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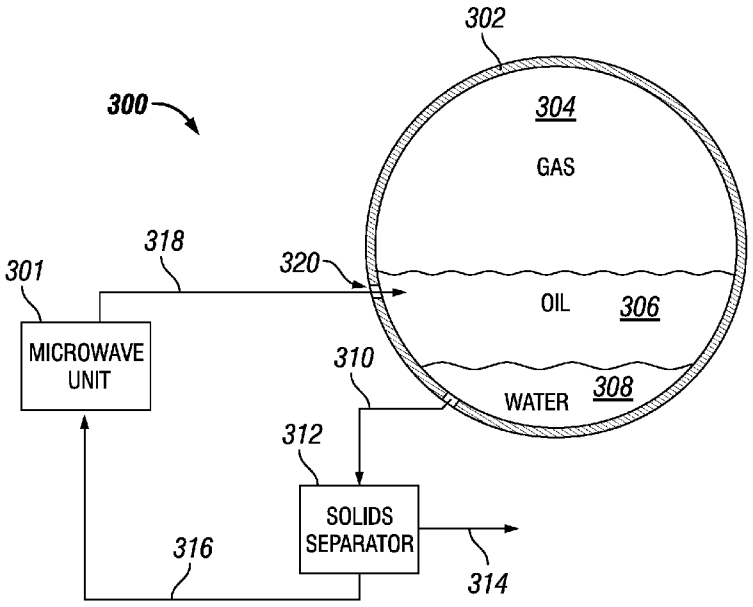

FIG. 3

(57) Abstract: Embodiments of the disclosure include processes using microwave heating to promote the separation of components of crude oil. In some embodiments, microwave-heated water may be used to heat the interphase between the gas phase and the oil phase of a crude oil stream to promote the separation of sulfur (for example, H_2S) and light end components of the crude oil stream. In some embodiments, microwave-heated water may be used to heat the interphase between the oil phase and the water phase of a crude oil stream to promote the separation of water, salt, or both of the crude oil stream. Systems having a microwave unit to provide microwave-heated water to crude oil stream are also provided.

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PCT PATENT APPLICATION

CRUDE QUALITY ENHANCEMENT BY SIMULTANEOUS CRUDE STABILIZATION, SWEETENING, AND DESALTING VIA MICROWAVE ASSISTED HEATING

BACKGROUND

Field of the Disclosure

[0001] The present disclosure generally relates to the processing of crude oil. More specifically, embodiments of the disclosure relate to crude quality enhancement using microwaves.

Description of the Related Art

[0002] Elemental sulfur and sulfur compounds are naturally present in many petroleum crude oils. The amount of sulfur varies over a wide range; for example, crude oil from Texas contains about 0.1 weight percent sulfur, whereas crude oil from Saudi Arabia and Kuwait contains about 3 weight percent sulfur to 5 weight percent sulfur. Crude oil may also include a wide variety of sulfur-containing compounds. Such sulfur-containing compounds range from hydrogen sulfide, which is a gas at room temperature, to organosulfur compounds that vaporize at over 1000° F.

[0003] Sulfur compounds are undesirable because of their odors and because sulfur compounds such as hydrogen sulfide are corrosive. The corrosive nature of sulfur compounds contributes significantly to the costs of construction, operation and maintenance of a petroleum refinery. Additionally, sulfur compounds may cause problems in gasoline engines and can contribute to environmental pollution. Sulfur in crude oil can generate hydrogen sulfide and other sulfur containing gases during transportation and, consequently, increase the difficulty of such operations.

SUMMARY

[0004] When crude petroleum is processed in an oil refinery, one of the steps is the separation of the crude into various products based on boiling points. The unit typically used for this separation is a distillation column operated at atmospheric pressure and is commonly

referred to as the crude still. Such oil refinery processes may yield a variety of useful fuels and desirable petroleum products, such as lower-boiling gasoline, middle distillate fuels such as kerosene and diesel oil, to fuel oil for heating, and higher-boiling waxes and heavy oils such as lubricating oil and asphalt products. The separation of the hydrocarbons also separates the sulfur compounds so that the lower boiling hydrocarbons contain lower-boiling sulfur compounds and higher-boiling hydrocarbons contain higher-boiling sulfur compounds.

[0005] Many technologies have been developed relating to sweetening and desulfurizing gasolines and other petroleum stocks depending upon the particular type of sulfur compound to be removed. Some technologies for sweetening, desulfurizing, or both include: oxidation reactions, solvent extraction, adsorption, metal catalysis, and hydrodesulphurization. However, most of these technologies are based on conventional refining techniques and have a relatively high cost. Furthermore, these technologies fail to sufficiently address the problem of removing sulfur and resulting formed sulfur compounds such as H_2S.

[0006] In some embodiments, a method of processing crude oil is provided. The method includes irradiating water at a first temperature with microwaves to produce heated water at a second temperature such that the second temperature is greater than the first temperature. The method further includes providing the heated water to a crude oil stream. The crude oil stream includes a gas phase, an oil phase, and a water phase. The method also includes providing the crude oil stream to a downstream crude oil processing unit.

[0007] In some embodiments, providing the heated water to the crude oil stream includes directing the heated water at a gas-oil interphase of the crude oil stream. In some embodiments, providing the heated water to the crude oil stream includes directing a first portion of the heated water at a gas-oil interphase of the crude oil stream and directing a second portion of the heated water at an oil-water interphase of the crude oil stream. In some embodiments, the method also includes disrupting an oil-water emulsion using the second portion of the heated water. In some embodiments, the method further includes obtaining the water at the first temperature from the crude oil stream. In some embodiments, the method also includes separating solids from the water before irradiating the water with microwaves to produce the heated water at the second temperature. In some embodiments, the water includes treated water from a water treatment unit of a crude oil processing plant. In some embodiments, the crude oil processing unit includes a high pressure production trap (HPPT), a low pressure production trap (LPPT), a stabilization unit, a desalter, or a dehydrator. In

some embodiments, the method includes producing a gas stream and a separated crude oil stream from the crude oil processing unit. Additionally, in some embodiments, the method includes boiling an H_2S component of the crude oil stream using the heated water and, in some embodiments, boiling light end components of the crude oil stream using the heated water. In some embodiments, the microwaves have a frequency of 915 MHz. In some embodiments, the second temperature is 194°F to 250°F.

[0008] In some embodiments, a system is provided that includes a pipe configured to transport a crude oil stream to a crude oil processing unit and a microwave unit upstream from the crude oil processing unit and coupled to the pipe. The microwave unit is configured to receive water at a first temperature from the crude oil stream and irradiate the water to produce heated water at a second temperature, wherein the second temperature is greater than the first temperature. The outlet of the microwave unit is coupled to an inlet of the pipe such that the inlet is configured to direct the heated water at an oil-gas interphase of the crude oil stream. In some embodiments, the system further includes a solids separator coupled to the microwave unit, the solids separator configured to separate solids from the water before the microwave unit receives the water. In some embodiments, the crude oil processing unit includes a high pressure production trap (HPPT), a low pressure production trap (LPPT), or a stabilization unit. In some embodiments, the crude oil stream is a first crude oil stream having a first composition and the crude oil processing unit is configured to output a second crude oil stream having a second composition. In some embodiments, the system includes a crude oil analyzer configured to determine at least one parameter of the second crude oil stream and a controller. The controller is configured to receive the at least one parameter from the crude oil analyzer, compare the at least one parameter to a respective at least one threshold value and modify a power of the microwaves based on the comparison. In some embodiments, the at least one parameter includes H_2S content, salt content, or Reid vapor pressure.

[0009] In some embodiments, a system is provided that includes a pipe configured to provide a crude oil stream to a crude oil processing unit and a microwave unit upstream of the crude oil processing unit and coupled to the pipe. The microwave unit is configured to irradiate water at a first temperature to produce heated water at a second temperature, wherein the second temperature is greater than the first temperature. An outlet of the microwave unit is coupled to a first inlet of the pipe such that the first inlet is configured to direct a first portion of the heated water at an oil-gas interphase of the crude oil stream. The outlet of the microwave unit is further coupled to a second inlet of the pipe such that the

second inlet configured to direct a second portion of the heated water at an oil-water interphase of the crude oil stream. In some embodiments, the water includes treated water from a water treatment unit. In some embodiments, the crude oil processing unit includes a desalter or a dehydrator. In some embodiments, the crude oil stream is a first crude oil stream having a first composition and the crude oil processing unit is configured to output a second crude oil stream having a second composition such that the crude oil processing unit is configured to output a second crude oil stream having a second composition. In some embodiments, the system includes a crude oil analyzer configured to determine at least one parameter of the second crude oil stream and a controller configured to receive the at least one parameter from the crude oil analyzer, compare the at least one parameter to a respective at least one threshold value, and modify a power of the microwaves based on the comparison. In some embodiments, the at least one parameter includes H_2S content, salt content, or Reid vapor pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a schematic diagram of a prior art crude oil stripping operation;

[0011] FIG. 2 is a schematic diagram of a crude oil processing operation using microwave heating in accordance with an example embodiment of the disclosure;

[0012] FIG. 3 is a schematic diagram of a first configuration with a microwave unit in accordance with an example embodiment of the disclosure;

[0013] FIG. 4 is a schematic diagram of a second configuration with a microwave unit in accordance with another example embodiment of the disclosure;

[0014] FIG. 5 is a schematic diagram of a crude oil processing operation using microwave heating and a control system in accordance with an example embodiment of the disclosure;

[0015] FIG. 6 is a schematic diagram of a crude oil processing operation using microwave heating and a control system in accordance with another example embodiment of the disclosure;

[0016] FIG. 7 is a block diagram of a gas-oil separation process having one or more microwave units in accordance with an example embodiment of the disclosure;

[0017] FIG. 8 is a flowchart of a process for processing crude oil using microwaves in accordance with an embodiment of the disclosure; and

[0018] FIG. 9 is a flowchart of a process for processing crude oil using microwaves in accordance with another embodiment of the disclosure.

DETAILED DESCRIPTION

[0019] The present disclosure will now be described more fully with reference to the accompanying drawings, which illustrate embodiments of the disclosure. This disclosure may, however, be embodied in many different forms and should not be construed as limited to the illustrated embodiments. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art.

