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(54) **OVERHEAD RECYCLE PROCESS APPARATUS AND METHOD OF OVERHEAD RECYCLE PROCESSING OF HYDROCARBONS**

(57) An overhead recycle process apparatus (100) comprises a heat exchange arrangement (116, 118, 120, 146, 150, 198) and a separator (110) in fluid communication with an absorber (104) and a de-ethaniser (106), the absorber (104) having a reflux inlet port (164). An ethane rectifier (170) in fluid communication with the de-ethaniser (106) is also provided, the de-ethaniser

(106) being arranged to provide cooling by heat exchange to an overhead stream path (194) of the ethane rectifier (170). The ethane rectifier (170) comprises a reflux drum (182) having an ethane outlet port (184) and a vapour phase outlet port (185) in fluid communication with the reflux inlet port (164) of the absorber (104).

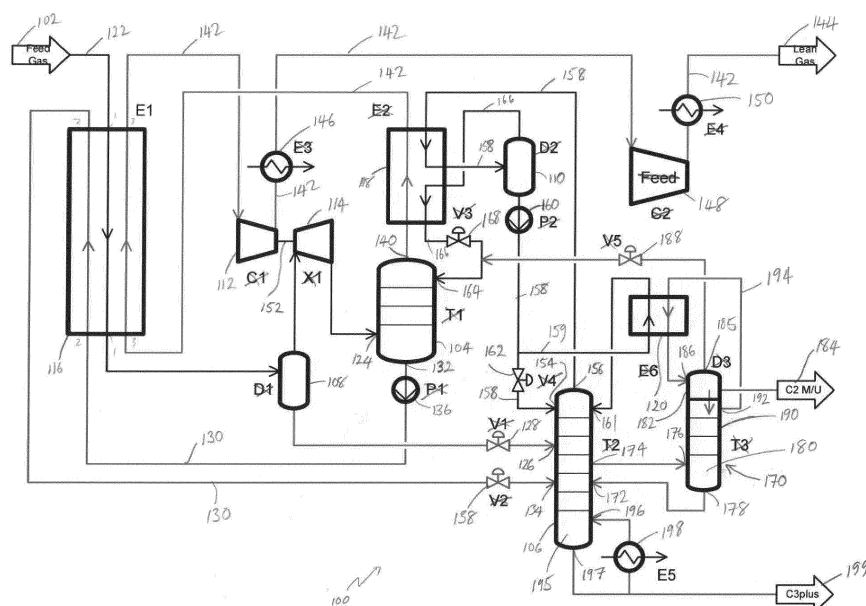


Figure 1

Description

[0001] The present invention relates to an overhead recycle process apparatus of the type that, for example, recovers hydrocarbon products having a molecular weight heavier than ethane from natural gas. The present invention also relates to a method of overhead recycle processing of hydrocarbons, the method being of the type that recovers hydrocarbon products having a molecular weight heavier than ethane from natural gas.

[0002] In the field of hydrocarbon recovery from natural gas, processes for the recovery hydrocarbons having molecular weights heavier than ethane, for example natural gas liquids, are known. One known process is the so-called overhead recycle process that essentially draws a vapour stream from a de-ethaniser for condensation and then introduction into an absorber as reflux in order to rectify vapour leaving an expander. Heavier hydrocarbon fractions are thereby absorbed in the absorber for recovery from a bottom product reservoir of the de-ethaniser. The process is described in US patent no. 4,617,039, and is optimised for bulk propane recovery.

[0003] It is often the case that recovery of considerable quantities of ethane from the natural gas, for example 90% or more, when recovering the heavier hydrocarbon fractions is not commercially justified, because a demand for large quantities of ethane is lacking. Nevertheless, a demand exists, for example in the refrigerant market, to justify recovering a smaller quantity of ethane, for example less than about 10%, such as less than 5%.

[0004] Known process architectures for the recovery of smaller quantities of ethane from the natural gas employ, for example, a sequence of fractionating units, for example a de-methaniser and a de-ethaniser. However, such configurations are not cost-effective for recovering relatively small quantities of ethane from the natural gas where the primary consideration is the recovery of the molecularly heavier hydrocarbon fractions. Additionally, if applied in the context of the overhead recycle process described above, efficiency of extraction of propane would be reduced.

[0005] According to a first aspect of the present invention, there is provided an overhead recycle process apparatus comprising: a heat exchange arrangement; a separator in fluid communication with an absorber and a de-ethaniser, the absorber having a reflux inlet port; and an ethane rectifier in fluid communication with the de-ethaniser, the de-ethaniser being arranged to provide cooling by heat exchange to an overhead stream path of the ethane rectifier; and the ethane rectifier comprises a reflux drum having an ethane outlet port and a vapour outlet port in fluid communication with the reflux inlet port of the absorber.

[0006] The de-ethaniser may comprise a bottom product outlet port arranged to provide hydrocarbon fractions having a molecular weight heavier than a molecular weight of ethane.

[0007] The apparatus may further comprise: a side

stream circuit; wherein the de-ethaniser may comprise a side stream inlet port and a side stream outlet port; the side stream outlet port may be disposed above the side stream inlet port of the de-ethaniser; the ethane rectifier may comprise a rectifier bottom product inlet port, a rectifier bottom product outlet port and a bottom product reservoir; the side stream circuit may extend from the side stream outlet port into the bottom product reservoir via the rectifier bottom product inlet port and returns to the side stream inlet port via the rectifier bottom product outlet port; and the side stream outlet port may be located at a location along the de-ethaniser corresponding to an expected presence of elevated levels of ethane content in the de-ethaniser.

