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- (71) **Applicant:** UOP LLC [US/US]; 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US).
- (72) **Inventors:** KING, Stephen T.; Uop Llc, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US). LANKTON, Steven; Uop Llc, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US). ZHU, Xin X.; Uop Llc, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US).
- (74) **Agent:** GOODING, Arthur E.; Uop Llc, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US).

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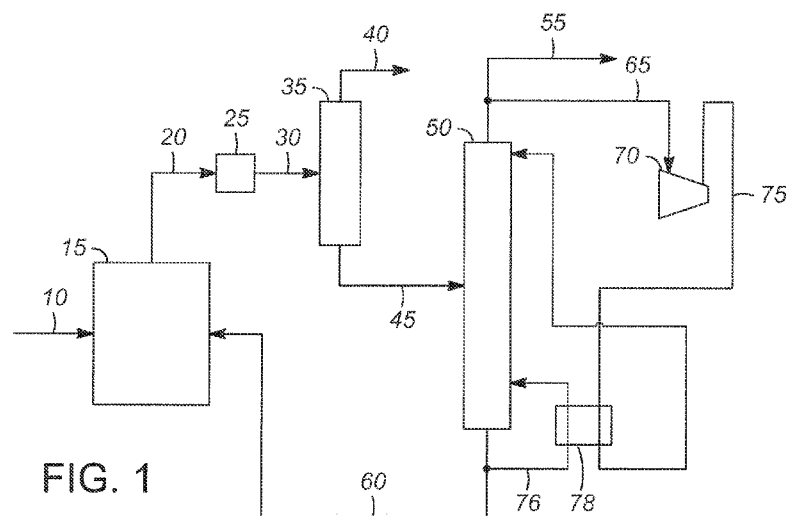


FIG. 1

(57) **Abstract:** Fractionation systems utilizing a rectifying column with a stripping column are described. The liquid from the rectifying column bottoms is sent to the first tray of the stripping column, while the overhead stream from the stripping column is sent to the bottom of the rectifying column. Processes for separating feed streams are also described.

FRACTIONATION SYSTEM AND METHOD INCLUDING
DEPROPANIZER COLUMN AND BOTTOMS STRIPPING COLUMN

STATEMENT OF PRIORITY

5 This application claims the benefit of U.S. Provisional Application No. 61/869,483 which was filed on August 23, 2013 and U.S. Application No. 14/041,565 which was filed on September 30, 2013.

BACKGROUND OF THE INVENTION

10 Olefin hydrocarbons are valued for the production of a variety of materials, including many petrochemicals. In some dehydrogenation processes, short chain saturated hydrocarbons are modified to form a corresponding olefin. A particularly useful olefin is propylene, which is produced by dehydrogenation of propane. Propylene is an enormously useful petrochemical commodity with demand steadily growing. Propylene is used in the
15 production of polypropylene, acrylonitrile, acrylic acid, acrolein, and many others useful compounds. Polypropylene is widely used in many consumer and industrial products.

 Propane dehydrogenation processes that produce olefins such as propylene may include feeding propane to a dehydrogenation unit where it is dehydrogenated using a catalyst to form propylene. A compressor compresses the effluent from the dehydrogenation
20 unit to a high pressure to recover unreacted propane and propylene in a recovery section. The compressed reactor effluent is cryogenically chilled to separate hydrogen from hydrocarbon and maximize propylene and propane recovery.

 The hydrocarbon product stream may be communicated from the recovery unit to a de-ethanizer distillation column where ethane and lighter components are recovered as an
25 overhead gas, and propane and propylene, and heavy boiling compounds are removed as bottoms. These bottoms are then communicated to a propylene-propane splitter distillation column where propylene is recovered as an overhead liquid and unreacted propane from the bottoms may be recycled back to the dehydrogenation unit.

 These processes often require significant energy input to boil, pressurize and
30 otherwise process the various steps. The significant energy demands lead to high costs and other disadvantages.

SUMMARY OF THE INVENTION

One aspect of the invention is a fractionation system. In one embodiment, the fractionation system includes a rectifying column having a feed inlet between a top and a bottom tray, a reflux inlet at the top tray a fluid inlet at the bottom tray, an overhead product outlet at the first tray, and a bottoms outlet at the bottom tray; a rectifying column reboiler in communication with the rectifying column; a stripping column having a fluid inlet at a top tray, an overhead outlet at the top tray, and a bottoms outlet at a bottom tray, the bottoms outlet of the rectifying column being in fluid communication with the fluid inlet of the stripping column, the overhead outlet of the stripping column being in fluid communication with the fluid inlet of the rectifying column; and a stripping column reboiler in communication with the stripping column.

Another aspect of the invention is a process of separating a feed stream. In one embodiment, the process includes introducing the feed stream into a feed inlet of a rectifying column, the feed inlet between a top tray and a bottom tray, the rectifying column having a reflux inlet at the top tray, a fluid inlet at the bottom tray, an overhead product outlet at the first tray, and a bottoms outlet at the bottom tray. The feed stream is separated in the rectifying column into an overhead product stream and a bottoms stream. The bottoms stream from the rectifying column is introduced into a fluid inlet in a stripping column, the fluid inlet at a top tray of the stripping column, the stripping column having an overhead outlet at the top tray, and a bottoms outlet at a bottom tray. The bottoms stream from the rectifying column is separated into an overhead stream and a bottoms stream in the stripping column. The overhead stream from the stripping column is introduced into the fluid inlet of the rectifying column. A portion of the overhead product stream from the rectifying column is refluxed to the reflux inlet of the rectifying column. At least a portion of the bottoms stream from the rectifying column is reheated in a rectifying column reboiler, and at least a portion of the bottoms stream from the stripping column is reheated in a stripping column reboiler.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates one embodiment of a process for producing propylene.

Fig. 2 illustrates one embodiment of a distillation section used in the process of Fig. 1.

Fig. 3 illustrates another embodiment of a process for producing propylene.

Fig. 4 illustrates one embodiment of a distillation section used in the process of Fig. 3.

Fig. 5 illustrates one embodiment of a distillation section of the present invention which can be used in the process of Fig. 3.

Fig. 6 illustrates another embodiment of a distillation section of the present invention which can be used in the process of Fig. 3.

DETAILED DESCRIPTION OF THE INVENTION

10 A fractionation system has been developed which utilizes a single rectifying column with a stripping column. The liquid from the rectifying column bottoms is sent to the first tray in the stripping column, while the overhead stream from the stripping column is sent back to the bottom of the rectifying column. This arrangement reduces the capital and operating costs compared to a system with two rectifying columns.

15 In addition to capital and operating cost savings, the fractionation system simplifies the control and operation of the fractionation because there is only one reflux line instead of two.

In considering various invention embodiments illustrated herein, it will be appreciated that the invention will find utility in applications for production of olefins from paraffins in general and is not limited to propylene production. Significant utility exists, however, when invention embodiments are practiced with propylene with the result that corresponding example embodiments have been selected for illustration herein.