[0020] Embodiments of the disclosure include the use of microwave heating to promote the separation of components of crude oil, such as performed in a crude oil processing plant. In some embodiments, microwaves may be used to heat a crude oil stream to promote the separation of sulfur (for example, H_2S) and light end components from the crude oil stream. In such embodiments, the microwaves may be used to provide interphase heating between the gas phase and the oil phase of the crude oil stream. In some embodiments, microwaves may be used to heat a crude oil stream to promote the separation of water, salt, or both from the crude oil stream. In such embodiments, the microwaves may be used to provide interphase heating between the oil phase and the water phase of the crude oil stream.

[0021] In some embodiments, microwave heating may be used to heat the interphase between the gas phase and the oil phase of the crude oil. In some embodiments, microwave heated water may be directed at the gas-oil interphase of a crude oil stream to promote the separation of sulfur components and light end components. In such embodiments, the gas-oil interphase heating may promote the separation of sulfur (for example, H_2S) and light end components, as the composition of the crude oil at the gas-oil interphase includes such components having lower- boiling components than other components of the crude oil. In some embodiments, the gas-oil interphase heating may provide sufficient heating to boil the sulfur components (for example, H_2S) and light end components while heavier components remain in the liquid phase. In some embodiments, the gas-oil interphase heating may provide

heating to promote the separation of sulfur (for example, H_2S) and light end components in a downstream processing unit (for example, a stabilization unit).

[0022] In some embodiments, microwave heating may be used to heat the interphase between the oil phase and the water phase of the crude oil. In some embodiments, microwave heated water may be directed at the oil-water interphase of a crude oil stream to promote the separation of water and salt. In such instances, the oil-water interphase heating may disrupt the emulsion present in the oil-water interphase. The disruption of the emulsion may promote the coalescence of larger water droplets that settle to the bottom of the crude oil stream via gravity. The gravity separation of the larger water droplets facilitates the separation of salt dissolved in the water phase of the crude oil. In some embodiments, the oil-water interphase heating may provide heating to promote the separation of water, salt, or both in a downstream processing unit (for example, a desalter).

[0023] Advantageously, crude oil processing using the microwave heating techniques described in the disclosure may result in improved economics and operability of a crude oil processing plant, such as by reducing energy costs, maintenance costs, and capital costs. For example, as described herein, crude oil processing using microwave heating in the manner described in the disclosure may reduce or eliminate the energy requirements of a separation unit (for example, a stabilization unit) of a crude oil processing plant. In another example, crude oil processing using microwave heating may eliminate the use of a stabilization unit if the separation achieved by the microwave heating meets or exceeds a crude oil specification.

[0024] FIG. 1 depicts a prior art crude oil stabilization operation 100 (also referred to as a crude oil "stripping operation") of a crude oil processing plant that has associated operational and capital costs as described *infra*. As shown in FIG. 1, a stabilizer tower 102 may receive a crude oil feed stream 104 and output a gas stream 106 and a stabilized crude oil stream 108. The feed stream 104 may be heated via a heated stream 110 produced by a heat source 112 (for example, steam or a furnace). The heated stream may be or include a portion of the stabilized crude oil stream 108.

[0025] The stabilizer tower 102 includes multiple trays 114 which, in combination with the heat from the heated stream 110, provide for separation of vapor and liquid from the feed stream 104. The heated stream 110 may be used to generate vaporized crude, depicted as vapor flow 116, from the feed stream 104. As shown in FIG. 1, the vapor flow 116 is in a

countercurrent flow with a downward flowing liquid flow 118 from the feed stream 104 and condensed crude vapors. As the heating occurs at the bottom of the stabilizer tower 102, the temperature profile in the stabilizer tower 102 is greatest at the bottom of the tower 102 (at around 175°F) to lowest at the top of the tower 102 (at around 150°F). The temperature profile promotes the separation of H_2S and light end components from the crude oil feed stream 104. Each of the trays 114 enables separation of the feed stream 104 to occur via vaporization and condensation between the vapor flow 116 and liquid flow 118. As the vapor flow 116 flows to the top of the stabilizer tower 102, the vapor composition includes increasing concentrations of H_2S and light end components. The stabilizer tower 102 may be operated at a lesser pressure (for example, in the range of 3 pounds-per-square inch gauge (psig) to 5 psig) to promote the separation of the vapor and liquid.

[0026] The fuel cost to operate the stabilizer tower 102 using steam as the heat source 112 or a furnace as the heat source 112 may vary according to the capability of the crude oil processing facility. For example, assuming a fuel gas tariff of about $2.5/million British Thermal Units (MMBtu), the annual fuel gas cost to run the prior art crude oil stabilization operation 100 may be in the range of $2M/year to over $20M/year, depending on production rates. Increasing energy efficiency of a crude oil stripping operation may thus reduce fuel gas consumption and operating costs. The prior art crude oil stripping operation 100 may, in addition to having an energy intensive operation, have a high capital cost, a high risk of losing desired product due to unselective separation, and a high cost of maintenance.

[0027] Other crude oil processing operations, such as desalting, of a crude oil processing plant also have associated operational and capital costs. A crude oil desalting operation may use water (for example, freshwater or wash water) to first mix with the remnant water. The mixing dilutes the salt concentration in the remnant water and results in the formation of an oil-water emulsion. The oil-water emulsion may be disrupted by chemical treatment (for example, a demulsifier), and an electrical treatment (for example, an electrostatic field). For example, the electrostatic field generated in a dehydrator and desalter unit promotes coalescence of small water droplets resulting from the mixing between the remnant water and added water. The formation and subsequent coalescence of the water droplets assists in the settling and thus, separation, of water from the oil using gravity. This separation may be modeled according to Stoke's law, shown in Equation 1:

$$Vt = \frac{1.78 \times 10^{-6} (\Delta SG) d^2}{\mu} \quad (1)$$

[0028] Where Vt is the droplet settling velocity of water, ΔSG is the difference in specific gravity relative to water, d is the droplet diameter in microns, and μ is the viscosity of the continuous phase (that is, the viscosity of the oil). Equation 1 illustrates that heating affects both the specific gravity and viscosity and, consequently, increases the droplet settling velocity Vt. However, although heating decreases the viscosity, oil viscosity is significantly greater than the water viscosity. Thus, heating the crude oil phase may increase the speed of separation of water from the crude oil and, consequently, may increase the separation of salt from the crude oil.

[0029] With the foregoing in mind, FIG. 2 depicts crude oil processing operation 200 of a crude oil processing plant using microwave heating in accordance with an example embodiment of the disclosure. FIG. 2 depicts a microwave unit 202 having a microwave source 204, a control unit 206, and a pressure vessel 208. For example, the crude oil processing operation 200 may be representative of a crude oil stabilization operation.

[0030] The microwave unit 202 receives a crude oil feed stream 210. In some embodiments, the feed stream 210 may be dewatered crude oil. As will be appreciated raw crude oil may be a relatively homogenous 3-phase stream of water, oil and gas. In some embodiments, waste water may be separated from the raw crude oil, such as at an upstream facility, before the crude oil is provided to the crude oil stripping operation 200.

[0031] The crude oil feed stream 210 may be directly or indirectly heated by microwaves provided by the microwave source 204 of the microwave unit 202. In some embodiments, the microwave source 204 may provide microwaves having a frequency in the range of about 890 MHz to about 940 MHz or a frequency in the range of about 2400 MHz to about 2500 MHz. In some embodiments, the microwave source 204 may provide microwaves having a frequency of about 915 MHz or about 2450 MHz. In other embodiments, the microwave source 204 may provide microwaves at different frequencies. In some embodiments, the microwave source 204 may be manufactured by Industrial Microwave Systems, LLC, of New Orleans, Louisiana, USA. In some embodiments, as described further herein, the microwave source 204 may be used to heat water, and the heated water may be provided to the crude oil feed stream to heat the crude oil.

[0032] After heating by the microwave unit 202, the heated crude oil stream 212 may be provided to the pressure vessel 208 for processing. For example, the pressure vessel 208 may be a stabilization unit that operates in a similar manner to the stabilizer tower 102 described *supra*. Separated gas 214 and stabilized crude oil 216 may exit the pressure vessel 208 and be provided to downstream facilities for further processing.

[0033] The microwaves from the microwave source 204 may, by directly or indirectly heating the crude oil feed stream 210, selectively target sulfur-containing components and light end components in the crude oil feed stream 210. In some embodiments, the microwave unit 202 may be coupled to a pipe transporting the crude oil feed stream and may be positioned relatively close to the pressure vessel 208 so that the separated H_2S and light end components may be more effectively removed from the vessel 208. In other embodiments, as described further in the disclosure, microwave heating of a crude oil stream may be used to promote dehydration, desalting, and other operations of crude oil processing.

[0034] Some embodiments may include the retrofit or modification of existing microwave systems to provide microwave heating of a crude oil stream. For example, in some embodiments a microwave water cut meter used to measure the water content in crude oil may be retrofitted or modified for use as the microwave unit 202 for microwave heating of the crude oil feed stream 210. In some embodiments, the microwave unit 202 may be a spool microwave unit that connects via flanges and does not require any vessel for mounting to existing pipe.

[0035] The control unit 206 may control the amount of microwaves emitted to achieve a desired crude oil specification via a feedback loop. For example, the amount of H_2S and light end components in the stabilized crude oil 216 may be measured at a sample point 220, and a signal 222 indicative of the amount of H_2S and light end components may be provided to the control unit 206 via an electrical circuit. The control unit 206 may provide a control signal 224 to the microwave source 204 to control the power of microwaves irradiating the crude oil feed stream 210. For example, the control unit 206 may provide a controls signal 224 to increase the power of the microwaves of the microwave source 204 or decrease the power of the microwaves of the microwave source 204.

[0036] As shown in FIGS. 3 and 4 and as described *infra*, embodiments of the disclosure further include a configurations of the microwave unit and the heated water output from the

microwave unit to promote the separation of components (for example, H_2S and light end components) from the crude oil. FIG. 3 depicts a first configuration 300 of a microwave unit 301 in accordance with an example embodiment of the disclosure. FIG. 3 depicts a cross-sectional view of a pipe 302 transporting crude oil composed of gas, oil, and water, as shown by gas phase 304, oil phase 306, and water phase 308. It should be appreciated that the gas phase 304, oil phase 306, and water phase 308 are merely illustrative and may not reflect the actual location or distribution of the phases of the crude oil in the pipe 302.