[0008] The reflux drum of the ethane rectifier may comprise a reflux inlet port and a rectification portion of the ethane rectifier may comprise an overhead stream outlet port; the overhead stream path may extend from the overhead stream outlet port to the reflux inlet port via the heat exchange arrangement so as to define an ethane reflux path.

[0009] The de-ethaniser may comprise a primary reflux inlet port, a secondary reflux inlet port and an overhead stream outlet port; a primary de-ethaniser reflux path may extend from the overhead stream outlet port of the de-ethaniser to the primary reflux inlet port of the de-ethaniser via the heat exchange arrangement and the separator; a secondary de-ethaniser reflux path may branch from the primary de-ethaniser reflux path and extend to the secondary reflux inlet port via the heat exchange arrangement; and the heat exchange arrangement may comprise an ethane reflux heat exchanger; the secondary de-ethaniser reflux path and the ethane reflux path may pass through the ethane reflux heat exchanger.

[0010] The apparatus may further comprise: a lean gas outlet path; a lean gas outlet port in fluid communication with the lean gas outlet path; wherein the heat exchange arrangement may comprise a first heat exchanger and a second heat exchanger; and a compressor; wherein the lean gas outlet path may extend from an overhead stream outlet port of the absorber to the lean gas outlet port, and pass through the second heat exchanger and the first heat exchanger; and the compressor may be in the lean gas outlet path after the first heat exchanger.

[0011] The apparatus may further comprise: a gas feed inlet port; another separator that may have an inlet port in fluid communication with the gas feed inlet port via the first heat exchanger; the another separator may have a vapour outlet port and a liquid outlet port.

[0012] The apparatus may further comprise: an expander operably coupled to the compressor; wherein the vapour outlet port of the another separator may be in fluid communication with the expander and the expander may be in fluid communication with a bottom product reservoir of the absorber; and the liquid outlet port of the another separator may be in fluid communication with a first feed inlet port of the de-ethaniser.

[0013] The apparatus may further comprise: a second

feed fluid path in fluid communication at one end thereof with a bottom fraction outlet port of the absorber and in fluid communication at another end thereof with a second feed inlet port of the de-ethaniser; wherein the second feed fluid path may pass through the first heat exchanger.

[0014] The separator may comprise a vapour outlet port and a liquid outlet port; the vapour outlet port may be in fluid communication with the reflux inlet port of the absorber via the second heat exchanger and the liquid outlet port may be in fluid communication with the primary reflux inlet port of the de-ethaniser.

[0015] The overhead outlet stream port of the de-ethaniser may be in fluid communication with an inlet port of the separator via the second heat exchanger.

[0016] The de-ethaniser may comprise: a bottom fraction reservoir, and a bottom fraction inlet port and a bottom fraction outlet port in fluid communication with the bottom fraction reservoir; and a reboiler circuit path may extend from the bottom fraction outlet port and return to the bottom fraction reservoir via the bottom fraction inlet port; the reboiler circuit path may pass through the heat exchange arrangement.

[0017] The de-ethaniser may comprise a heavy hydrocarbon fractions outlet port for hydrocarbon fractions having a molecular weight heavier than the molecular weight of ethane.

[0018] The apparatus may further comprise: a light fractions compression and cooling arrangement in fluid communication at a first end thereof with the lean gas outlet port and at a second end thereof with the first heat exchanger; wherein the compression and cooling arrangement may comprise the compressor.

[0019] The lean gas outlet port may be associated with hydrocarbon fractions having a molecular weight lighter than the molecular weight of ethane.

[0020] According to a second aspect of the present invention, there is provided a method of overhead recycle processing of hydrocarbons, the method comprising: drawing off ethane from a de-ethaniser; rectifying the drawn off ethane in a rectifier; generating reflux from an overhead stream path of the rectifier; and introducing the reflux into a reflux drum of the rectifier.

[0021] The method may further comprise providing an ethane rectifier having a reflux drum and an absorber; wherein an overhead stream of the reflux drum provides reflux to the absorber.

[0022] It is thus possible to provide an overhead recycle process apparatus and method capable of recovering relatively small quantities of ethane whilst recovering molecularly heavier hydrocarbon fractions from natural gas in an efficient and economic manner. Furthermore, the ethane recovered is of a desired purity, for example better than 95 mol%, such as better than 98 mol%. Additionally, the apparatus and method obviates the need to provide additional rotating hardware, for example compressors and pumps, in order to support recovery of the ethane.

[0023] At least one embodiment of the invention will now be described, by way of example only, with reference

to the accompanying drawings, in which:

Figure 1 is a schematic diagram of an overhead recycle process apparatus constituting an embodiment of the invention; and

Figures 2 to 4 are parts of a flow diagram of a method of overhead recycle processing constituting another embodiment of the invention.

[0024] Referring to Figure 1, an overhead recycle process apparatus 100 comprises a natural gas inlet port 102, an absorber 104 and a de-ethaniser 106 in fluid communication with each other via a heat exchange arrangement, a first separator 108, a second separator 110, a first compressor 112, an expander 114 and other components to be described later herein, for example Joule-Thomson devices, such as throttling devices, and pumps.

[0025] In this example, the heat exchange arrangement comprises a first heat exchanger 116, a second heat exchanger 118 and an ethane reflux heat exchanger 120.

[0026] An inlet fluid path 122 extends from the natural gas inlet port 102 and passes through the first heat exchanger 116 via first inlet and outlet ports of the first heat exchanger 116 and is in fluid communication with an inlet port of the first separator 108. The first separator 108 has a first vapour outlet port and a first liquid outlet port, the first vapour outlet port of the first separator 108 being in fluid communication with a bottom product inlet port 124 of the absorber 104 via the expander 114. The first liquid outlet port of the first separator 108 is in fluid communication with a first feed inlet port 126 of the de-ethaniser 106 via a first Joule-Thomson device, for example a first valve 128.

