axis.

13. The distillation tower of any one of claims 6-12, wherein the radiation source comprises a plurality of radiation sources and the radiation detector comprises a plurality of
35 radiation detectors.

14. A method for producing hydrocarbons in a distillation tower comprising:
forming solids in a controlled freeze zone section of the distillation tower;
emitting radiation from a first radiation source in the controlled freeze zone section
5 while the controlled freeze zone section forms no solids;
detecting radiation emitted by the first radiation source as a first radiation level;
detecting radiation emitted by the first radiation source as a second radiation level
after detecting the first radiation level;
determining whether the solids adhered to at least one of on and around a first
10 mechanical component included in the controlled freeze zone section based on the first
radiation level and the second radiation level; and
producing hydrocarbons from the distillation tower.
15. The method of claim 14, wherein the first mechanical component comprises one of:
15 (a) a wall of the controlled freeze zone section and (b) a channel of the controlled freeze zone
section.
16. The method of any one of claims 14-15, wherein determining whether the solids
adhered comprises: using the first radiation level to generate a baseline radiation level in the
20 controlled freeze zone section and comparing the second radiation level to a radiation
deviation range, the radiation deviation range dependent on the baseline radiation level.
17. The method of claim 16, wherein the radiation deviation range comprises a normal
radiation deviation range and an abnormal radiation deviation range indicative of solid
25 adhesion, and wherein the method further comprises determining that the solids adhered if the
second radiation level is within the abnormal radiation deviation range.
18. The method of any one of claims 14-17, further comprising emitting radiation from a
plurality of first radiation sources; detecting radiation emitted from each of the plurality of
30 first radiation sources as first radiation levels; and detecting radiation emitted from each of
the plurality of first radiation sources as second radiation levels.