Referring now to the Figures, Fig. 1 is a schematic of one example of a prior art process for producing propylene. Feed stream 10 is fed to a distillation section 15 where contaminants in the feed stream 10 are removed. The feed stream 10 may contain various components, with one example being at least 95% propane (wt), with impurities including ethane, and butanes. A distillation section output stream 20, which may be predominantly propane, is communicated to a reactor 25, where it is reacted with a catalyst to produce propylene. The reactor effluent may be chilled to enhance hydrocarbon recovery (not illustrated).

A reactor output stream 30 containing propylene (with some ethane and potentially other impurities) is communicated to a de-ethanizer column 35 where impurities

such as hydrogen, methane, ethane, and ethylene are removed as the overhead vapor 40. The product propylene and unreacted propane are taken as a de-ethanizer bottoms stream 45 to an olefin splitter 50. A splitter overhead stream 55 contains a high percentage of propylene. A splitter bottoms stream 60 containing unreacted propane and at least some heavy boiling components is recycled back to the distillation section 15 for removal of the heavy boiling components.

An additional splitter output stream 65 containing at least some, and in some cases as much as 100% vapor phase propylene is compressed in a heat pump compressor 70 (which may be referred to for convenience as "HPC 70"). The HPC output stream 75 heats a portion 76 of splitter bottoms stream 60 in heat exchanger 78 and is recycled to the splitter 50.

Fig. 2 shows one embodiment of a prior art distillation section 15. The feed stream 10 is fed to a depropanizer column 80 where it is separated into an overhead stream 85 and a bottoms stream 90. The overhead stream 85 is cooled in a heat exchanger 95 and sent to a column overhead receiver (or accumulator) 100. Condensed stream 105 is separated into reflux stream 110 which is sent to the depropanizer column 80 and distillation section output stream 20.

A portion 115 of the bottoms stream 90 is reheated in a steam reboiler 120 and returned to the depropanizer column 80.

In prior art systems such as this, it is desirable to achieve as high a rate of recovery as possible in the distillation column; the recycle and bottoms streams should be as low as possible in unreacted fuel (e.g., propane). In many prior art methods and systems, recovery rates exceeding 99% were disclosed, with the result that recycle and bottom streams included less than 1% unreacted fuel (e.g., propane).

In some prior art systems and methods, heat pump compressors such as HPC 70 produce excess heat that is lost to the environment. Fig. 3 illustrates an embodiment of a distillation section 15 designed to capture the excess heat through an HPC second output stream 120 which is put to valuable use through reboiler 125, as described in US Publication No. 2013/0131417, which is incorporated herein by reference. Important advantages, efficiencies and cost savings are thereby achieved.

In this embodiment, a higher pressure and temperature HPC second output stream 120 is communicated to a distillation section heat exchanger 125 where it is used to

heat a distillation section stream 130 that includes unreacted propane. Heat exchanger 125, as well as other heat exchangers discussed herein, may be of any conventional design, with one example being a counter-flow tube-in-shell design and another example using high heat transfer technologies such as HighfluxTM (available from UOP, Des Plaines, Ill.) or plate type exchangers. In some (but not all) embodiments, the heat exchanger 125 may be a reboiler, and may be referred to herein in some embodiments as such. The HPC second output stream 120 may then be communicated back to the splitter 50 as reflux (as illustrated) or may be communicated to other components such as a propylene collection tank (not illustrated).

In one example of this embodiment of distillation section 15' as shown in Fig. 4, there are first and second columns 150 and 155 arranged in series. In some embodiments, these columns may be referred to as depropanizer columns reflecting their purpose of conditioning propane to be suitable feed for reactor 25. The feed stream 10 containing propane and other hydrocarbons is fed to the first distillation column 150 where high boiling components are recovered at the first distillation column bottoms stream 160, and the propane is recovered in first distillation column overhead stream 165 and communicated through a heat exchanger 170 for cooling and then sent to reactor 25. Stream 172 is sent to first and second columns 150 and 155 as reflux.

The first distillation column bottoms stream 160 containing some propane as well as heavier boiling hydrocarbons is then communicated into the second distillation column 155 for recovery of the propane and concentration of the high boiling hydrocarbons.

The first distillation column bottoms stream 160 has been illustrated as a bottom streams from the first distillation column 150. It will be appreciated, however, that this first distillation column bottoms stream 160 could be extracted from the first distillation column 150 at different locations as desired, and therefore that the use of the term "bottoms stream" is for convenience only and is not intended to limit the scope of the invention. This likewise applies to other uses of "bottoms" herein when made in this context.

A distillation column overhead stream 175 from the second distillation column 155 containing a high proportion of propane is combined with the first distillation column overhead stream 165 and communicated to the reactor 25. A second distillation column reboiler 180 heats a second distillation column bottom recycle stream 185. A second distillation column bottoms stream 190 containing heavier components is removed for use as desired.

Designing first and second distillation columns 150 and 155 in this manner allowed for exploitation of heat from the HPC 70 (Fig. 3) that in the prior art was lost to the environment. The first distillation column reboiler 125 extracts heat from the HPC second output stream 120 to heat a first distillation column recycle stream 130. First distillation column 150 and HPC 70 (Fig. 3) have been designed so that the boiling point of first distillation column recycle stream 130 is lower than the temperature of the HPC second output stream 120 to make this feasible. This may be accomplished in many different particular configurations by varying operating temperatures, pressures, flow rates, propane recovery in first distillation column 150, number of stages or trays in first and second distillation columns 150 and 155, and other parameters. Some design parameters have been discovered, however, that are believed to provide particularly useful benefits and advantages.

For example, the first distillation column 150 was designed and operated so that the boiling point of the first distillation column recycle stream 130 was no more than 60°C. The first distillation column recycle stream 130 (as well as first distillation column bottoms stream 160, which is generally consistent in quality to that of recycle stream 130) also contained a significant amount of unreacted propane, which in some embodiments is at least 5% (by wt). The lower recovery amounts in this system were used to ensure that heat from the HPC second output stream 36 could be exploited. This can also be expressed in terms of the difference in quality of first distillation column recycle stream 130, as well as first distillation column bottoms stream 160 as compared to second distillation column bottom stream 190. In some embodiments, it was useful to operate with the first distillation column bottoms stream 160/first distillation recycle stream 130 having a boiling point that was at least 20°C lower than that of the second distillation column bottoms stream 190.

The quality of the first distillation column bottoms recycle stream 130 can affect the desired pressure level, and thereby, energy efficiency of using the HPC second output stream 120 for this purpose. Design parameters include exchanger design, flow rate, and temperature differential between first distillation column recycle stream 130 boiling point and HPC second output stream 120 temperature. In many situations, it was useful to maintain a temperature differential between first distillation column recycle stream 130 boiling point and HPC second output stream 120 temperature (with HPC second output stream 120 being hotter than first distillation column recycle stream 130) of at least 5°C to ensure that heat from the HPC second output stream 120 could be used to reheat the first distillation column

recycle stream 130. In some embodiments, the HPC second output stream 120 is compressed to a pressure of at least 25 kg/m^2 . When compressed to 30 kg/m^2 , the HPC second output stream 120 in some embodiments had a condensation temperature of 68°C , making it useful as a heat source for recycle streams having boiling points below 60°C .