[0027] A second feed path 130 is in fluid communication at a first end thereof with a bottom product outlet port 132 of the absorber 104 and at a second end thereof with a second feed inlet port 134. A first pump 136 is disposed in the second feed path 130 before the second feed path 130 passes through the first heat exchanger 116 via second inlet and outlet ports of the first heat exchanger 116. A second Joule-Thomson device, such as a second valve 138, is disposed in the second feed path 130 before the second end of the second feed path 130 reaches the second feed inlet port 134, but downstream of the first heat exchanger 116.

[0028] The absorber 104 has an overhead vapour outlet port 140 and a lean gas outlet path 142 is in fluid communication with the overhead vapour outlet port 140 at a first end thereof, a second end of the lean gas outlet path 142 being in fluid communication with a lean gas outlet port 144. From the overhead vapour outlet port 140, the lean gas outlet path 142 passes through the second heat exchanger 118 via first inlet and outlet ports of the second heat exchanger 118 before passing subsequently through the first heat exchanger 116 via third inlet and outlet ports thereof. The lean gas outlet path

142 then passes through a light fractions compression and cooling arrangement disposed between the first heat exchanger 116 and the lean gas outlet port 144. In this example, the light fractions compression and cooling arrangement comprises the first compressor 112 having an inlet port in fluid communication with the third outlet port of the first heat exchanger 116, an outlet port of the first compressor 112 being in fluid communication with an intermediary heat exchanger, for example an intercooler 146. An outlet port of the intercooler 148 is in fluid communication with an inlet port of a second compressor 148, an outlet port of the second compressor 148 being in fluid communication with a post-compression heat exchanger, for example a post- or after-cooler 150. An outlet port of the after-cooler 150 is in fluid communication with the lean gas outlet port 144. In this example, the first compressor 112 is operably coupled to the expander 114 by a drive shaft 152.

[0029] The de-ethaniser 106 also comprises a de-ethaniser primary reflux inlet port 154, and an overhead vapour outlet port 156 in fluid communication with a primary de-ethaniser reflux path 158 at a first end thereof, the primary de-ethaniser reflux path 158 being in fluid communication with the de-ethaniser primary reflux inlet port 154 at a second end thereof. The primary de-ethaniser reflux path 158 extends from the overhead vapour outlet inlet port 156 to an inlet port of the second separator 110, passing through the second heat exchanger 118 via second inlet and outlet ports thereof. The second separator 110 comprises a second vapour outlet port and a second liquid outlet port, the second liquid outlet port being in fluid communication with a second pump 160 and a third Joule-Thomson device, for example a third valve 162, disposed downstream of the second pump 160 before the primary de-ethaniser reflux path 158 reaches the de-ethaniser primary reflux inlet port 154.

[0030] A secondary de-ethaniser reflux path 159 is in fluid communication at a first end thereof with the primary de-ethaniser reflux path 158 between the second pump 160 and the third valve 162. The secondary de-ethaniser reflux path 159 passes through the ethane reflux heat exchanger 120 via first inlet and outlet ports thereof. A second end of the secondary de-ethaniser reflux path 159 is in fluid communication with a de-ethaniser secondary reflux inlet port 161.

[0031] The second vapour outlet port of the second separator 110 is in fluid communication with an absorber reflux inlet port 164 of the absorber 104 by way of an absorber reflux path 166 that is in fluid communication with the second vapour outlet port of the second separator 110 at a first end thereof. The absorber reflux path 166 also passes through the second heat exchanger 118 via third inlet and outlet ports of the second heat exchanger 118. A fourth Joule-Thomson device, for example a fourth valve 168, is disposed in the absorber reflux path 166 between the second heat exchanger 118 and the absorber reflux inlet port 164.

[0032] An ethane rectifier 170 is in fluid communication

with the de-ethaniser 106 via a side stream circuit. In this regard, the de-ethaniser comprises a side stream inlet port 172 and a side stream outlet port 174, the side stream outlet port 174 being disposed above the side stream inlet port 172. The ethane rectifier 170 comprises a rectifier bottom product inlet port 176, a rectifier bottom product outlet port 178 and a bottom product reservoir 180. The side stream circuit extends from the side stream outlet port 174 into the bottom product reservoir 180 via the rectifier bottom product inlet port 176 and returns to the side stream inlet port 172, below the side stream outlet port 174, via the rectifier bottom product outlet port 178. The side stream outlet port 174 is located at a location along the de-ethaniser 106 corresponding to an expected presence of elevated levels of ethane content in the de-ethaniser 106, and is located below the second feed inlet port 134, although it should be appreciated that in some embodiments the side stream outlet port 174 can be disposed slightly above the second feed inlet port 134.

[0033] The ethane rectifier 170 comprises a reflux drum 182 having an ethane outlet port 184, an overhead vapour outlet port 185 and a reflux inlet port 186, the overhead vapour outlet port 185 being in fluid communication with the absorber reflux inlet port 164 via a fifth Joule-Thomson device, for example a fifth valve 188. A rectification portion 190 of the ethane rectifier 170 comprises an overhead stream outlet port 192 in fluid communication with a first end of an overhead stream path 194, a second end of the overhead stream path 194 being in fluid communication with the reflux inlet port 186 via the ethane reflux heat exchanger 120.