[0037] In the example embodiment depicted in FIG. 3, a side-stream 310 of the water phase 308 may be drawn from the pipe 302 and provided to a solids separator 312. In some embodiments, the side stream 310 may constitute in the range of about 1% by volume to about 5% by volume of the crude oil flowing in the pipe 302. The solids separator 312 may remove particulate solids or other solid contaminants 314 from the water to prevent such solids from interfering with the flow to the microwave unit 301. The solids separator 312 may also prevent solid contaminants from flowing into the microwave unit 301 and impairing the heating efficiency of the microwave unit 301.

[0038] The separated water 316 output from the solids separator 312 may be provided to the microwave unit 301 for irradiation by microwaves to produce heated water 318. The heated water 318 may then be provided to the crude oil pipe 302. In some embodiments, the heated water 318 may be heated to a temperature in the range of about 194°F to about 250°F. In other embodiments, the heated water 318 may be heated to a temperature in the range of about 194°F to about 250°F. In some embodiments, the temperature of the heated water 318 may be based on the pressure capability of a downstream vessel receiving the crude oil in the crude oil pipe 302. It should be appreciated that such heating may be localized to the heated water 318 and may be sufficient to heat and, in some instances, boil some components (for example, H_2S and light end components) of the crude oil. In some embodiments, the microwave unit 301 may have flow chambers having a microwave waveguide that forms a double-ended resonant chamber with multiple radiofrequency (RF) energy reflections.

[0039] In some embodiments, the heated water 318 may be provided via a non-metallic pipe that couples the outlet of the microwave unit 301 to an inlet 320 of the crude oil pipe 302. In some embodiments, the inlet 320 of the heated water may be targeted at the oil and gas interphase between the oil phase 306 and the gas phase 304 to direct the heated water 318

at the oil-gas interphase. For example, in such embodiments, the inlet 320 may be located at a level of about 50% to about 60% from the top of the pipe 302.

[0040] In some embodiments, the microwave unit 301 may provide microwaves having a frequency in the range of about 890 MHz to about 940 MHz or a frequency in the range of about 2400 MHz to about 2500 MHz. In some embodiments, the microwave unit 301 may provide microwaves having a frequency of about 915 MHz or about 2450 MHz. In other embodiments, the microwave unit 301 may provide microwaves at different frequencies. In some embodiments, the microwave unit 301 may be manufactured by Industrial Microwave Systems, LLC, of New Orleans, Louisiana, USA. In some embodiments, the microwave unit 301 may be a retrofit or modification of an existing microwave system. In some embodiments, the microwave unit 301 may be a spool microwave unit that connects via flanges and does not require any vessel for mounting to existing pipe. In some embodiments, the microwave unit 301 may be placed directly in crude oil pipe 302 (in such embodiments, for example, the microwave unit 301 may have an electromagnetic-transparent housing).

[0041] The configuration 300 illustrated in FIG. 3 and described *supra* may provide heating to the top of the oil layer 306 where specific components (for example, H_2S and light end components) are predominant. In some embodiments, the heat provided by the heated water 318 may be sufficient to boil the some components (for example, H_2S and light end components) while retaining the heavy ends components in the liquid phases of the crude oil, such that sensible heat exists and no vaporization occurs. In contrast to the embodiment shown in FIG. 3, heating via a top position of the pipe 302 may be less effective, as the microwave-heated water must travel from the top of the pipe 302 and through the gas layer 302, and is farther from the water layer 308 where heating occurs. Advantageously, the configuration 300 shown in FIG. 3 also leverages the presence of remaining water in the water phase 308 of the crude oil.

[0042] In some embodiments, for example, the configuration 300 shown in FIG. 3 may be used to heat a crude oil stream to promote separation of components (for example, H_2S and light end components) from the crude oil. For example, the configuration shown in FIG. 3 may be used upstream of a separation unit (for example, a high pressure production trap, a low pressure production trap, a stabilization unit, and the like). In some embodiments, for example, the configuration shown in FIG. 3 may be used to place a microwave unit at the

entrance of a separation unit to heat a crude oil feed stream and promote separation of components from the crude oil.

[0043] FIG. 4 depicts a second configuration 400 of a microwave unit 401 in accordance with another example embodiment of the disclosure. FIG. 4 also depicts a cross-sectional view of a pipe 402 transporting crude oil composed of gas, oil, and water, as shown by gas phase 404, oil phase 406, and water phase 408. It should be appreciated that the gas phase 404, oil phase 406, and water phase 408 are merely illustrative and may not reflect the actual location or distribution of the phases of the crude oil in the pipe 402.

[0044] In contrast to the embodiment depicted in FIG. 3 and described *supra*, the embodiment shown in FIG. 4 includes the use of treated water 410 from a treated water source. For example, a crude oil processing plant may include sources of treated water for different uses, such as for oil processing and as a source for potable water. Consequently, the embodiment shown in FIG. 4 may be used without a separator and an additional side-stream of water drawn from the crude oil. It should be appreciated that the available of treated water and the distance to the source of treated water may be considerations for use of the configuration depicted in FIG. 4 as opposed to the configuration depicted in FIG. 3.

[0045] As shown in FIG. 4, treated water 410 may be provided to the microwave unit 401 for irradiation by microwaves to produce heated water 412. The heated water 412 output from the microwave unit 401 may be provided to the crude oil pipe 402. In some embodiments, the heated water 412 may be heated to a temperature in the range of about 194°F to about 250°F. In other embodiments, the heated water 318 may be heated to a temperature in the range of about 194°F to about 250°F. In some embodiments, the temperature of the heated water 318 may be based on the pressure capability of a downstream vessel receiving the crude oil in the crude oil pipe 302. It should be appreciated that such heating may be localized to the heated water 412 and may be sufficient to heat and, in some instances, boil some components (for example, H_2S and light end components) of the crude oil. In some embodiments, the microwave unit 401 may have flow chambers having a microwave waveguide that forms a double-ended resonant chamber with multiple radiofrequency (RF) energy reflections.

[0046] In some embodiments, the heated water 412 may be provided via a non-metallic pipe that couples the outlet of the microwave unit 401 to a first inlet 414 of the pipe 402. In

some embodiments, the first inlet 414 may be targeted at the oil and gas interphase between the oil phase 406 and the gas phase 404, such that a first portion 416 of the heated water is directed at the oil and gas interphase of the crude oil. For example, in such embodiments, the first inlet 414 may be located at a level of about 50% to about 60% from the top of the pipe 402. As previously discussed, providing the microwave-heated water at the oil-gas interphase provides localized heating that at the interphase to boil or improve the boiling of those components having lesser boiling points (for example, H_2S and light end component).

[0047] Additionally, the outlet of the microwave unit 401 may be coupled to a second inlet 418 of the pipe 402. In some embodiments, the second inlet 418 may be located at the oil and water interphase between the oil phase 406 and the water phase 408, such that a second portion 420 of the heated water 412 is directed at the oil and water interphase of the crude oil. The second portion 420 of the heated water 412 may be directed at the oil-water interphase to heat the water phase 408 and promote oil-water separation in subsequent processing units, such as a dehydrator or a desalter. As previously discussed, providing the microwave-heated water 412 at the oil-water interphase promotes the break-up of the emulsion present in the oil-water interphase and formation of larger water droplets that settle to the bottom via gravity, thus further promoting the separation of salt from the oil phase. In some embodiments, the use of the second portion 420 of the heated water 412 may depend on the pipe length, such as the pipe length between the inlet 418 and a subsequent processing unit.

[0048] In some embodiments, the microwave unit 401 may provide microwaves having a frequency in the range of about 890 MHz to about 940 MHz or a frequency in the range of about 2400 MHz to about 2500 MHz. In some embodiments, the microwave unit 401 may provide microwaves having a frequency of about 915 MHz or about 2450 MHz. In other embodiments, the microwave unit 401 may provide microwaves at different frequencies. In some embodiments, the microwave unit 401 may be manufactured by Industrial Microwave Systems, LLC, of New Orleans, Louisiana, USA. In some embodiments, the microwave unit 401 may be a retrofit or modification of an existing microwave system. In some embodiments, the microwave unit 401 may be a spool microwave unit that connects via flanges and does not require any vessel for mounting to existing pipe.

[0049] The configuration 400 illustrated in FIG. 4 and described *supra* may provide heating to the top of the oil phase 406 where specific components (for example, H_2S and light end components) are predominant. In some embodiments, the heat provided by the heated

water 416 may be sufficient to boil the some components (for example, H_2S and light end components) while retaining the heavy ends components in the liquid phases of the crude oil, such that sensible heat predominantly exists and no vaporization of heavy end components occurs. Additionally, the configuration 400 shown in FIG. 4 may promote separation of components (for example, water and salt) between the oil phase 406 and the water phase 408. Here again, the placement of the heated water portions 416 and 420 may be more effective than heating via a top position of the pipe 402. Further, the configuration 400 shown in FIG. 4 also leverages the presence of remaining water in the water phase 408 of the crude oil.

[0050] In some embodiments, for example, the configuration shown in FIG. 4 may be used to heat a crude oil stream to promote separation of components (for example, H_2S and light end components) from the crude oil. For example, the configuration shown in FIG. 4 may be used upstream of a separation unit (for example, a high pressure production trap, a low pressure production trap, a stabilization unit, and the like). Additionally, the configuration shown in FIG. 4 may be further used to promote separation between the oil phase and water phase of crude oil. For example, in some embodiments, the configuration shown in FIG. 4 may be used to position a microwave unit at the entrance of a separation unit such as a dehydrator or desalter to promote separation of water, salt, or both from the crude oil.

[0051] As shown in FIGS. 5 and 6 and as described *infra*, embodiments of the disclosure may further include a control system to monitor the crude oil parameters and adjust a microwave unit in response to the monitored crude oil parameters. FIG. 5 depicts a crude oil processing operation 500 using microwave heating and a control system 502 in accordance with an example embodiment of the disclosure. FIG. 5 also depicts a crude oil pipe 504, a mixer 506, a microwave unit 508, a pressure vessel 510, and a solids separator 512.

[0052] The crude oil pipe 504 may provide a crude oil stream to the mixer 506. The mixer 506 may be used, in some embodiments, to promote mixing of the crude oil steam. In some embodiments, the mixer 506 may be eliminated and the operation 500 may not include the mixer 506.

[0053] The microwave unit 508 and solids separator 512 may operate in a manner similar to the microwave source and solids separator described *supra* and illustrated in FIG. 3. For example, a side-stream 516 of the water may be drawn from the crude oil pipe 504 and

provided to the solids separator 512 for removal of solid contaminants 518 from the water. The solids separator 512 may also prevent solid contaminants from flowing into the microwave unit 508 and impairing the heating efficiency of the microwave unit 508. The solids separator 512 may output filter water 520.