**FIG. 1**

**FIG. 2**

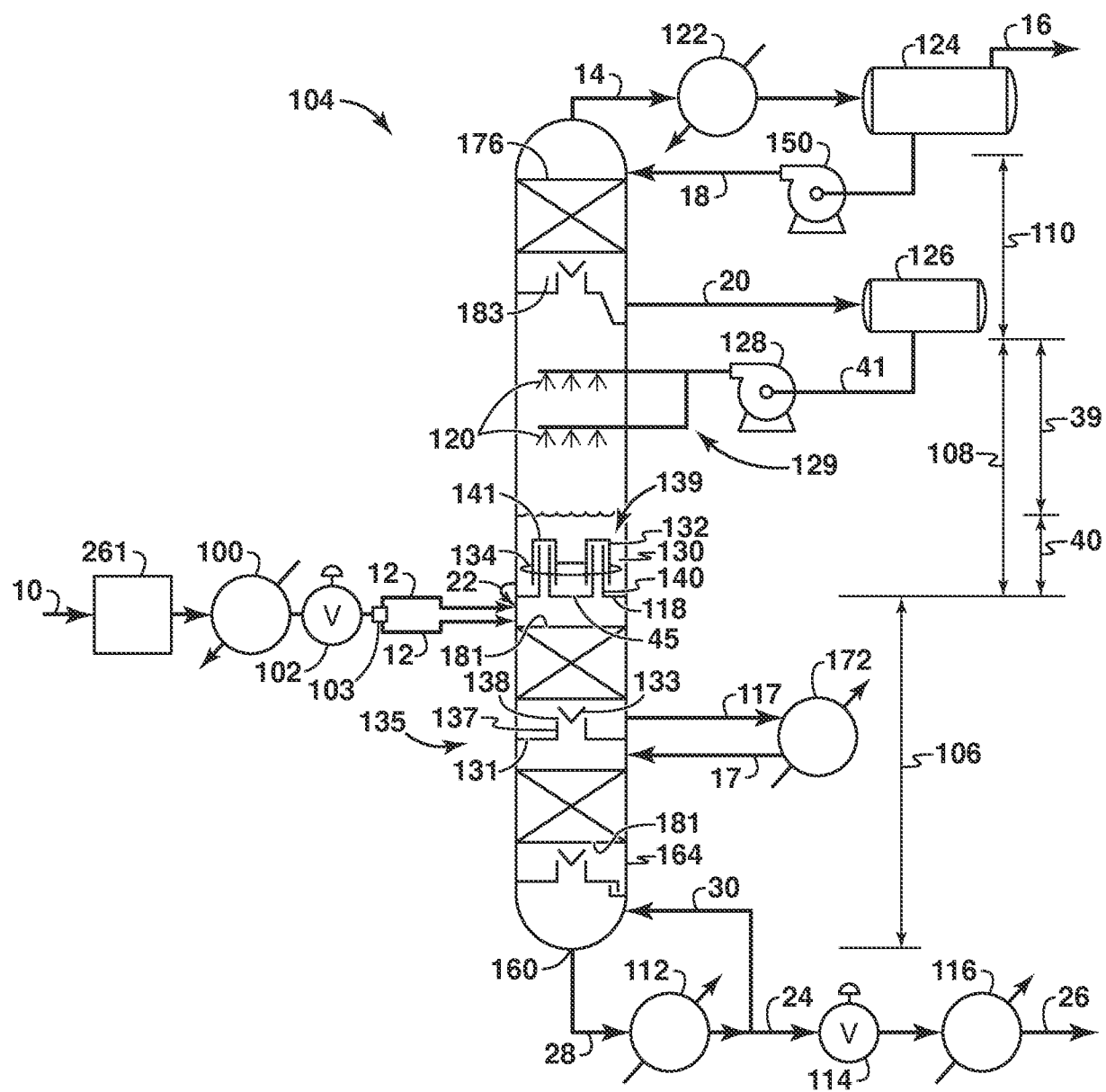


FIG. 3

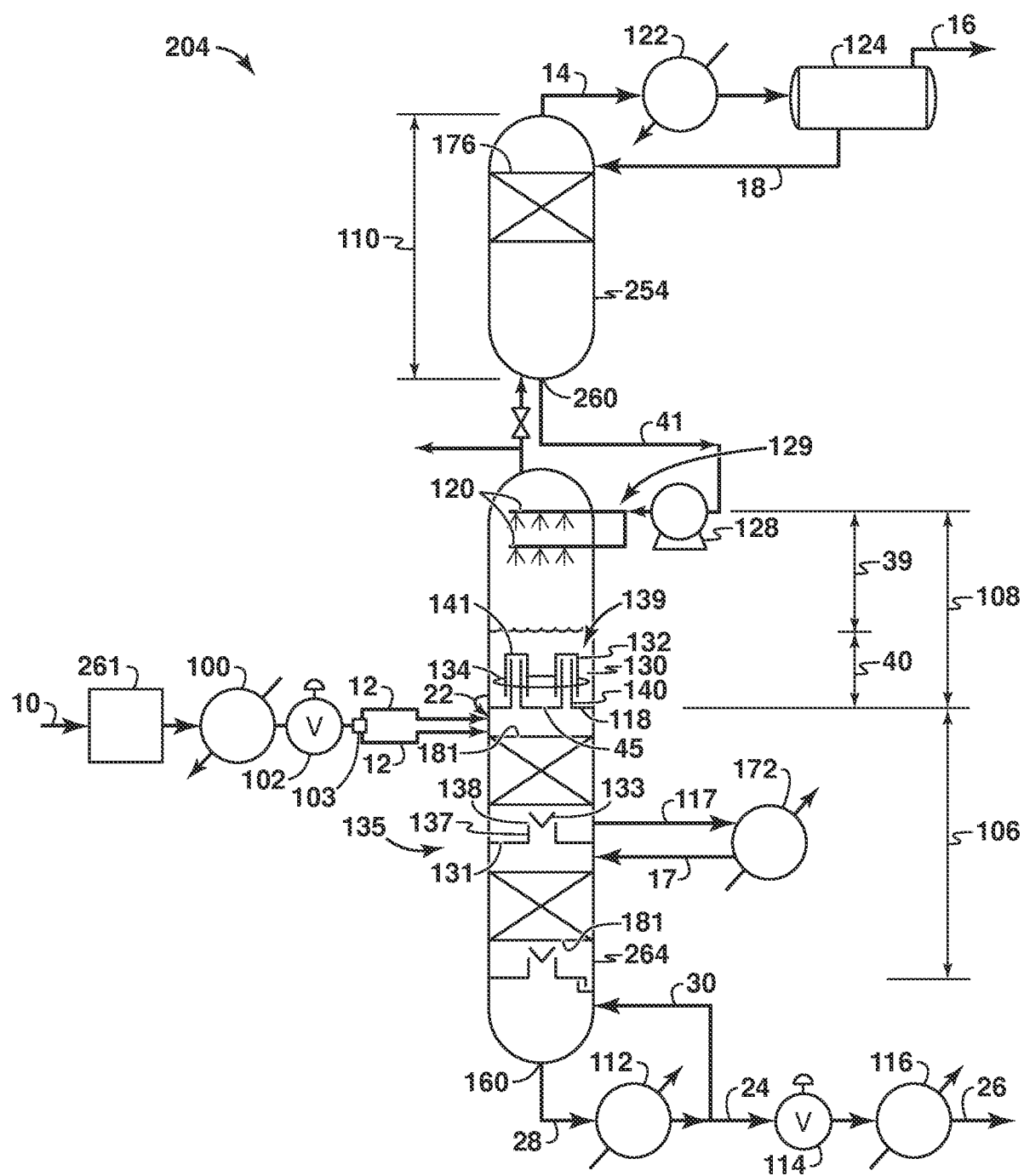