[0034] The de-ethaniser 106 also comprises a bottom fractions reservoir 195, and a bottom fractions inlet port 196 and a bottom fractions outlet port 197 in fluid communication with the bottom fractions reservoir 195. A reboiler circuit path extends from the bottom fractions outlet port 197 and returns to the bottom fractions reservoir 195 via the bottom fractions inlet port 196. In this example, the reboiler circuit path passes through a reboiler heat exchanger 198. The bottom fractions outlet port 197 is also in fluid communication with a heavy hydrocarbon fractions outlet port 199 at a temperature of between about 110°C and about 130°C, for example about 118°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.4 MPa (34 bar abs).

[0035] In this example, the heat exchange arrangement also comprises the intercooler 146, the after-cooler 150 and the reboiler heat exchanger 198.

[0036] In operation (Figures 2 to 4), natural gas is supplied at the natural gas inlet port 102. In this example, the gas is at a temperature of between about 10°C and about 60°C, for example about 40°C, and a pressure of between about 4 MPa (40 bar abs) and about 8 MPa (80 bar abs), for example about 6 MPa (60 bar abs). The natural gas follows the inlet fluid path 122 and passes through the first heat exchanger 116, where the natural gas is cooled and partially liquefied (Step 200) through

heat exchange, to yield a fluid between -55°C and about -35°C in temperature, for example about -44°C, and between about 3.9 MPa (39 bar abs) and about 7.9 MPa (79 bar abs) in pressure, for example 5.9 MPa (59 bar abs). The cooled and partially liquefied natural gas then enters the first separator 108 (Step 202), the vapour fraction being between about 0.94 mol/mol and about 0.99 mol/mol, for example about 0.97 mol/mol. The liquid fraction of the cooled natural gas leaves the first separator 108 and is cooled further by passage through the first valve 128 before entering (Step 204) the de-ethaniser 106 at a temperature of between about -65°C and about -45°C, for example about -56°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.4 MPa (34 bar abs). The vapour fraction of the cooled liquid fraction is between about 0.15 mol/mol and about 0.3 mol/mol, for example about 0.23 mol/mol.

[0037] The vapour fraction of the cooled natural gas enters the expander 114 where the vapour fraction undergoes expansion (Step 206) leading to a drop in pressure and temperature of the vapour fraction. The expanded vapour, which is now partially condensed, is then fed (Step 208) into a bottom product reservoir of the absorber 104. In this example, the expanded vapour is at a temperature of between about -80°C and about -60°C, for example about -71°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.2 MPa (32 bar abs). The vapour fraction of the expanded vapour is between about 0.9 mol/mol and about 0.98 mol/mol, for example about 0.96 mol/mol.

[0038] In the absorber 104, vapour fractions leaving the absorber 104 via the overhead vapour outlet port 140 do so at a temperature of between about -85°C and about -65°C, for example about -75°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.2 MPa (32 bar abs), and follow the lean gas outlet path 142 and pass through the second heat exchanger 118 and then the first heat exchanger 116. Thereafter, the light fractions compression and cooling arrangement comprising the first and second compressors 112, 148 and the intercooler 146 and the post-cooler 150 compress and cool (Step 210) the so-called "light" fractions present in the lean gas outlet path 142, for example nitrogen, methane and ethane. The light fractions have a lower molecular weight than propane and are present at the lean gas outlet port 144, and are at a temperature of between about 10°C and about 60°C, for example about 37°C, and a pressure of between about 4 MPa (40 bar abs) and about 10 MPa (100 bar abs), for example about 6 MPa (60 bar abs). In this example, the lean gas outlet path 142 supports cooling in the first and second heat exchangers 116, 118.

[0039] Liquid fractions at the bottom of the absorber 104 leave the absorber 104 at a temperature of between about -80°C and about -65°C, for example about -72°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.2

MPa (32 bar abs), and are pumped by the first pump 136 so as to follow the second feed fluid path 130, the liquid fractions passing through the first heat exchanger 116, thereby experiencing heating and partial vaporisation.

5 Thereafter, the warmed liquid fractions pass through the second valve 138, resulting in the cooling of the liquid fractions in the second feed fluid path 130, and then enter the de-ethaniser 106 via the second feed inlet port 134 (Step 212) at a temperature of between about -10°C and
10 about 30°C, for example about 10°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.4 MPa (34 bar abs). The vapour fraction of the fluid entering the de-ethaniser 106 is between about 0.7 mol/mol and about 1.0 mol/mol,
15 for example about 0.82 mol/mol.

[0040] An overhead vapour stream emanates from the overhead vapour port 156 of the de-ethaniser 106 at a temperature of between about -15°C and about 10°C, for example about -2°C, and a pressure of between about
20 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.4 MPa (34 bar abs), and follows the primary de-ethaniser reflux path 158 and enters the second separator 110 (Step 220) at a temperature of between about -25°C and about 0°C, for example about
25 -16°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.3 MPa (33 bar abs). The vapour fraction of the fluid entering the second separator 110 is between about 0.75 mol/mol and about 0.95 mol/mol, for example about 0.86
30 mol/mol. Vapour fractions leave the second separator 110 and follow the absorber reflux path 166 and pass through the second heat exchanger 118 and the fourth valve 168 where the vapour fractions are cooled (Step 222) before entering the absorber 104 via the absorber
35 reflux inlet port 164 at a temperature of between about -80°C and about -65°C, for example about -72°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.2 MPa (32 bar abs). The vapour fraction of the fluid entering the
40 absorber 104 via the absorber reflux inlet port 164 is between about 0.2 mol/mol and about 0.35 mol/mol, for example about 0.27 mol/mol.