[0054] The filtered water 520 output from the solids separator 512 may be provided to the microwave unit 508 for heating by microwaves. The microwave unit 508 (which, in some embodiments, includes the microwave source) may output heated water 522 which is then provided to the crude oil feed stream via an inlet 524 of the pipe 504. In some embodiments, the heated water 522 may be provided via a non-metallic pipe that couples the outlet of the microwave unit 508 to the inlet 524. In some embodiments, the inlet 524 of the crude oil pipe 504 may be located such that the heated water 522 is directed at the oil and gas interphase of the crude oil feed stream. For example, in such embodiments, the inlet 524 to the crude oil pipe 504 may be located at a level of about 50% to about 60% from the top of the pipe 504.

[0055] In some embodiments, the microwave unit 508 may provide microwaves having a frequency in the range of about 890 MHz to about 940 MHz or a frequency in the range of about 2400 MHz to about 2500 MHz. In some embodiments, the microwave unit 508 may provide microwaves at a frequency of about 915 MHz or about 2450 MHz. In other embodiments, the microwave unit 508 may provide microwaves at different frequencies. In some embodiments, the microwave unit 508 may be manufactured by Industrial Microwave Systems, LLC, of New Orleans, Louisiana, USA. In some embodiments, the microwave unit 508 may be coupled to the pipe 504 transporting the crude oil feed stream and positioned relatively close to the pressure vessel 510 so that the separated H_2S and light end components may be more effectively removed from the vessel 508. As previously noted, some embodiments may include the retrofit or modification of existing microwave systems to provide heating for crude oil stripping.

[0056] After heating by the microwave unit 508, the heated crude oil stream may be provided to the pressure vessel 510 for separation. For example, separated gas 526 and separated crude oil 528 may exit the pressure vessel 510 and be provided to downstream facilities for further processing. Additionally, produced water 530 from the crude oil may exit the pressure vessel 510.

[0057] The control system 502 includes a controller 532 and an analyzer 534. The analyzer 534 may detect the properties of the separated crude oil 528 to determine parameters (for example, properties and composition) of the separated crude oil 528. For example, in some embodiments, the analyzer 534 may analyze the separated crude oil 528 to determine the amount of H_2S present in the separated crude oil 528, the amount of light end components present in the crude oil 528, and the Reid vapor pressure (RVP) of the separated crude oil 528. The analyzer 534 may output a signal 536 indicative of the determined parameters of the separated crude oil 528 to the controller 532.

[0058] The controller 532 receives the signal 536 and may determine whether the crude oil parameters deviate from a crude oil specification for the separated crude oil 528. Based on the determination, the controller 532 may provide a control signal 538 to the microwave unit 508. The control signal 538 may modify the power of microwaves used to irradiate the treated water 522 and, consequently, the temperature of the heated water 522 provided to the crude oil feed stream via the inlet 524. In some embodiments, the controller 532 may compare the crude oil parameter to a stored value, such as a value obtained from the crude oil specification. In some embodiments, the comparison may determine whether the crude oil parameter deviates from the stored value by a threshold amount or threshold percentage. In some embodiments, the controller 532 may compare the crude oil parameter to a threshold value to determine whether crude oil parameter is less than or exceeds the threshold value. In some embodiments, the control system 502 may monitor and control the microwave unit 508 based on one parameter or multiple parameters. In other embodiments, the control system 502 may monitor and control the microwave unit 508 based on a parameter (for example, temperature of the heated water 522).

[0059] For example, in some embodiments, the amount of H_2S in the separated crude oil 528 may be compared to a threshold value for stabilized crude oil that meets or exceeds a crude oil specification. If the controller 532 determines that the amount of H_2S in the separated crude oil 528 exceeds the threshold value, the controller 532 may increase the power of the microwave unit 508 via the control signal 538. To promote removal of H_2S, for example, the controller 532 may increase the power of the microwave unit 508 to raise the temperature of the heated water 522, thus providing more heating at the oil-gas interphase of the crude oil.

[0060] In some embodiments, the controller 532 may include a processor and memory to enable processing of crude oil parameters received from the analyzer. For example, the controller 532 may include one or more processors. In some embodiments, the controller 532 may include an application-specific integrated circuit (AISC). Additionally, in some embodiments the controller 532 may include a single-core processors and multicore processors. The controller 532 may further include a memory (which may include one or more tangible non-transitory computer readable storage mediums) such as volatile memory, such as random access memory (RAM), and non-volatile memory, such as ROM, flash memory, a hard drive, any other suitable optical, magnetic, or solid-state storage medium, or a combination thereof. The memory may store executable computer code having computer program instructions for implementing one or more techniques described in the disclosure, For example, the executable computer code may include instructions for processing parameters of crude oil and controlling a microwave unit in accordance with embodiments of the present disclosure.

[0061] In some embodiments, the control system 502 may include or implement aspects of the performance monitoring described in U.S. Patent No. 9,092,124 entitled "System and method for effective plant performance monitoring in gas oil separation plant (GOSP)" and issued July 28, 2015, a copy of which is incorporated by reference.

[0062] FIG. 6 depicts an operation unit 600 of a crude oil processing plant using microwave heating and a control system 602 in accordance with an example embodiment of the disclosure. FIG. 6 also depicts a crude oil pipe 604, a mixer 606, a microwave unit 608, and a pressure vessel 610.

[0063] The crude oil pipe 604 may provide a crude oil stream to the mixer 606. The mixer 606 may be used, in some embodiments, to promote mixing of the crude oil steam. In some embodiments, the mixer 606 may be eliminated and the operation 600 may not include the mixer 606.

[0064] The microwave unit 608 (which may include a microwave source) may operate in a manner similar to the microwave source and separator illustrated *supra* and described in FIG. 4. For example, treated water 612 may be provided to the microwave unit 608 for heating by microwaves. The microwave unit 608 may output heated water 614 which may be provided to the crude oil feed stream via an inlet 616 of the pipe 604. In some embodiments, the heated

water 614 may be provided via a non-metallic pipe that couples the outlet of the microwave unit 608 to the inlet 616. In some embodiments, the inlet 616 of the crude oil pipe 604 may be located such that the heated water 614 is directed at the oil and gas interphase of the crude oil feed stream. For example, in such embodiments, the inlet 616 to the crude oil pipe 604 may be located at a level of about 50% to about 60% from the top of the pipe 604. In some embodiments, a first portion of the heated water 614 may be directed at the oil-gas interphase of the crude oil feed stream via the inlet 616, and a second portion of the heated water 614 may be directed at the oil-water interphase of the crude oil feed stream via a second inlet.

[0065] In some embodiments, the microwave unit 608 may provide microwaves having a frequency in the range of about 890 MHz to about 940 MHz or a frequency in the range of about 2400 MHz to about 2500 MHz. In some embodiments, the microwave unit 608 may provide microwaves at a frequency of about 915 MHz or about 2450 MHz. In other embodiments, the microwave unit 608 may provide microwaves at different frequencies. In some embodiments, the microwave unit 608 may be manufactured by Industrial Microwave Systems, LLC, of New Orleans, Louisiana, USA. In some embodiments, the microwave unit 608 may be positioned relatively close to the pressure vessel 610 so that the separated H_2S and light end components may be more effectively removed from the vessel 610.

[0066] After heating by the microwave unit 608, the heated crude oil stream may be provided to the pressure vessel 610 for gas and liquid separation. Separated gas 618 and separated crude oil 620 may exit the pressure vessel 610 and be provided to downstream facilities for further processing. As also shown in FIG. 6, produced water 622 from the crude oil may exit the pressure vessel 610.

[0067] Some embodiments may include the retrofit or modification of existing microwave systems to provide heating for crude oil stripping. For example, in some embodiments a microwave water cut meter used to measure the water content in crude oil may be retrofitted or modified for use as the microwave unit 608 for heating for separation of H_2S and light end components in the crude oil stripping operation 600.

[0068] The control system 602 may operate in a manner similar to the control system 502 depicted in FIG. 5 and discussed *supra*. For example, the control system 602 shown in FIG. 6 includes a controller 624 and an analyzer 626. The analyzer 626 may analyze the separated crude oil 620 to determine parameters (for example, properties and composition) of the

stabilized crude 620. For example, in some embodiments, the analyzer 626 may analyze the separated crude oil 620 to determine the amount of H_2S present in the separated crude oil 620, the amount of light end components present in the separated crude oil 620, and the Reid vapor pressure (RVP) of the separated crude oil 620. The analyzer 626 may output a signal 628 indicative of determined parameters of the separated crude oil 620 to the controller 624.

[0069] The controller 624 receives the signal 628 and may determine whether the crude oil parameters deviate from a crude oil specification for the separated crude oil 620. Based on the determination, the controller 624 may provide a control signal 630 to the microwave unit 608. The control signal 630 may modify the amount of microwaves used to heat the treated water 612 and, consequently, the temperature of the heated water 614 provided to the crude oil feed stream via the inlet 616. In some embodiments, the controller 624 may compare the crude oil parameter to a stored value, such as a value obtained from the crude oil specification. In some embodiments, the comparison may determine whether the crude oil parameter deviates from the stored value by a threshold amount or threshold percentage. In some embodiments, the controller 624 may compare the crude oil parameter to a threshold value to determine whether crude oil parameter is less than or exceeds the threshold value. In some embodiments, the control system 602 may monitor and control the microwave unit 608 based on one parameter or multiple parameters. In other embodiments, the control system 602 may monitor and control the microwave unit 608 based on a parameter (for example, temperature of the heated water 614).

[0070] For example, in some embodiments, the amount of H_2S in the separated crude oil 620 may be compared to a threshold value for stabilized crude oil that meets or exceeds a crude oil specification. If the controller 624 determines that the amount of H_2S in the separated crude oil 620 exceeds the threshold value, the controller 624 may modify the operation of the microwave unit 608 via the control signal 630. To promote removal of H_2S, for example, the controller 624 may increase the power of the microwave unit 608 to raise the temperature of the heated water 614, thus providing more heating at the oil-gas interphase of the crude oil.

[0071] In another example, the amount of salt in the separated crude oil 620 may be compared to a threshold salt value for stabilized crude oil that meets or exceeds a crude oil specification. If the controller 624 determines that the amount of salt in the separated crude oil 620 exceeds the threshold value, the controller 624 may modify the operation of the

microwave unit 608 via the control signal 630. To promote removal of salt, for example, the controller 624 may increase the power of the microwave unit 608 to raise the temperature of the heated water 614 and provide more heating at the oil-water interphase of the crude oil.