5 The bottoms stream 190 of the second distillation column 155 is generally consistent with bottoms streams from single distillation columns. It has a much lower unreacted propane content than the bottoms stream 160 from the first distillation column 150 and correspondingly higher concentration of longer chain hydrocarbons, with a boiling point of 100°C or more. Low or even medium pressure steam or other suitable heated medium may
10 accordingly be required by the second distillation column reboiler 180.

 In one embodiment, the first column was specified with 56 trays to recover 10% of the C_3 material in the net bottoms and to maintain 100 mppm of $\text{nC}_4 + \text{C}_{4=}$ (normal butane and C_4 olefin) in the overhead vapor. The second column had 67 trays and was specified to recover 0.5% of the C_3 material feed to the depropanizer system in the net
15 bottoms while maintaining the 100 mppm of $\text{nC}_4 + \text{C}_{4=}$ in the overhead vapor. Together, the depropanizer system recovers 99.5% of C_3 material in the net overhead with 100 mppm of $\text{nC}_4 + \text{C}_{4=}$ net overhead purity. The two column system allows a lower first column bottoms temperature so it can be reboiled with the heat pump compressor second stage (HPC2) discharge.

20 Although Fig. 4 illustrates two distillation columns 150 and 155 arranged in series, three or more columns could be used in other embodiments.

 However, the capital and operating costs for two large depropanizer columns are high. It would be desirable to reduce the capital costs, or the operating costs, and preferably both for the distillation section.

25 A system has been developed employing a single rectifying column combined with a smaller stripping column. The liquid from the rectifying column bottoms is sent to the first tray in the stripping column, where the C_3 hydrocarbons are stripped out of the heavies. The overhead stream of the C_3 vapor from the stripping column is sent back to the bottom of the rectifying column. This allows the rectification to occur in one column instead of two
30 columns, and there are fewer trays in the stripping column (e.g., from 67 trays to 14 trays).

 Control and operation of the fractionation system are simplified because there is only one reflux line instead of two.

Fig. 5 illustrates one embodiment of a distillation section 15''. The distillation section includes a rectifying column 200 and a smaller stripping column 205. Feed 10 is introduced into the rectifying column 200 where it is separated into an overhead stream 210 and bottoms stream 215.

5 The overhead stream 210 from the rectifying column 200 is cooled in a heat exchanger 220 and sent to a column overhead receiver 225. Condensed stream 230 is separated into reflux stream 235, which is sent to the rectifying column 200, and distillation section output stream 20.

10 The rectifying column bottoms stream 215 is sent to the top tray of the stripping column 205. The overhead stream 240 from the stripping column 205 is sent to the rectifying column 200 below the bottom tray.

HPC second output stream 242 is sent to rectifying column heat exchanger/reboiler 245 to heat rectifying column recycle stream 250.

15 In some embodiments, a steam reboiler 255 can be used to heat a second rectifying column recycle stream 260. The steam reboiler 255 can be used to supplement the heat provided by the HPC second output stream 242, if desired. For example, the system could be designed to utilize the steam reboiler in certain conditions, or it could be designed to supply a certain percentage of the required heating (e.g., HPC second output stream 75%/steam reboiler 25%).

20 The bottoms stream 265 from stripping column 205 containing heavier components is removed for use as desired. Stripping column recycle stream 270 is heated in steam reboiler 275 and returned to the stripping column 205.

25 The rectifying column bottoms temperature can be specified to keep the 5.56 degree C (10 degree F) log mean temperature difference (LMTD) and duty of the heat recovery reboiler equal to that of the two column system. This allows the discharge pressure of the HPC2 to be maintained at the same level as for the two column system.

30 The stripping column is specified so that the fractionation system maintains the 99.5% recovery of C₃ material in the net overhead required for propane dehydrogenation processes. To achieve this recovery, the stripping column bottoms temperature is set at 104.4°C (220°F) with a depropanizer overhead pressure of 1.765 MPa (g) (256 psig). This allows the stripping column to remove or strip out the C₃ material from the heavy C₄₊ material so the valuable C₃ material can be sent back to the rectifying column as vapor. The

104.4°C (220°F) temperature is in the range for 276 kPa (g) (40 psig) steam as the heating medium for the stripping column reboiler. For example, the rectifying column could be sized for sieve trays with a column diameter of 13', while the stripping column could be sized with sieve trays with a column diameter of 5'. Column tray counts and rectifying column feed location can be optimized to maximize column energy consumption.

Instead of having separate vessels for the rectifying column and the stripping column as shown in Fig. 5, the distillation section 15''' can include a rectifying column 280 and a stripping column 285 in the same vessel. In this arrangement, as illustrated in Fig. 6, the stripping column 285 is stacked underneath the rectifying column 280 in a swaged arrangement.

In the arrangement shown in Fig. 6, a liquid accumulator tray 290 separates the rectifying column 280 from the stripping column 285. The heat recovery reboiler 295 feeds off the liquid accumulator tray 290. HPC second output stream 300 is used to heat recycle stream 305. The rectifying column reboiler inlet and outlet for recycle stream 305 are in the space between the bottom tray of the rectifying column 280 and the liquid accumulator tray 290, with the rectifying column reboiler outlet positioned above the rectifying column reboiler inlet. Typically, the rectifying column inlet is a sump that is 1.5 pipe diameters deep. This allows the accumulator tray deck to free drain into the inlet line.

Liquid from the liquid accumulator tray 290 flows through the downcomer 310 into tray S1 of the stripping column 285, and vapor from tray S1 flows up through vapor riser 315 of the liquid accumulator tray 290 into the bottom of the rectifying column 280.

The liquid accumulator tray is designed with sufficient liquid residence time (e.g., a 30 second residence time) for the process reboiler inlet to stabilize the vaporization. Additionally, the bottom of the reboiler return nozzle will be above the liquid level of the accumulator tray to allow for adequate vapor/liquid disengagement of the return line (e.g., 45.7 cm (18 in) above the liquid level of the accumulator). Also, the top of the reboiler return nozzle will be below the top of the vapor riser height so that no liquid from the reboiler return will spill down the vapor riser (e.g., 30.5 cm (12 in) below the top of the vapor riser height). The distance between the top of the vapor riser and the tray above the accumulator tray will be equal to the tray spacing in the column section above the accumulator tray (typically 45.7-61.0 cm (18-24 in)). The total vapor riser area will be sufficient so that the stripping column vapor can be channeled and evenly distributed into the rectifying column with minimal

pressure drop (e.g., 20% of the total column cross-sectional area). The reboiler inlet draw nozzle will be located in a sump (e.g., the sump can be 1.5 times the pipe diameter of the draw nozzle in height, width, and depth). The reboiler inlet line will typically be flush with the bottom of the sump to provide a liquid seal in the reboiler inlet line. The distance
5 between the sump and the tray below will be equal to the tray spacing (typically 45.7-61.0 cm (18-24 in)). Stripping column bottoms stream 320 containing heavier components is removed. Recycle stream 325 is heated in steam reboiler 330 and recycled back to the stripping column 285.