[0041] Liquid fractions leave the second separator 110 and are pumped (Step 226) by the second pump 160 to the de-ethaniser primary reflux inlet port 154 via the third valve 162, which serves to cool the liquid fractions passing therethrough. The cooled liquid fractions then enter the de-ethaniser primary reflux inlet port 154 at a temperature of between about -25°C and about 0°C, for example about -15°C, and a pressure of between about 2.5
45 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.4 MPa (34 bar abs) and serve as reflux (Step 228). A portion of the liquid fractions is tapped off the primary de-ethaniser reflux path 158 so as to follow the secondary de-ethaniser reflux path 159, the tapped off liquid fractions pass (Step 230) through the ethane
50 reflux heat exchanger 120 to support cooling by the ethane reflux heat exchanger 120, before entering (Step

232) the de-ethaniser 106 via the secondary reflux inlet port 161 a temperature of between about 0°C and about 20°C, for example about 12°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.3 MPa (33 bar abs). The vapour fraction of the fluid entering the de-ethaniser 106 via the secondary reflux inlet port 161 is between about 0.1 mol/mol and about 0.35 mol/mol, for example about 0.26 mol/mol. When tapped off, the tapped off liquid fractions mentioned above are at a temperature of between about -25°C and about 0°C, for example about -15°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.8 MPa (38 bar abs). The flow fraction of the secondary de-ethaniser reflux path 159 is between about 60% and about 100%, for example about 90%, of the total liquid leaving the separator 110 in the primary de-ethaniser reflux path 158.

[0042] A proportion of the bottom fractions leaving the de-ethaniser 106 via the bottom fraction outlet port 197 follow a reboiler circuit path (Step 234) and are heated and partially vaporised in the reboiler heat exchanger 198 and reintroduced into the bottom fraction reservoir 195 of the de-ethaniser 106. The remaining proportion of the bottom fractions leaving the de-ethaniser 106 via the bottom fraction outlet port 197 are drawn off (Step 236) via the heavy hydrocarbon fractions outlet port 199.

[0043] Ethane present in the de-ethaniser 106 is circulated (Step 240) through a side stream circuit; the ethane vapour leaves the de-ethaniser 106 via the side stream outlet port 174 at a temperature of between about 60°C and about 80°C, for example about 70°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.4 MPa (34 bar abs), and enters the bottom product reservoir 180 of the ethane rectifier 170. Lighter fractions in vapour phase rise through the ethane rectifier 170, whilst heavier liquid fractions reside in the bottom product reservoir 180, and are returned to the de-ethaniser via the rectifier bottom product outlet port 178 and the side stream inlet port 172 at a temperature of between about 50°C and about 70°C, for example about 60°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.4 MPa (34 bar abs). The vapour fractions travelling up the rectification portion 190 of the ethane rectifier 170 encounter reflux originating from the reflux drum 182, which serves to rectify the vapour fractions before the vapour fractions leave the rectification portion 190 of the ethane rectifier 170 via the overhead stream outlet port 192 at a temperature of between about 5°C and about 25°C, for example about 14°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.4 MPa (34 bar abs). The vapour fractions then follow the overhead stream path 194 and pass through the ethane reflux heat exchanger 120 in which they are cooled and at least partially condensed (Step 242), before entering the reflux drum 182 via the reflux inlet port

186 at a temperature of between about 0°C and about 20°C, for example about 11°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.4 MPa (34 bar abs) to provide the reflux mentioned above. The reflux comprises between about 0 mol/mol and about 0.1 mol/mol vapour, for example about 0 mol/mol vapour. The reflux travels down the rectification portion 190 of the ethane rectifier 170, and a proportion of the ethane in the reflux drum 182 is drawn (Step 244) from the reflux drum 182 at the ethane outlet port 184 at a temperature of between about 0°C and about 20°C, for example about 11°C, and a pressure of between about 2.5 MPa (25 bar abs) and about 4 MPa (40 bar abs), for example about 3.4 MPa (34 bar abs).

[0044] An overhead drum stream leaving the reflux drum 182 via the overhead vapour outlet port 185 undergoes cooling by passage through the fifth valve 188, before being fed into the absorber reflux path 166 where the cooled overhead drum stream contributes (Step 246) to the reflux entering the absorber 104 via the absorber reflux inlet port 164.

[0045] The skilled person should appreciate that the above-described implementations are merely examples of the various implementations that are conceivable within the scope of the appended claims. Indeed, although in this example, a heat exchanger arrangement comprises the various heat exchangers, the skilled person will appreciate that cooling can be provided using any suitable manner of cooling and distribution of cooling apparatus.

[0046] Although the above examples have been described in the context of gases, the skilled person should appreciate that fluids can be employed.

Claims

1. An overhead recycle process apparatus (100) comprising:

a heat exchange arrangement (116, 118, 120, 146, 150, 198);
a separator (110) in fluid communication with an absorber (104) and a de-ethaniser (106), the absorber (104) having a reflux inlet port (164); and an ethane rectifier (170) in fluid communication with the de-ethaniser (106), the de-ethaniser (106) being arranged to provide cooling by heat exchange to an overhead stream path (194) of the ethane rectifier (170); and
the ethane rectifier (170) comprises a reflux drum (182) having an ethane outlet port (184) and a vapour outlet port (185) in fluid communication with the reflux inlet port (164) of the absorber (104).

2. An apparatus as claimed in Claim 1, wherein the de-

ethaniser (106) comprises a bottom product outlet port (197) arranged to provide hydrocarbon fractions having a molecular weight heavier than a molecular weight of ethane.