[0072] In some embodiments, the controller 624 may include a processor and memory to enable processing of crude oil parameters received from the analyzer. For example, the controller 624 may include one or more processors. In some embodiments, the controller 624 may include an application-specific integrated circuit (AISC). Additionally, in some embodiments the controller 624 may include a single-core processors and multicore processors. The controller 624 may further include a memory (which may include one or more tangible non-transitory computer readable storage mediums) such as volatile memory, such as random access memory (RAM), and non-volatile memory, such as ROM, flash memory, a hard drive, any other suitable optical, magnetic, or solid-state storage medium, or a combination thereof. The memory may store executable computer code having computer program instructions for implementing one or more techniques described in the disclosure, For example, the executable computer code may include instructions for processing parameters of crude oil and controlling a microwave unit in accordance with embodiments of the present disclosure.

[0073] In some embodiments, the control system 602 may include or implement aspects of the performance monitoring described in U.S. Patent No. 9,092,124 entitled "System and method for effective plant performance monitoring in gas oil separation plant (GOSP)" and issued July 28, 2015, a copy of which is incorporated by reference.

[0074] In some embodiments, a microwave source may be placed upstream of one or more units of a gas oil separation plant (GOSP). FIG. 7 depicts a gas oil separation process 700 of a gas oil separation plant and having one or more microwave units in accordance with an example embodiment of the disclosure. The gas oil separation process 700 includes a high pressure production trap (HPPT) 702, a low pressure production trap (LPPT) 704, a dehydrator 706, a desalter 708, a stabilization unit 710, and a compression train 712.

[0075] As shown in FIG. 7, a wet crude feed 714 may be provided to the HPPT 702 to separate oil, gas, and water in the wet crude feed 714. Separated water 716 and separated oil 718 exits the HPPT 702, and the separated gas 720 may be provided to the compression train 712 for gas processing. The crude oil output from the HPPT 702 is provided to the LPPT 704

for further separation of oil, gas, and water at a low pressure. Separated gas 722 exits the LPPT 704 and may be combined with the separated gas 720 from the HPPT 702 and provided to the compression train 712 for gas processing. The crude oil 724 output from the LPPT 702 is provided to the dehydrator 706 for removal of formation water from the crude oil. Separated water 726 exits the dehydrator 706, and the crude oil 728 output from the dehydrator 706 is provided to the desalter 708.

[0076] Wash water 730 may also be provided to the desalter 708 for removal of salt from the crude oil to meet or exceed salt content specifications for the crude oil. Separated water 732 exits the desalter 708, and the crude oil 734 output from the desalter 708 is provided to the stabilization unit 710. The crude stabilization unit 710 may also include or be referred to as a stripper unit and may separate H_2S and light end components 736 from the crude oil to meet H_2S and vapor pressure specifications for the crude oil. The stabilization unit 710 outputs stabilized crude 738 having, for example, salt content, H_2S, and light end components within a desired crude oil specification.

[0077] In some embodiments, a microwave unit 740 may be placed upstream of the HPPT 702 (for example, at an entrance to the HPPT 702) to improve separation of oil, gas, and water in the crude oil in the HPPT 702. As shown in FIG. 7, in some embodiments, a microwave unit 742 may be placed downstream of the HPPT 702 and upstream of the LPPT 704 (for example, at an entrance to the LPPT 704) to improve separation of oil, gas, and water in the crude oil in the LPPT 704. In some embodiments, a microwave unit 744 may be placed downstream of the LPPT 704 and upstream of the dehydrator 706 (for example, at an entrance to the dehydrator 706) to improve dehydration of the crude oil. In some embodiments, a microwave unit 746 may be placed downstream of the dehydrator 706 and upstream of the desalter 708 (for example, at an entrance to the desalter 708) to improve desalting of the crude oil. In some embodiments, a microwave unit 748 may be placed downstream of the desalter 708 and upstream of the stabilization unit 710 (for example, at an entrance to the stabilization unit 710). For example, in such embodiments, the microwave unit 748 may promote the removal of H_2S and light end components by heating at the oil-gas interphase of the crude oil before the crude oil is processed in the stabilization unit 710.

[0078] In some embodiments, a gas oil separation plant having the units depicted in FIG. 7 may have one of or any combination of the microwave units 740, 742, 744, 746, and 748. For example, in some embodiments, a gas oil separation plant may only have the microwave unit

742 for improving separation in the HPPT 702 and the microwave unit 724 for improving separation in the LPPT 704. In another example, if effective oil, gas, and water separation is not achieved in the upstream units of a gas oil separation plant, the microwave unit 748 may be used to improve separation in the stabilization unit 710. In some embodiments, any of the microwave units 740, 742, 744, 746, and 748 may be implemented in the configuration 300 described *supra* and depicted in FIG. 3. In some embodiments, any of the microwave units 740, 742, 744, 746, and 748 may be implemented in the configuration 400 described *supra* and depicted in FIG. 4. It should be appreciated that the implementation of the microwave units 740, 742, 744, 746, and 748 in the configuration 400 described *supra* and depicted in FIG. 4 may depend on the availability of treated water and the distance to a source of treated water.

[0079] In some embodiments, one or more of the microwave units 740, 742, 744, 746, and 748 may each be controlled via control system similar to the control systems 502 and 602 discussed *supra*. For example, if the amount of salt in the stabilized crude oil 738 exceeds a threshold salt value, the microwave unit 746 may be controlled to increase the temperature of the crude oil provided to the desalter 708. Similarly, other microwave units may be controlled via a control system in response to monitored crude oil parameters in the crude oil 738.

[0080] FIG. 8 depicts a process 800 for processing crude oil using microwave heating in accordance with an example embodiment of the disclosure. Initially, water may be obtained from a crude oil stream (block 802). For example, as previously discussed, water from a water phase of a crude oil stream may be obtained as a side-stream from a pipe transporting crude oil. Solids may be separated from the water using a solids separator to produce filtered water (block 804). For example, a solids separator may remove particulate solids and other solid contaminants from the water obtained from the crude oil stream.

[0081] The filtered water may be irradiated with microwaves in a microwave to produce heated water (block 806). For example, the filtered water from the solids separator may be at a first temperature and the filtered water may be heated to a second temperature by irradiation with microwaves. The heated water from the microwave unit may be directed at a gas-oil interphase of the crude oil stream (block 808). For example, the heated water may be directed from an outlet of the microwave unit to an inlet at a crude oil pipe that directs the heated water to the gas-oil interphase of the crude oil stream. The crude oil stream may then be provided to a crude oil processing unit (such as a high pressure production trap (HPPT), low

pressure production trap (LPPT), or stabilization unit) for processing (block 810). As discussed *supra*, the heating of the gas-oil interphase via the heated water may promote separation of components (for example, H_2S and light end components) of crude oil stream in the crude processing unit.

[0082] FIG. 9 depicts a process 900 for processing crude oil using microwave heating in accordance with an example embodiment of the disclosure. Initially, treated water may be obtained from a water treatment unit (block 902), such as a water treatment unit if a crude oil processing plant (for example, a gas-oil separation plant). The treated water may be irradiated with microwaves in a microwave to produce heated water (block 904). For example, the treated water from may be at a first temperature and the treated water may be heated to a second temperature by irradiation with microwaves. A first portion of the heated water from the microwave unit may be directed at a gas-oil interphase of the crude oil stream (block 906). For example, the heated water may be directed from an outlet of the microwave unit to a first inlet at a crude oil pipe that directs the heated water to the gas-oil interphase of the crude oil stream in the pipe.

[0083] A second portion of the heated water from the microwave unit may be directed at an oil-water interphase of the crude oil stream (block 908). For example, the heated water may be directed from an outlet of the microwave unit to a second inlet at a crude oil pipe that directs the heated water to the oil-water interphase of the crude oil stream in the pipe. The crude oil stream may then be provided to a crude oil processing unit (such as a dehydrator or desalter) for processing (block 910). As previously discussed, the heating of the gas-oil interphase via the heated water may promote separation of components (for example, H_2S and light end components) of crude oil stream. Additionally, the heating of the oil-water interphase via the heated water may promote separation of water and salt of the crude oil stream via, in some embodiments, gravity separation.

[0084] Ranges may be expressed in the disclosure as from about one particular value, to about another particular value, or both. When such a range is expressed, it is to be understood that another embodiment is from the one particular value, to the other particular value, or both, along with all combinations within said range.

[0085] Further modifications and alternative embodiments of various aspects of the disclosure will be apparent to those skilled in the art in view of this description. Accordingly,

this description is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the general manner of carrying out the embodiments described in the disclosure. It is to be understood that the forms shown and described in the disclosure are to be taken as examples of embodiments. Elements and materials may be substituted for those illustrated and described in the disclosure, parts and processes may be reversed or omitted, and certain features may be utilized independently, all as would be apparent to one skilled in the art after having the benefit of this description. Changes may be made in the elements described in the disclosure without departing from the spirit and scope of the disclosure as described in the following claims. Headings used described in the disclosure are for organizational purposes only and are not meant to be used to limit the scope of the description.

CLAIMS

What is claimed is:

1. A method of processing crude oil, comprising:

irradiating water at a first temperature with microwaves to produce heated water at a second temperature, the second temperature greater than the first temperature;

providing the heated water to a crude oil stream, the crude oil stream comprising a gas phase, an oil phase, and a water phase; and

providing the crude oil stream to a downstream crude oil processing unit.

2. The method of any one of the preceding claims, wherein providing the heated water to the crude oil stream comprises directing the heated water at a gas-oil interphase of the crude oil stream.

3. The method of any one of the preceding claims, wherein providing the heated water to the crude oil stream comprises:

directing a first portion of the heated water at a gas-oil interphase of the crude oil stream; and

directing a second portion of the heated water at an oil-water interphase of the crude oil stream.

4. The method of claim 3, comprising disrupting an oil-water emulsion using the second portion of the heated water.

5. The method of any one of the preceding claims, comprising obtaining the water at the first temperature from the crude oil stream.

6. The method of claim 5, comprising separating solids from the water before irradiating the water with microwaves to produce the heated water at the second temperature.

7. The method of any one of the preceding claims, wherein the water comprises treated water from a water treatment unit of a crude oil processing plant.