The overhead stream 335 from the rectifying column 280 is cooled in a heat
10 exchanger 340 and sent to a column overhead receiver 345. Condensed stream 350 is separated into a reflux stream 355 which is sent to the rectifying column 280 and distillation section output stream 20.

The rectifying column was designed to maintain a 30% recovery of C_3 material in the rectifying column net bottoms stream (215) being sent to the stripping column.
15 This allows the temperature in the bottoms to be 56°C and 96% C_3 material (molar basis). This is ideal temperature and composition for the rectifying column bottoms so that the heat pump compressor discharge stream (e.g., 86°C) can be used to reboil the rectifying column and allow condensation of the heat pump material at the outlet of the hot side of the reboiler (e.g., 67°C). Thus, the rectifying column reboiler will transfer the heat from the heat pump
20 compressor discharge stream to the rectifying column. This is feasible since the thermodynamic properties of C_3 material are similar. The rectifying column bottoms will be slumped to the stripping column where the C_3 material will be stripped out and the heavy C_{4+} material will be concentrated. The temperature of the stripping column bottoms will be fixed at 104°C which will strip out the C_3 material from the heavier C_{4+} material. The C_3 material
25 will be returned to the bottom section of the rectifying column (stream 240). The C_3 vapor stream provides additional stripping vapor to the rectifying column and aids in fractionation of the rectifying column.

For example, the rectifying column 200/280 was designed and operated so that the bubble point of the rectifying column recycle stream 250/305 was no more than 60°C.
30 The rectifying column recycle stream 250/305 (as well as rectifying column bottoms stream 215, which is generally consistent in quality to that of recycle stream 250) also contained a significant amount of unreacted propane, which in some embodiments is at least 5% (by wt).

The lower recovery amounts in this system were used to ensure that heat from the HPC second output stream 242/300 could be utilized to reboil the material in the depropanizer rectifying column.

The composition of both the rectifying column bottoms stream 250/305 and the HPC second output stream 242/300 can affect the heat pump compressor utility consumption, and thereby, the feasibility of using the HPC second output stream 242/300 for this purpose. Design parameters include exchanger design, flow rate, and temperature differential between rectifying column recycle stream 250/305 bubble point and HPC second output stream 242/300 temperature. It is useful to maintain a log mean temperature difference (or LMTD) within the rectifying column reboiler 295 of greater than 5°C between the HPC second output stream 242/300 and the rectifying column reboiler inlet stream 305. This is to allow for adequate heat exchange within the reboiler and allow the cold side of the reboiler (rectifying side) to vaporize and the hot side (or heat pump side) to condense). In some embodiments, the HPC second output stream 242/300 is compressed to a pressure of at least 3 MPa (g) (30 bar(g)). When compressed to 3 MPa (g) (30 bar (g)), the HPC second output stream 242/300 in some embodiments had a condensation temperature of 68°C, making it useful as a heat source to reboil liquids with bubble points near 60°C.

SPECIFIC EMBODIMENTS

While the following is described in conjunction with specific embodiments, it will be understood that this description is intended to illustrate and not limit the scope of the preceding description and the appended claims.

A first embodiment of the invention is a fractionation system comprising a rectifying column having a feed inlet between a top and a bottom tray, a reflux inlet at the top tray, a fluid inlet at the bottom tray, an overhead product outlet at the first tray, and a bottoms outlet at the bottom tray; a rectifying column reboiler in communication with the rectifying column; a stripping column having a fluid inlet at a top tray, an overhead outlet at the top tray, and a bottoms outlet at a bottom tray, the bottoms outlet of the rectifying column being in fluid communication with the fluid inlet of the stripping column, the overhead outlet of the stripping column being in fluid communication with the fluid inlet of the rectifying column; and a stripping column reboiler in communication with the stripping column. The

fractionation system of claim 1 wherein the rectifying column and the stripping column are in separate vessels. The fractionation system of claim 1 wherein the rectifying column and the stripping column are in a single vessel, the rectifying column being positioned above the stripping column, the rectifying column having a diameter, and the stripping column having a diameter less than the diameter of the rectifying column. The fractionation system of claim 3 wherein the rectifying column is separated from the stripping column by a liquid accumulator tray. The fractionation system of claim 1 further comprising a condenser having an inlet in fluid communication with the product overhead outlet of the rectifying column, and an outlet in fluid communication with the reflux inlet of the rectifying column. The fractionation system of claim 1 wherein at least a portion of a heat source for the rectifying column reboiler is a stream from a heat pump compressor. The fractionation system of claim 6 wherein an outlet and an inlet for the rectifying column reboiler are in a space below the bottom tray and above the bottom of the rectifying column, the rectifying column reboiler outlet being positioned above the rectifying column reboiler inlet. The fractionation system of claim 6 wherein the heat pump compressor is in fluid communication with a splitter column, the splitter column being downstream of a reactor, the reactor being in fluid communication with the overhead product outlet of the rectifying column. The fractionation system of claim 6 wherein the rectifying column reboiler further comprises a valve to control flow of a recycle stream to the rectifying column reboiler. The fractionation system of claim 1 wherein the overhead product outlet of the rectifying column is in fluid communication with a reactor. The fractionation system of claim 1 wherein the overhead product outlet of the rectifying column is above the top tray of the rectifying column, the reflux inlet of the rectifying column is above the top tray of the rectifying column and below the overhead product outlet, the overhead outlet of the stripping column is above the top tray of the stripping column, the fluid inlet of the stripping column is above the top tray of the stripping column and below the overhead outlet of the stripping column, and the fluid inlet of the rectifying column is below the bottom tray of the rectifying column and above the bottoms outlet of the rectifying column. The fractionation system of claim 1 wherein the rectifying column reboiler is a thermosyphon reboiler.