3. An apparatus as claimed in Claim 1 or Claim 2 or Claim 3, further comprising:

a side stream circuit (172, 174, 176, 178, 180); wherein

the de-ethaniser (106) comprises a side stream inlet port (172) and a side stream outlet port (174), the side stream outlet port (174) being disposed above the side stream inlet port (172) of the de-ethaniser (106);

the ethane rectifier (170) comprises a rectifier bottom product inlet port (176), a rectifier bottom product outlet port (178) and a bottom product reservoir (180);

the side stream circuit (172, 174, 176, 178, 180) extends from the side stream outlet port (174) into the bottom product reservoir (180) via the rectifier bottom product inlet port (176) and returns to the side stream inlet port (172) via the rectifier bottom product outlet port (178); and the side stream outlet port (174) is located at a location along the de-ethaniser (170) corresponding to an expected presence of elevated levels of ethane content in the de-ethaniser (106).

4. An apparatus as claimed in any one of the preceding claims, wherein the reflux drum (182) of the ethane rectifier (170) comprises a reflux inlet port (186) and a rectification portion (190) of the ethane rectifier (170) comprises an overhead stream outlet port (192), the overhead stream path (194) extending from the overhead stream outlet port (192) to the reflux inlet port (186) via the heat exchange arrangement (120) so as to define an ethane reflux path.

5. An apparatus as claimed in Claim 4, wherein the de-ethaniser (106) comprises a primary reflux inlet port (154), a secondary reflux inlet port (161) and an overhead stream outlet port (156); a primary de-ethaniser reflux path (158) extends from the overhead stream outlet port (156) of the de-ethaniser (106) to the primary reflux inlet port (154) of the de-ethaniser (106) via the heat exchange arrangement (118) and the separator (110); a secondary de-ethaniser reflux path (159) branching from the primary de-ethaniser reflux path (158) and extending to the secondary reflux inlet port (161) via the heat exchange arrangement (120); and the heat exchange arrangement (120) comprises an ethane reflux heat exchanger (120), the secondary de-ethaniser reflux path (159) and the ethane reflux path passing through the ethane reflux heat ex-

changer (120).

6. An apparatus as claimed in any one of the preceding claims, further comprising:

a lean gas outlet path (142);
a lean gas outlet port (144) in fluid communication with the lean gas outlet path (142); wherein the heat exchange arrangement (116, 118, 120, 146, 150, 198) comprises a first heat exchanger (116) and a second heat exchanger (118); and a compressor (112); wherein the lean gas outlet path (142) extends from an overhead stream outlet port (140) of the absorber to the lean gas outlet port (144), passing through the second heat exchanger (118) and the first heat exchanger (116); and the compressor (112) is in the lean gas outlet path (142) after the first heat exchanger (116).

7. An apparatus as claimed in Claim 6, further comprising:

a gas feed inlet port (102);
another separator (108) having an inlet port in fluid communication with the gas feed inlet port (102) via the first heat exchanger (116), the another separator (108) having a vapour outlet port and a liquid outlet port.

8. An apparatus as claimed in Claim 7, further comprising:

an expander (114) operably coupled to the compressor (112); wherein the vapour outlet port of the another separator (108) is in fluid communication with the expander (114) and the expander (114) is in fluid communication with a bottom product reservoir of the absorber (104); and the liquid outlet port of the another separator (108) is in fluid communication with a first feed inlet port (126) of the de-ethaniser (106).

9. An apparatus as claimed in Claim 6 or Claim 7 or Claim 8, further comprising:

a second feed fluid path (130) in fluid communication at one end thereof with a bottom fraction outlet port (132) of the absorber (104) and in fluid communication at another end thereof with a second feed inlet port (134) of the de-ethaniser (106); wherein the second feed fluid path (130) passes through the first heat exchanger (116).

10. An apparatus as claimed in Claim 6, when dependent upon Claim 5, wherein the separator (110) com-

prises a vapour outlet port and a liquid outlet port, the vapour outlet port being in fluid communication with the reflux inlet port (164) of the absorber (104) via the second heat exchanger (118) and the liquid outlet port being in fluid communication with the primary reflux inlet port (154) of the deethaniser (106). 5

11. An apparatus as claimed in Claim 10, wherein the overhead outlet stream port (156) of the de-ethaniser (106) is in fluid communication with an inlet port of the separator (110) via the second heat exchanger (118). 10

12. An apparatus as claimed in any one of the preceding claims, wherein 15
the de-ethaniser (106) comprises a bottom fraction reservoir (195), and a bottom fraction inlet port (196) and a bottom fraction outlet port (197) in fluid communication with the bottom fraction reservoir (195); and 20
a reboiler circuit path extends from the bottom fraction outlet port (197) and returns to the bottom fraction reservoir (195) via the bottom fraction inlet port (196), the reboiler circuit path passing through the heat exchange arrangement (198). 25

13. An apparatus as claimed in any one of Claims 1 to 11, wherein the de-ethaniser (106) comprises a heavy hydrocarbon fractions outlet port (199) for hydrocarbon fractions having a molecular weight heavier than the molecular weight of ethane. 30

14. An apparatus as claimed in Claim 6, further comprising: 35
a light fractions compression and cooling arrangement (112, 146, 148, 150) in fluid communication at a first end thereof with the lean gas outlet port (144) and at a second end thereof with the first heat exchanger (116); wherein 40
the compression and cooling arrangement (112, 146, 148, 150) comprises the compressor (112).

15. A method of overhead recycle processing of hydrocarbons, the method comprising: 45
drawing off (240) ethane from a de-ethaniser (106);
rectifying the drawn off ethane in a rectifier (170);
generating reflux (242) from an overhead stream path of the rectifier (170); and 50
introducing the reflux into a reflux drum (182) of the rectifier (170).