8. The method of any one of the preceding claims, wherein the crude oil processing unit comprises a high pressure production trap (HPPT), a low pressure production trap (LPPT), a stabilization unit, a desalter, or a dehydrator.

9. The method of any one of the preceding claims, comprising producing a gas stream and a separated crude oil stream from the crude oil processing unit.

10. The method of any one of the preceding claims, comprising boiling an H_2S component of the crude oil stream using the heated water.

11. The method of any one of the preceding claims, comprising boiling light end components of the crude oil stream using the heated water.

12. The method of any one of the preceding claims, wherein the microwaves have a frequency of 915 MHz.

13. The method of any one of the preceding claims, wherein the second temperature comprises 194°F to 250°F.

14. A system, comprising:

a pipe configured to transport a crude oil stream to a crude oil processing unit; and

a microwave unit upstream from the crude oil processing unit and coupled to the pipe, the microwave unit configured to:

receive water at a first temperature from the crude oil stream; and,

irradiate the water to produce heated water at a second temperature, wherein the second temperature is greater than the first temperature;

wherein an outlet of the microwave unit is coupled to an inlet of the pipe, the inlet configured to direct the heated water at an oil-gas interphase of the crude oil stream.

15. The system of claim 14, comprising a solids separator coupled to the microwave unit, the solids separator configured to separate solids from the water before the microwave unit receives the water.

16. The system of claims 14 or 15, wherein the crude oil processing unit comprises a high pressure production trap (HPPT), a low pressure production trap (LPPT), or a stabilization unit.

17. The system of claims 14, 15, or 16, wherein the crude oil stream comprises a first crude oil stream having a first composition, and wherein the crude oil processing unit is configured to output a second crude oil stream having a second composition.

18. The system of claims 14, 15, 16, or 17, comprising:

a crude oil analyzer configured to determine at least one parameter of the second crude oil stream;

a controller configured to:

receive the at least one parameter from the crude oil analyzer;

compare the at least one parameter to a respective at least one threshold value; and

modify a power of the microwaves based on the comparison.

19. The system of claim 18, wherein the at least one parameter comprises H_2S content, salt content, or Reid vapor pressure.

20. A system, comprising:

a pipe configured to provide a crude oil stream to a crude oil processing unit; and

a microwave unit upstream of the crude oil processing unit and coupled to the pipe, the microwave unit configured to irradiate water at a first temperature to produce heated water at a second temperature, wherein the second temperature is greater than the first temperature;

wherein an outlet of the microwave unit is coupled to a first inlet of the pipe, the first inlet configured to direct a first portion of the heated water at an oil-gas interphase of the crude oil stream;

wherein the outlet of the microwave unit is further coupled to a second inlet of the pipe, the second inlet configured to direct a second portion of the heated water at an oil-water interphase of the crude oil stream.

21. The system of claim 20, wherein the water comprises treated water from a water treatment unit.

22. The system of claims 20 or 21, wherein the crude oil processing unit comprises a desalter or a dehydrator.

23. The system of claims 20, 21, or 22, wherein the crude oil stream comprises a first crude oil stream having a first composition, and wherein crude oil processing unit is configured to output a second crude oil stream having a second composition.

24. The system of claims 20, 21, 22, or 23, comprising:

a crude oil analyzer configured to determine at least one parameter of the second crude oil stream;

a controller configured to:

receive the at least one parameter from the crude oil analyzer;

compare the at least one parameter to a respective at least one threshold value;

modify a power of the microwaves based on the comparison.

25. The system of claim 24, wherein the at least one parameter comprises H_2S content, salt content, or Reid vapor pressure.

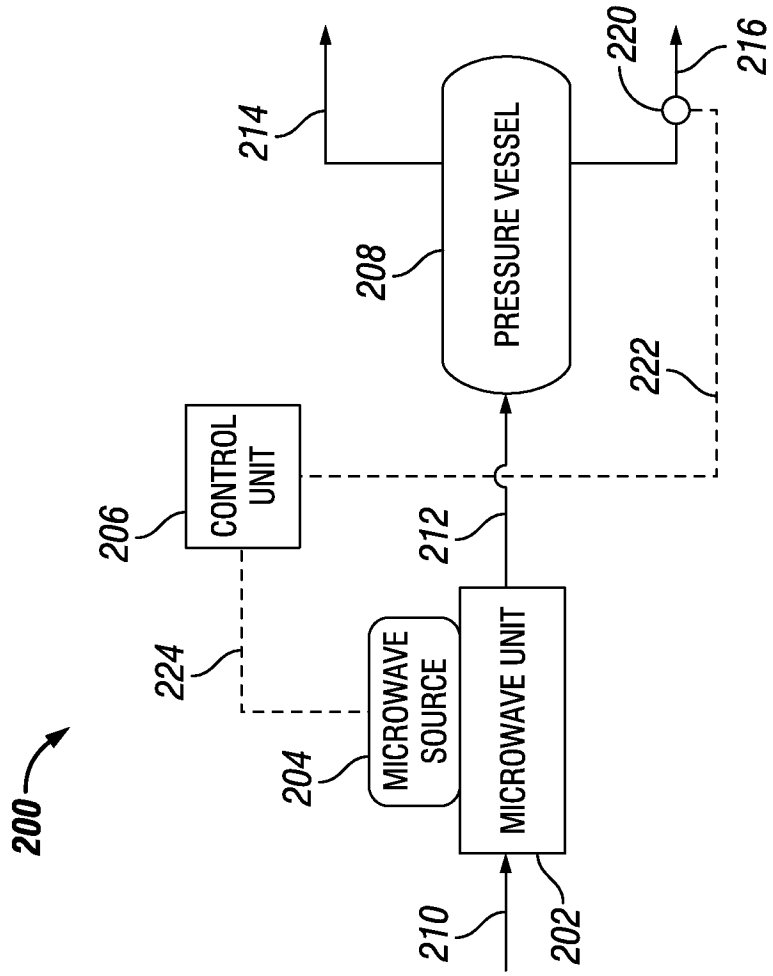


FIG. 2

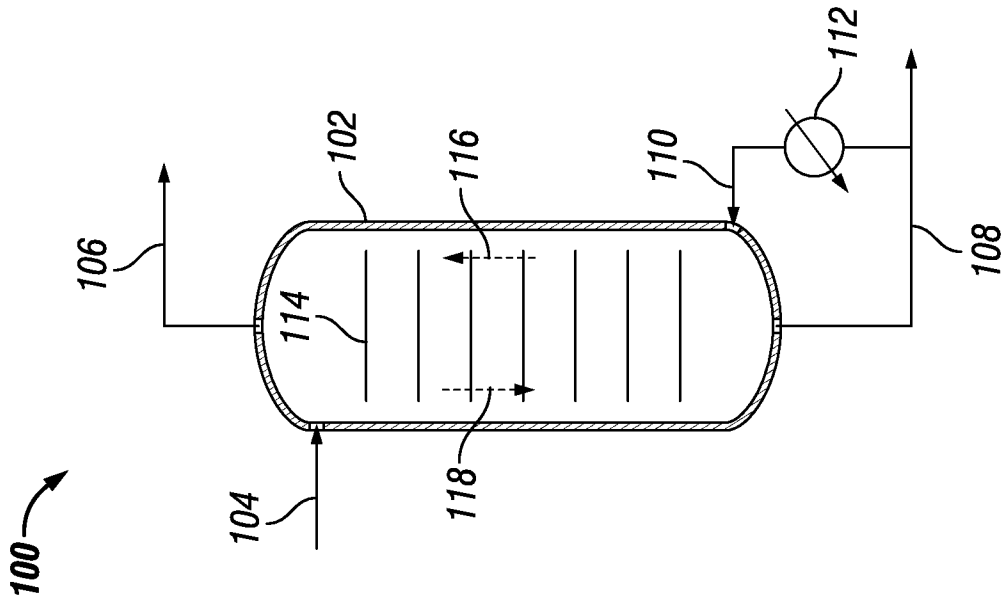
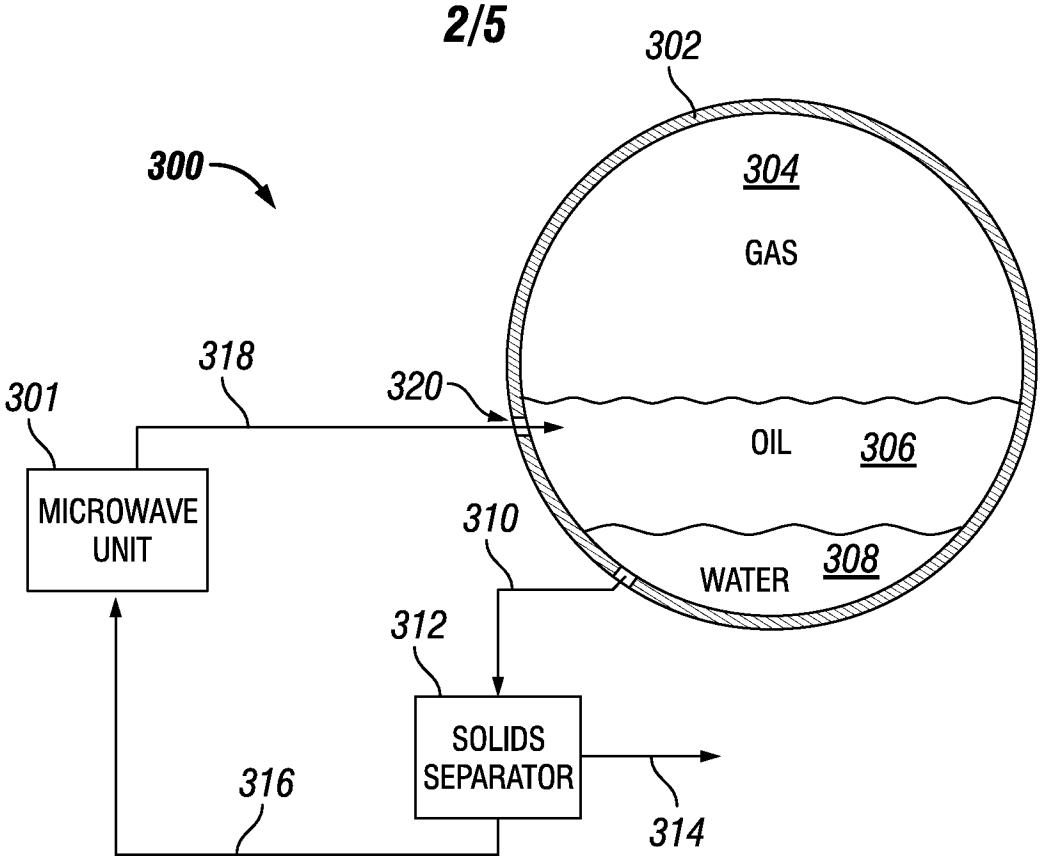