A second embodiment of the invention is a process of separating a feed stream comprising introducing the feed stream into a feed inlet of a rectifying column, the feed inlet between a top tray and a bottom tray, the rectifying column having a reflux inlet at the top

tray, a fluid inlet at the bottom tray, an overhead product outlet at the first tray, and a bottoms outlet at the bottom tray; separating the feed stream in the rectifying column into an overhead product stream and a bottoms stream; introducing the bottoms stream from the rectifying column into a fluid inlet in a stripping column, the fluid inlet at a top tray of the stripping column, the stripping column having an overhead outlet at the top tray, and a bottoms outlet at a bottom tray; separating the bottoms stream from the rectifying column into an overhead stream and a bottoms stream in the stripping column; introducing the overhead stream from the stripping column into the fluid inlet of the rectifying column; refluxing a portion of the overhead product stream from the rectifying column to the reflux inlet of the rectifying column; reheating at least a portion of the bottoms stream from the rectifying column in a rectifying column reboiler; and reheating at least a portion of the bottoms stream from the stripping column in a stripping column reboiler. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein reheating at least the portion of the bottoms stream from the rectifying column in the rectifying column reboiler comprises placing at least the portion of the bottoms stream from the rectifying column in thermal communication with a stream from a heat pump compressor. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising introducing a second portion of the overhead product stream from the rectifying column into a reactor; separating the reactor effluent in a splitter column; and condensing an overhead stream from the splitter column in the heat pump compressor forming a compressed stream, wherein a portion of the compressed stream comprises the stream from the heat pump compressor. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein an outlet and an inlet for the rectifying column reboiler are in a space below the bottom tray of the rectifying column reboiler and above the bottom of the rectifying column, the rectifying column reboiler outlet being positioned above the rectifying column reboiler inlet. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the rectifying column and the stripping column are in separate vessels. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the rectifying column and the stripping column are in a single vessel,

the rectifying column being positioned above the stripping column, the rectifying column having a diameter, and the stripping column having a diameter less than the diameter of the rectifying column. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the rectifying column and the stripping column are separated by a liquid accumulator tray, and wherein introducing the bottoms stream from the rectifying column into the fluid inlet in the stripping column comprises introducing the bottoms stream through a downcomer in the fluid accumulator tray, and wherein introducing the overhead stream from the stripping column into the fluid inlet of the rectifying column comprises introducing the overhead stream through a vapor riser in the liquid accumulator tray.

While at least one exemplary embodiment has been presented in the foregoing detailed description of the invention, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the invention. It being understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope of the invention as set forth in the appended claims.

WHAT IS CLAIMED IS:

1. A fractionation system comprising: a rectifying column (200) having a feed inlet between a top and a bottom tray, a reflux inlet at the top tray, a fluid inlet at the bottom tray, an overhead product outlet at the first tray, and a bottoms outlet at the bottom tray; a rectifying column reboiler (245) in communication with the rectifying column (200); a stripping column (205) having a fluid inlet at a top tray, an overhead outlet at the top tray, and a bottoms outlet at a bottom tray, the bottoms outlet of the rectifying column (200) being in fluid communication with the fluid inlet of the stripping column (205), the overhead outlet of the stripping column (205) being in fluid communication with the fluid inlet of the rectifying column (200); and a stripping column reboiler (255) in communication with the stripping column (205).
2. The fractionation system of claim 1 wherein the rectifying column (200) and the stripping column (205) are in separate vessels.
3. The fractionation system of claim 1 wherein the rectifying column (280) and the stripping column (285) are in a single vessel, the rectifying column (280) being positioned above the stripping column (285), the rectifying column (280) having a diameter, and the stripping column (285) having a diameter less than the diameter of the rectifying column (280).
4. The fractionation system of claim 3 wherein the rectifying column (280) is separated from the stripping column (285) by a liquid accumulator tray (290).
5. The fractionation system of any of claims 1-4 wherein at least a portion of a heat source for the rectifying column reboiler (245) is a stream (242) from a heat pump compressor (70).
6. The fractionation system of claim 5 wherein the heat pump compressor (70) is in fluid communication with a splitter column (50), the splitter column (50) being downstream of a reactor (25), the reactor (25) being in fluid communication with the overhead product outlet of the rectifying column (200).
7. A process of separating a feed stream comprising: introducing the feed stream (10) into a feed inlet of a rectifying column (200), the feed inlet between a top tray and a bottom tray, the rectifying column (200) having a reflux inlet at the top tray, a fluid inlet at

the bottom tray, an overhead product outlet at the first tray, and a bottoms outlet at the bottom tray; separating the feed stream (10) in the rectifying column (200) into an overhead product stream (210) and a bottoms stream (215); introducing the bottoms stream (215) from the rectifying column (200) into a fluid inlet in a stripping column (205), the fluid inlet at a top tray of the stripping column (205), the stripping column (205) having an overhead outlet at the top tray, and a bottoms outlet at a bottom tray; separating the bottoms stream (215) from the rectifying column (200) into an overhead stream (240) and a bottoms stream (265) in the stripping column (205); introducing the overhead stream (240) from the stripping column (205) into the fluid inlet of the rectifying column (200); refluxing a portion (235) of the overhead product stream (210) from the rectifying column (200) to the reflux inlet of the rectifying column (200); reheating at least a portion (250) of the bottoms stream (215) from the rectifying column (200) in a rectifying column reboiler (245); and reheating at least a portion (270) of the bottoms stream (265) from the stripping column (205) in a stripping column reboiler (275).

8. The process of claim 7 wherein reheating at least the portion (250) of the bottoms stream (215) from the rectifying column (200) in the rectifying column reboiler (245) comprises: placing at least the portion (250) of the bottoms stream (215) from the rectifying column (200) in thermal communication with a stream (242) from a heat pump compressor (70).

9. The process of claim 8 further comprising: introducing a second portion (20) of the overhead product stream (210) from the rectifying column (200) into a reactor (25); separating the reactor effluent (30) in a splitter column (50); and condensing an overhead stream (65) from the splitter column (50) in the heat pump compressor (70) forming a compressed stream, wherein a portion (120) of the compressed stream comprises the stream from the heat pump compressor (70).

10. The process of any of claims 7-9 wherein the rectifying column (280) and the stripping column (285) are in a single vessel, the rectifying column (280) being positioned above the stripping column (285), the rectifying column (280) having a diameter, and the stripping column (285) having a diameter less than the diameter of the rectifying column (280), and wherein the rectifying column (280) and the stripping column (285) are

separated by a liquid accumulator tray (290), and wherein introducing the bottoms stream from the rectifying column (280) into the fluid inlet in the stripping column (285) comprises introducing the bottoms stream through a downcomer (310) in the fluid accumulator tray (290), and wherein introducing the overhead stream from the stripping column (285) into the
5 fluid inlet of the rectifying column (280) comprises introducing the overhead stream through a vapor riser (315) in the liquid accumulator tray (290).