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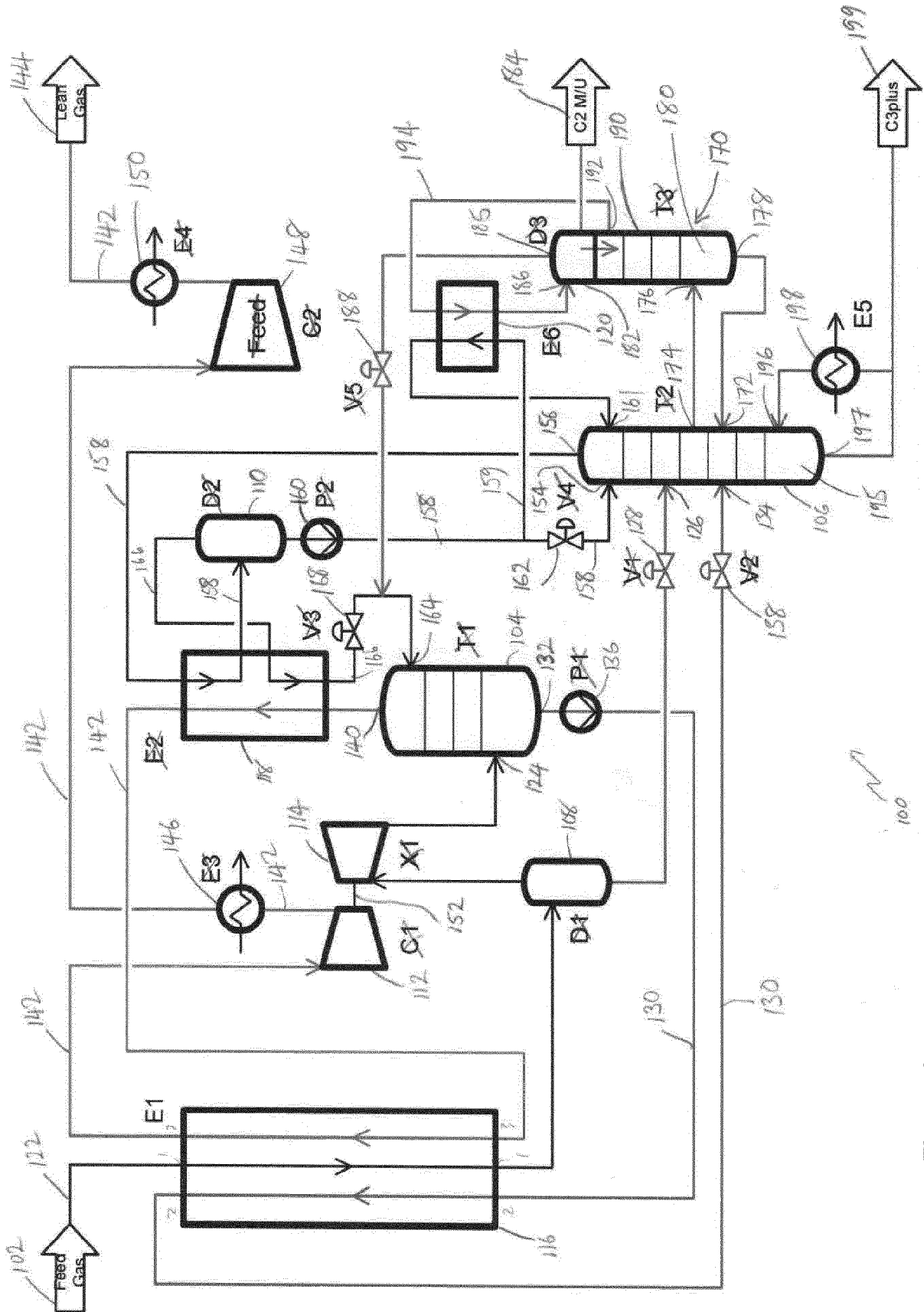