FIG. 1
(Prior Art)


300
302
304
GAS
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SOLIDS SEPARATOR
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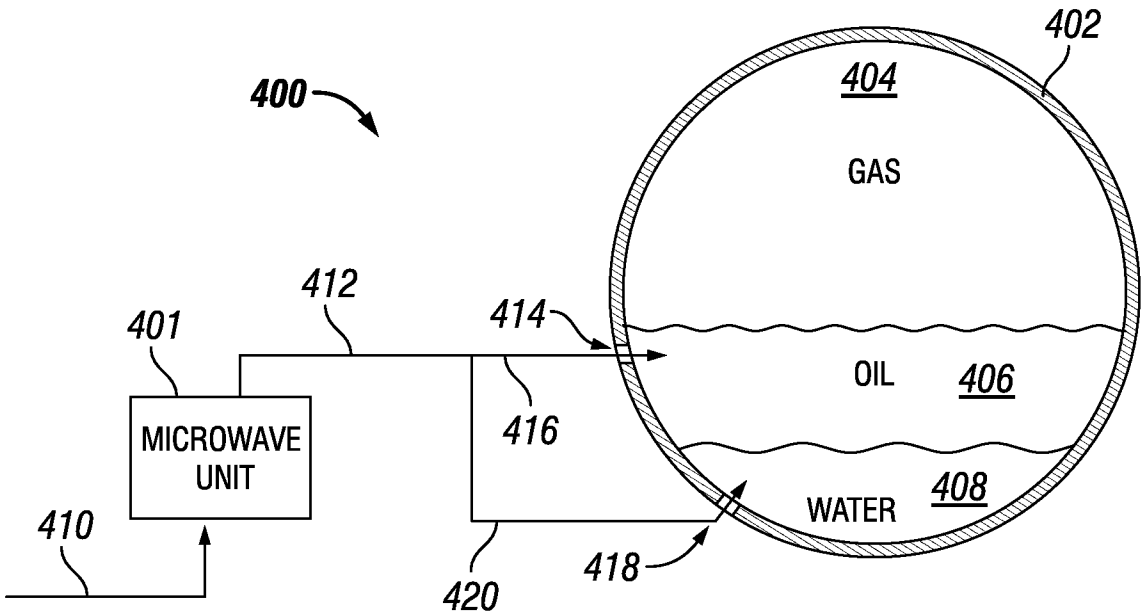
314

FIG. 3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402
404
GAS
412
414
401
OIL
406
MICROWAVE UNIT
416
WATER
408
410
418
420

FIG. 4

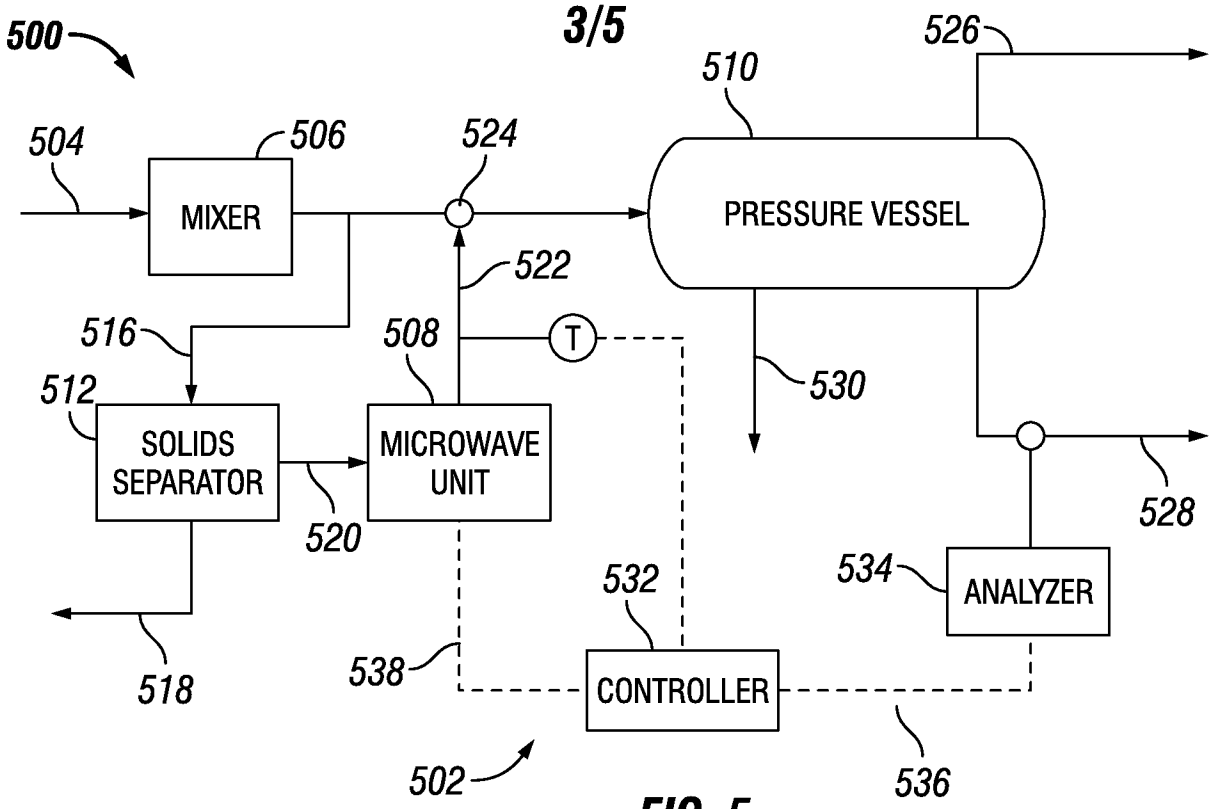
500
504
506
524
526
510
MIXER
PRESSURE VESSEL
522
516
508
T
512
530
SOLIDS SEPARATOR
MICROWAVE UNIT
520
528
534
ANALYZER
532
518
538
CONTROLLER
502
536

FIG. 5

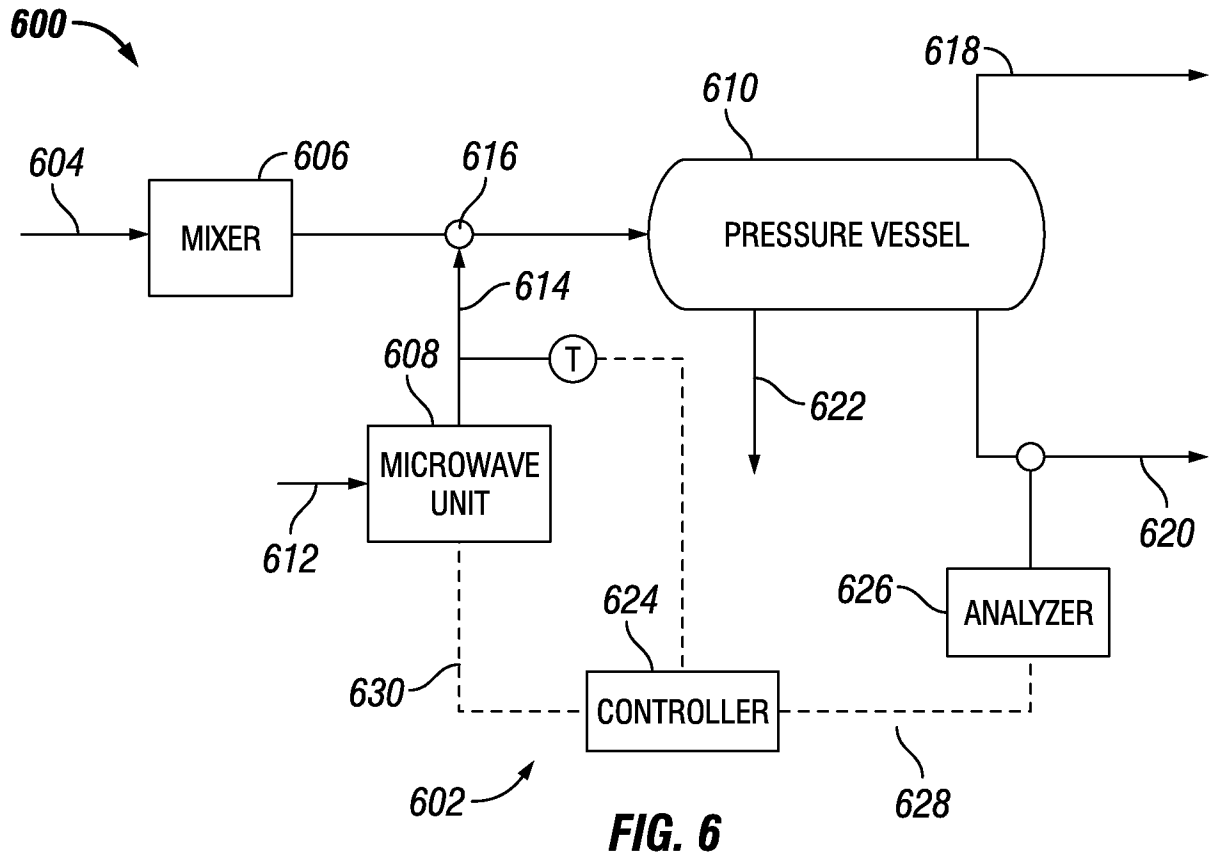
600
604
606
616
618
610
MIXER
PRESSURE VESSEL
614
608
T
622
MICROWAVE UNIT
612
620
626
ANALYZER
624
630
CONTROLLER
602
628