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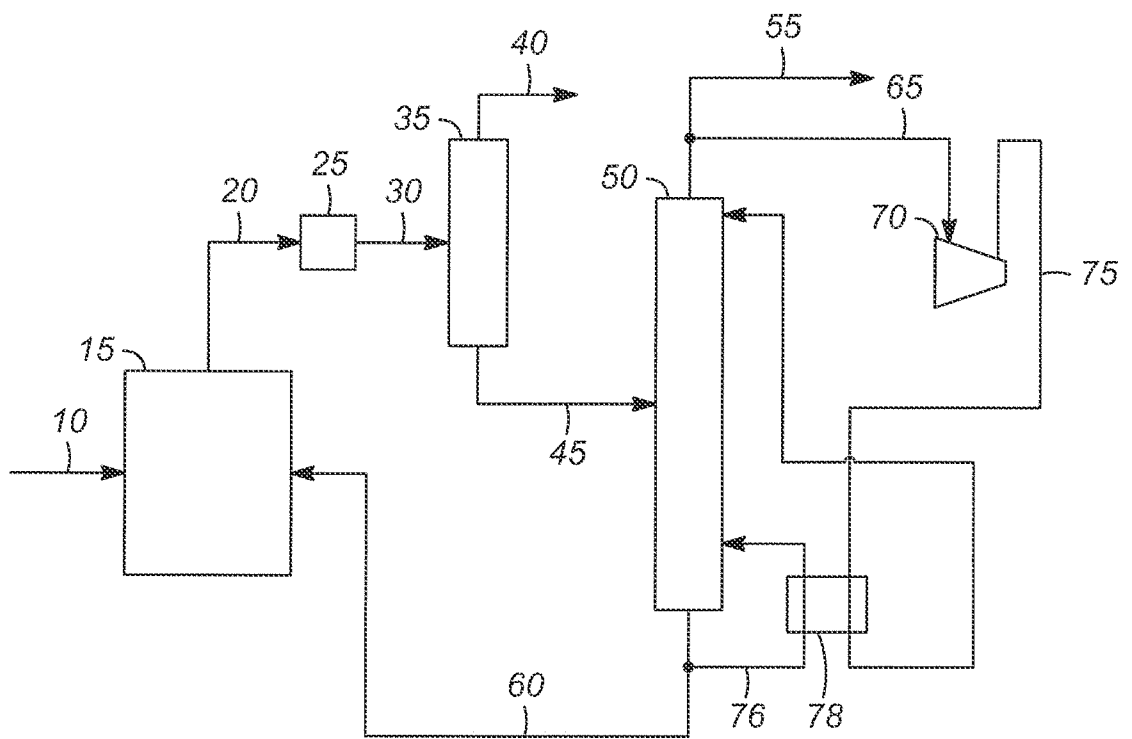


FIG. 1

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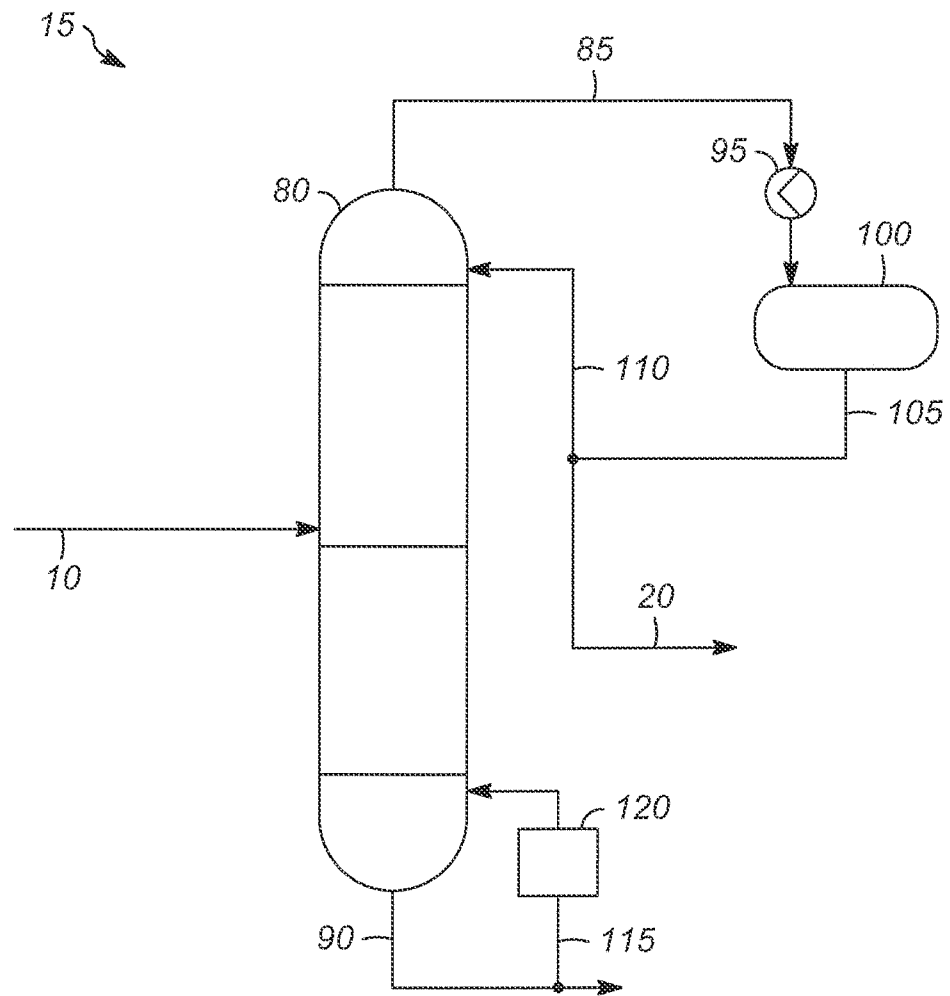


FIG. 2

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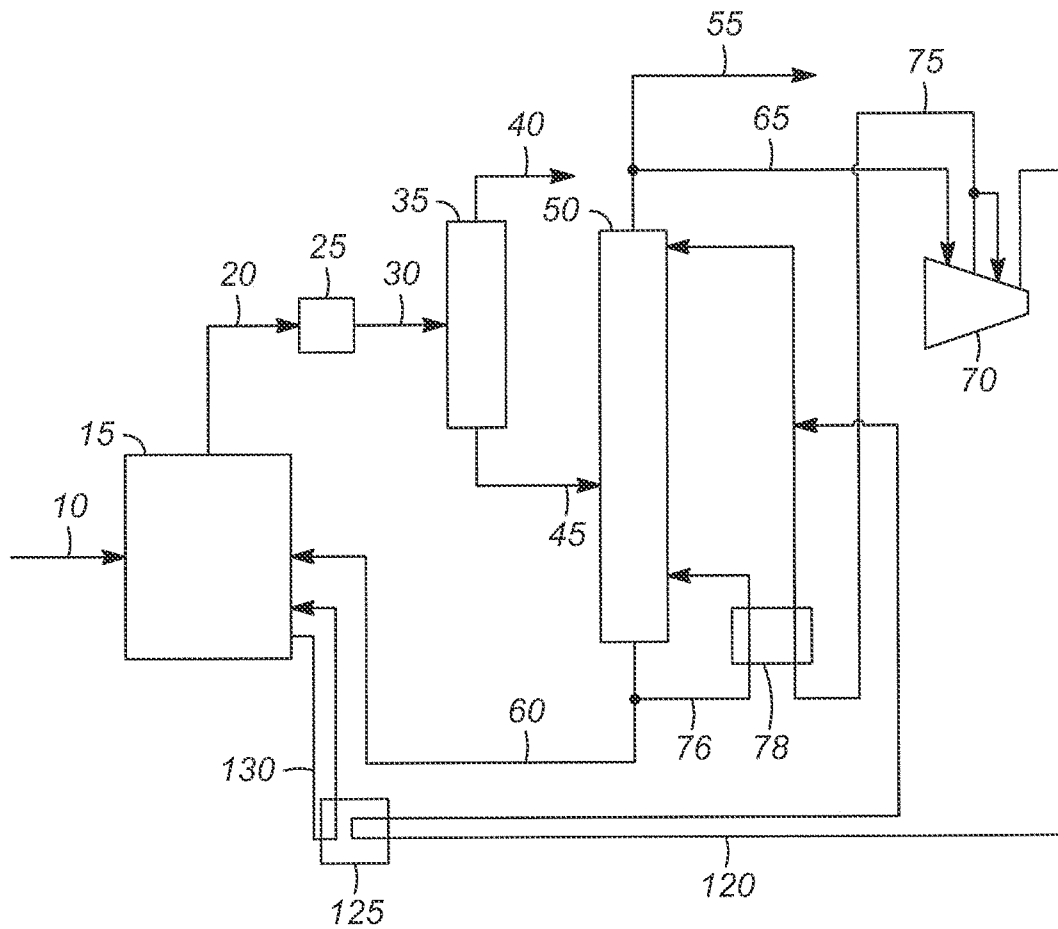