FIG. 4

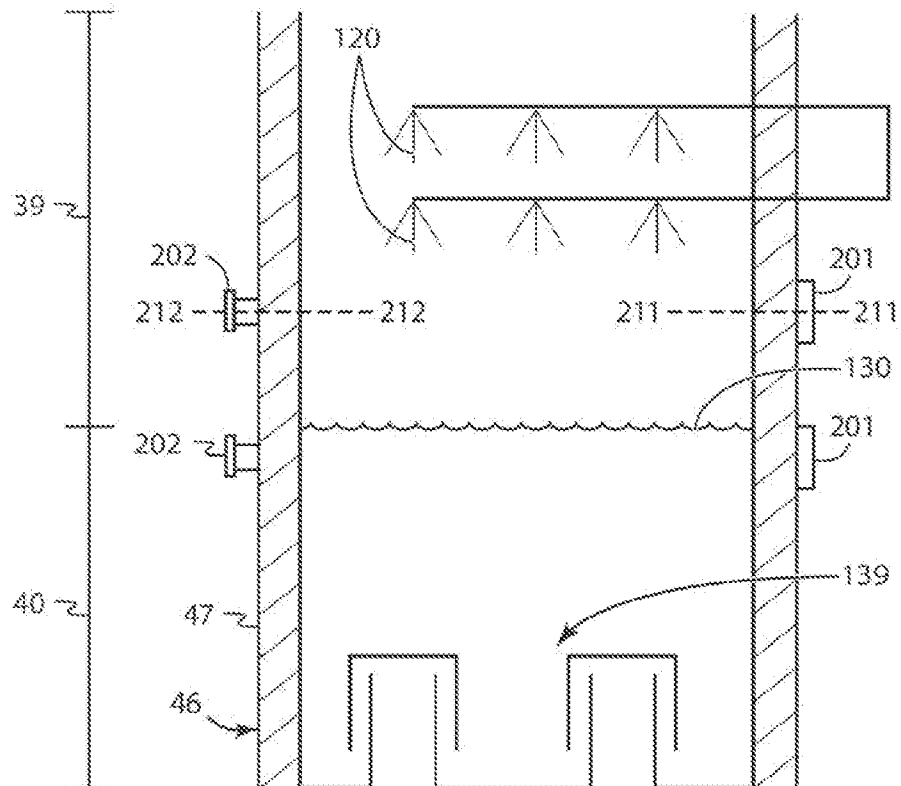
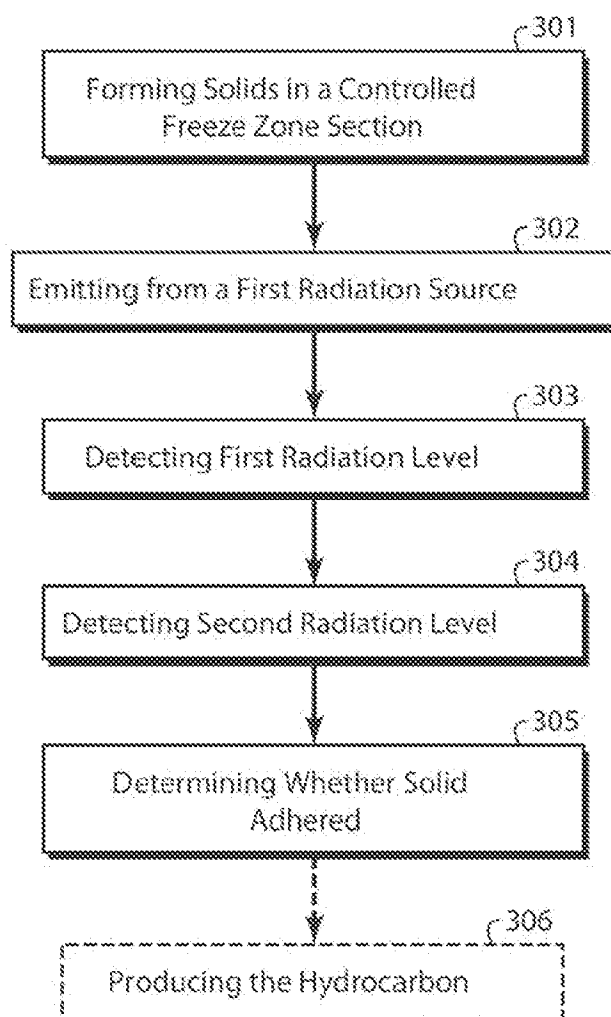


FIG. 5

**FIG. 6**