FIG. 6

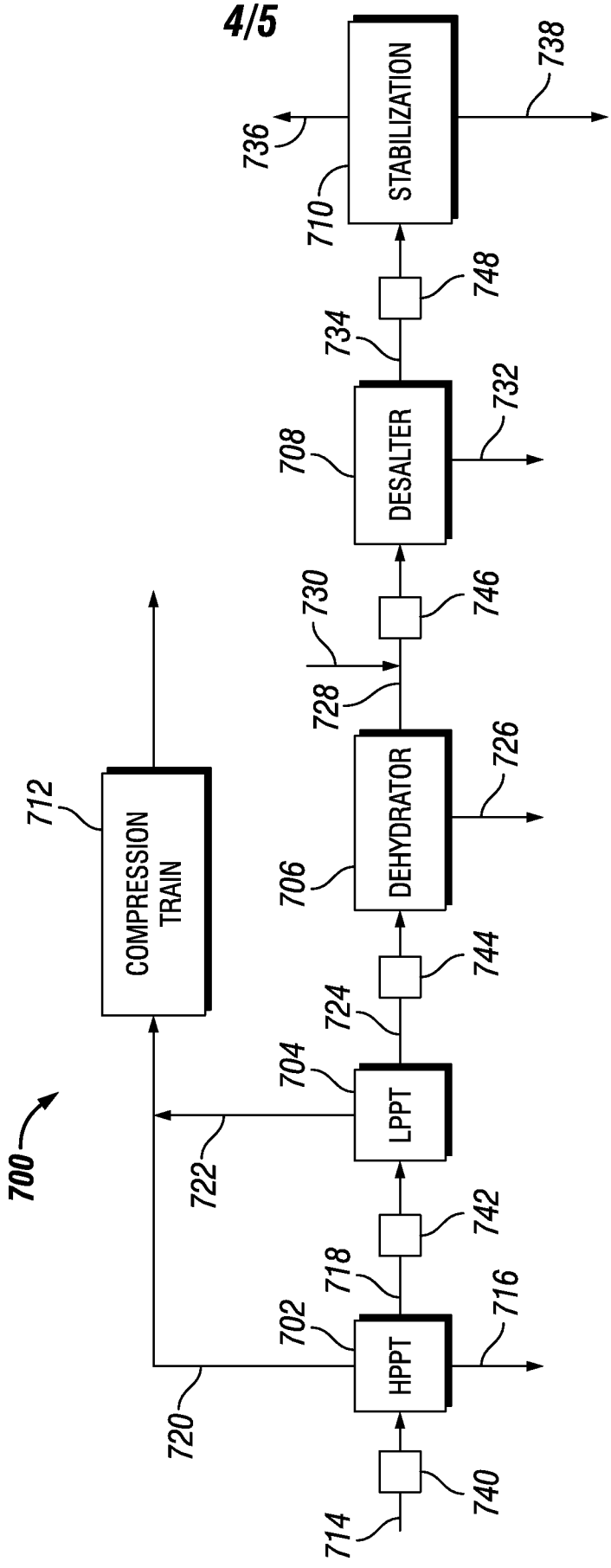
700
712
COMPRESSION TRAIN
720
722
HPPT
LPPT
DEHYDRATOR
DESALTER
STABILIZATION
702
704
706
708
710
714
716
718
724
726
728
730
732
734
736
738
740
742
744
746
748

FIG. 7

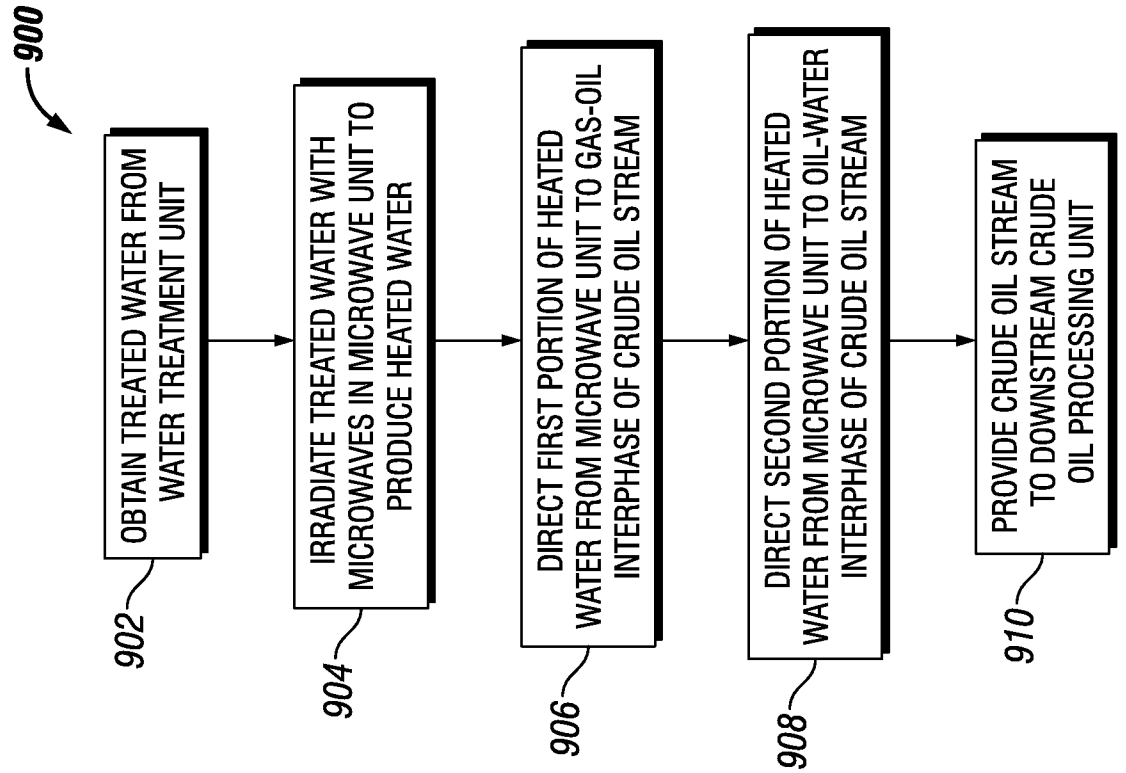
900
OBTAIN TREATED WATER FROM WATER TREATMENT UNIT
902
IRRADIATE TREATED WATER WITH MICROWAVES IN MICROWAVE UNIT TO PRODUCE HEATED WATER
904
DIRECT FIRST PORTION OF HEATED WATER FROM MICROWAVE UNIT TO GAS-OIL INTERPHASE OF CRUDE OIL STREAM
906
DIRECT SECOND PORTION OF HEATED WATER FROM MICROWAVE UNIT TO OIL-WATER INTERPHASE OF CRUDE OIL STREAM
908
PROVIDE CRUDE OIL STREAM TO DOWNSTREAM CRUDE OIL PROCESSING UNIT
910

FIG. 9

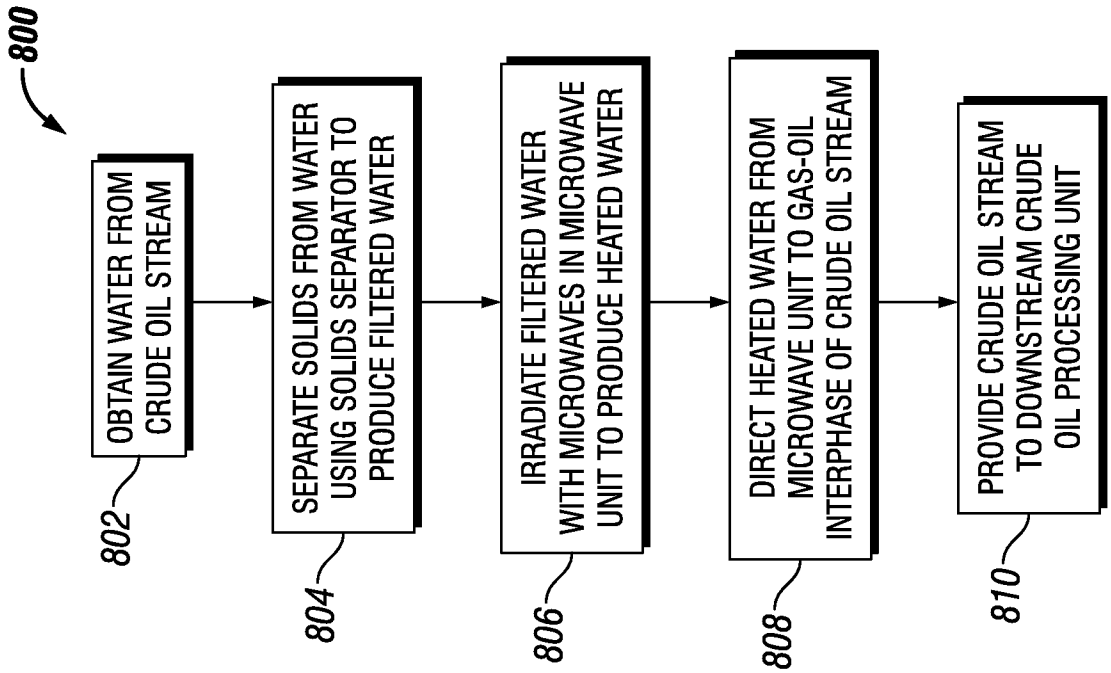
800
OBTAIN WATER FROM CRUDE OIL STREAM
802
SEPARATE SOLIDS FROM WATER USING SOLIDS SEPARATOR TO PRODUCE FILTERED WATER
804
IRRADIATE FILTERED WATER WITH MICROWAVES IN MICROWAVE UNIT TO PRODUCE HEATED WATER
806
DIRECT HEATED WATER FROM MICROWAVE UNIT TO GAS-OIL INTERPHASE OF CRUDE OIL STREAM
808
PROVIDE CRUDE OIL STREAM TO DOWNSTREAM CRUDE OIL PROCESSING UNIT
810

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/039429

A. CLASSIFICATION OF SUBJECT MATTER
INV. C10G31/08 C10G31/06 C10G32/02 C10G33/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10G F24H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 806 231 A (CHIRINOS MARIA L [VE] ET AL) 21 February 1989 (1989-02-21) column 3, lines 45-68; figure 2	1-25
Y	US 2 785 120 A (METCALF RICHARD J) 12 March 1957 (1957-03-12) column 5, line 64 - column 6, line 33; figure 1	1-25
Y	US 2015/192326 A1 (AGUILAR NOEL GABRIEL [US] ET AL) 9 July 2015 (2015-07-09) paragraphs [0001], [0017]	1-25

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 September 2017	29/09/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Galleiske, Anke

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2017/039429

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4806231 A	21-02-1989	CA 1248902 A	17-01-1989
		EP 0142278 A2	22-05-1985
		NO 844199 A	22-04-1985
		US 4806231 A	21-02-1989
US 2785120 A	12-03-1957	NONE	
US 2015192326 A1	09-07-2015	NONE	