FIG. 3

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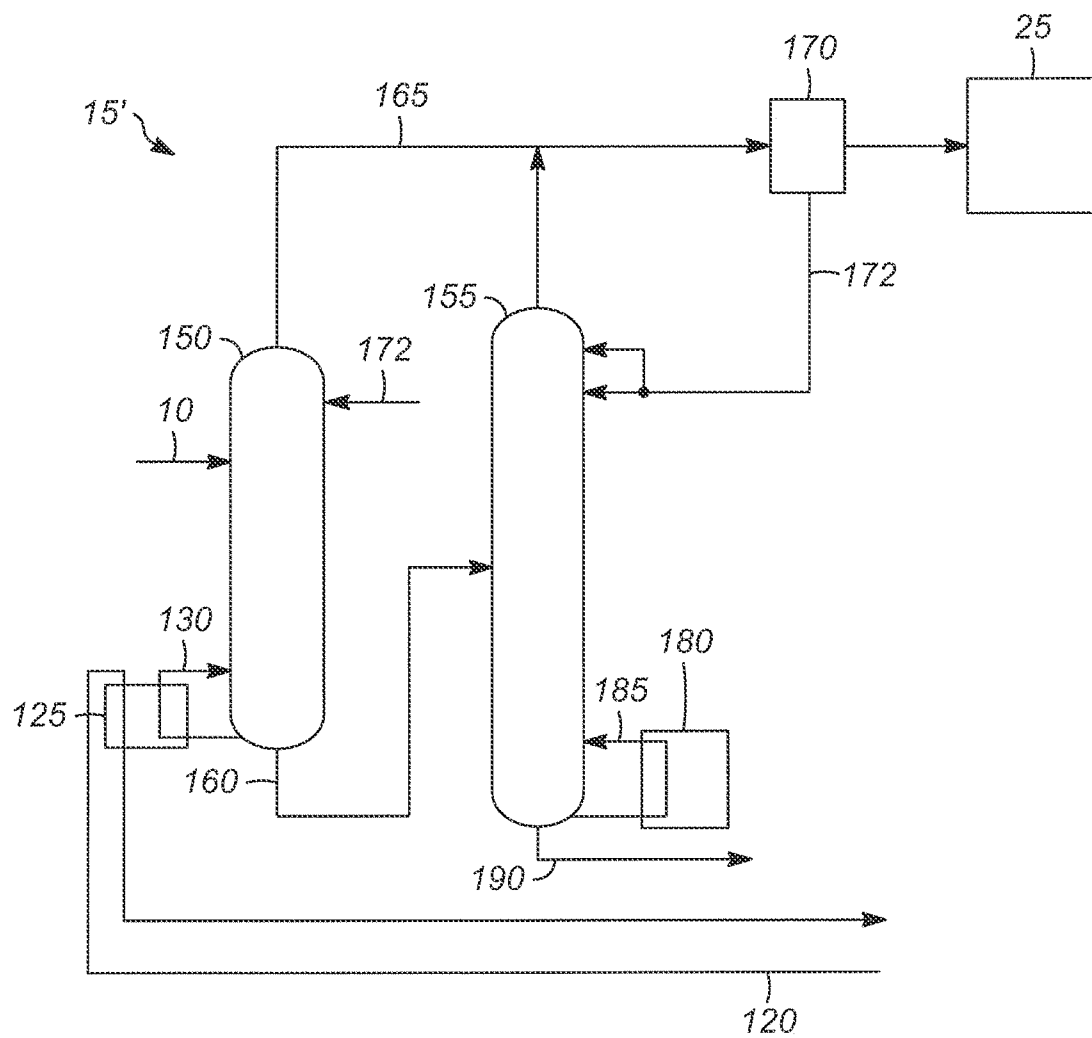


FIG. 4

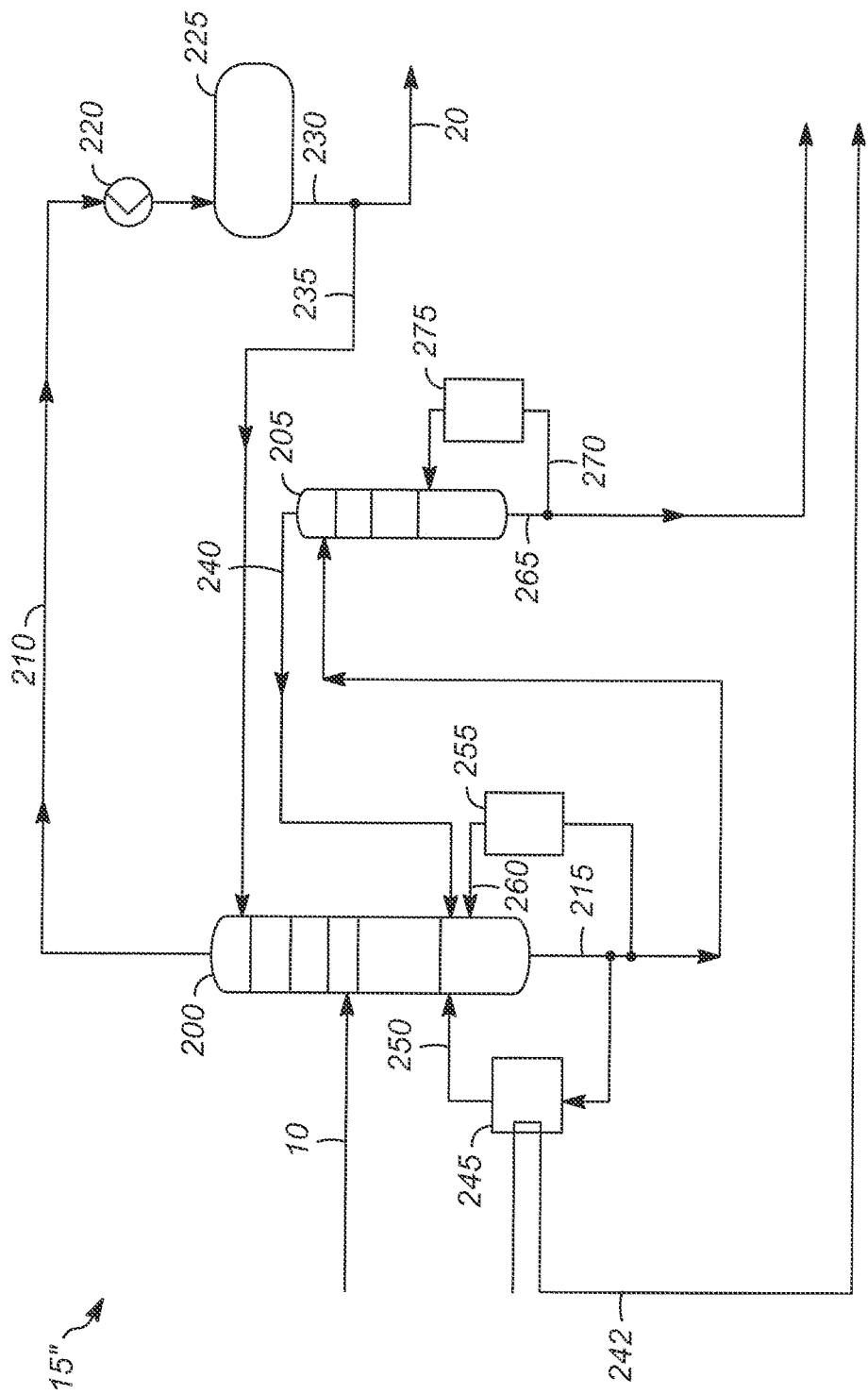


FIG. 5

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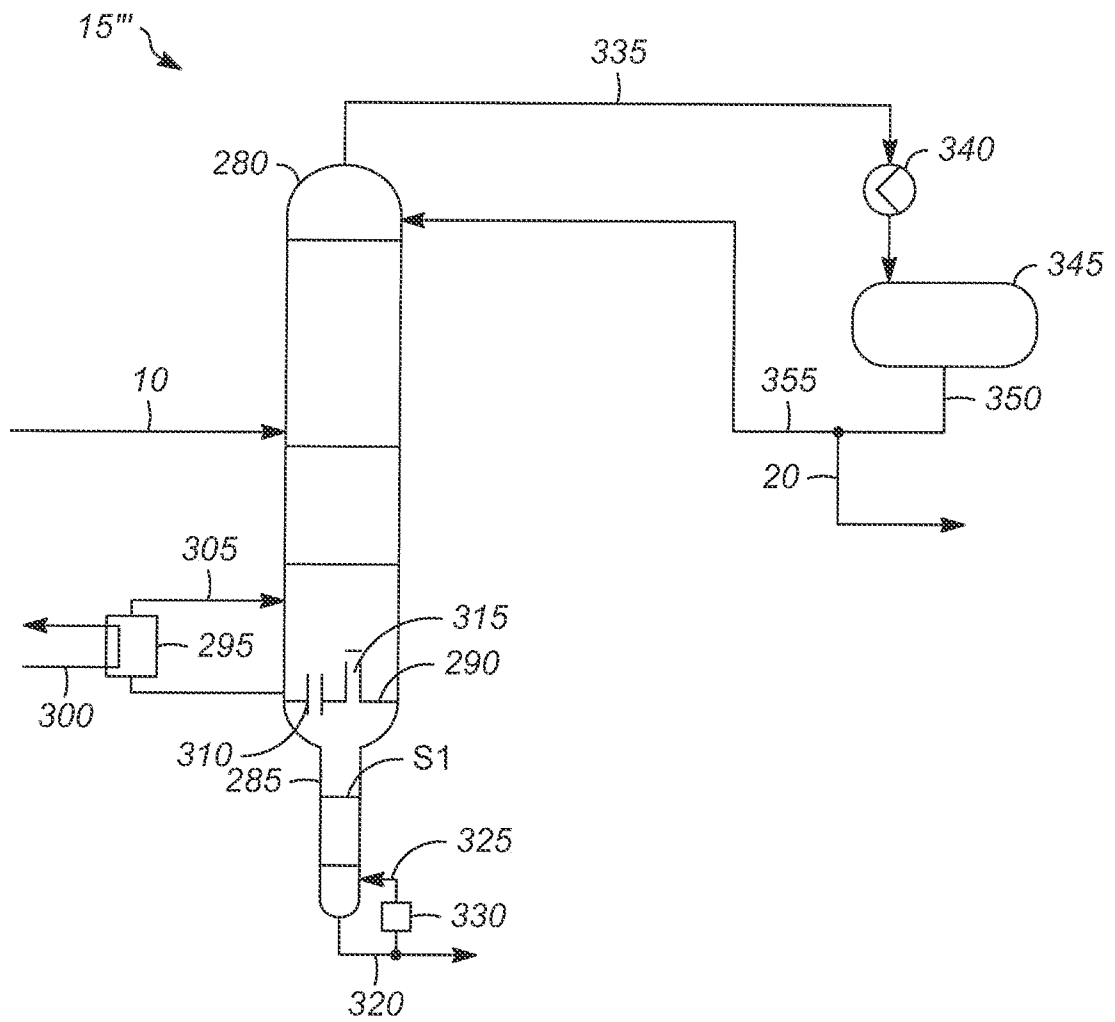


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/044798**A. CLASSIFICATION OF SUBJECT MATTER****B01D 3/02(2006.01)i, B01D 3/00(2006.01)i**

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)

B01D 3/02; B01D 3/28; B01D 3/34; C07C 5/00; C02F 1/04; B01D 3/26; B01D 3/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & keywords: rectifying column, stripping column, reboiler, depropanizer, propane, propylene, propene, fractionation, reflux, tray, dehydrogenation

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013-0131417 A1 (WERBA, G. et al.) 23 May 2013 See abstract; paragraphs [0018]-[0020], [0024]-[0029]; claims 1, 2, 7-9, 11-13; figures 2-4.	1-10
A	WO 2010-062462 A2 (UOP LLC.) 3 June 2010 See abstract; paragraphs [0015]-[0021]; claim 1; figures 1, 2.	1-10
A	US 2012-0125761 A1 (NAKAIWA, M. et al.) 24 May 2012 See abstract; paragraphs [0003], [0057]-[0068]; claims 1, 2; figures 1, 4.	1-10
A	US 2010-0108487 A1 (TOWNSEND, D. W.) 6 May 2010 See abstract; paragraphs [0022]-[0024], [0030], [0031], [0035], [0037], [0042], [0050], [0051]; figures 1, 2.	1-10
A	US 2008-0257711 A1 (CHEN, M. R. et al.) 23 October 2008 See abstract; paragraphs [0027]-[0030]; claim 1; figure 1.	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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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

27 October 2014 (27.10.2014)

Date of mailing of the international search report

28 October 2014 (28.10.2014)

Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

HEO, Joo Hyung

Telephone No. +82-42-481-8150



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/044798

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