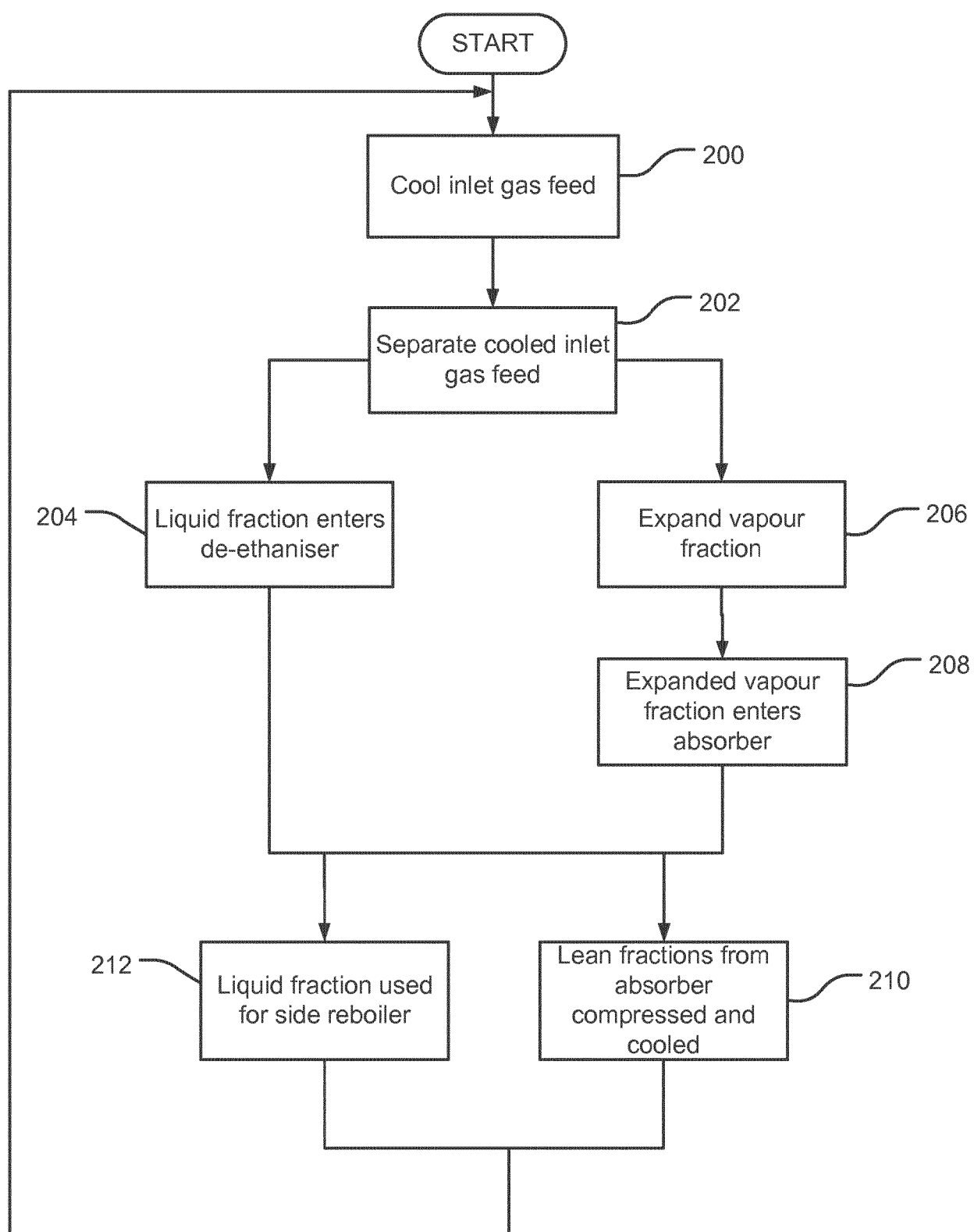
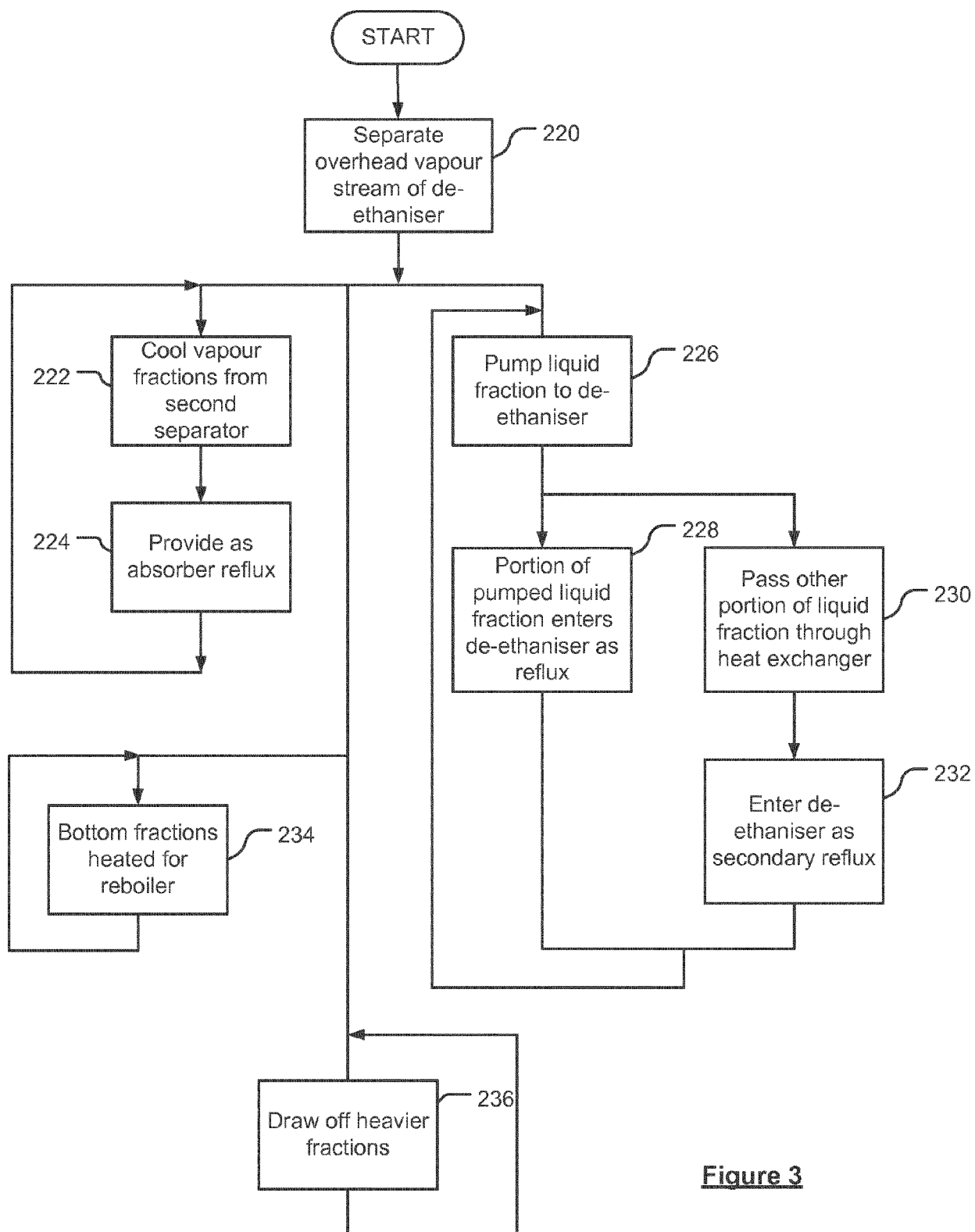


Figure 1

**Figure 2**

**Figure 3**

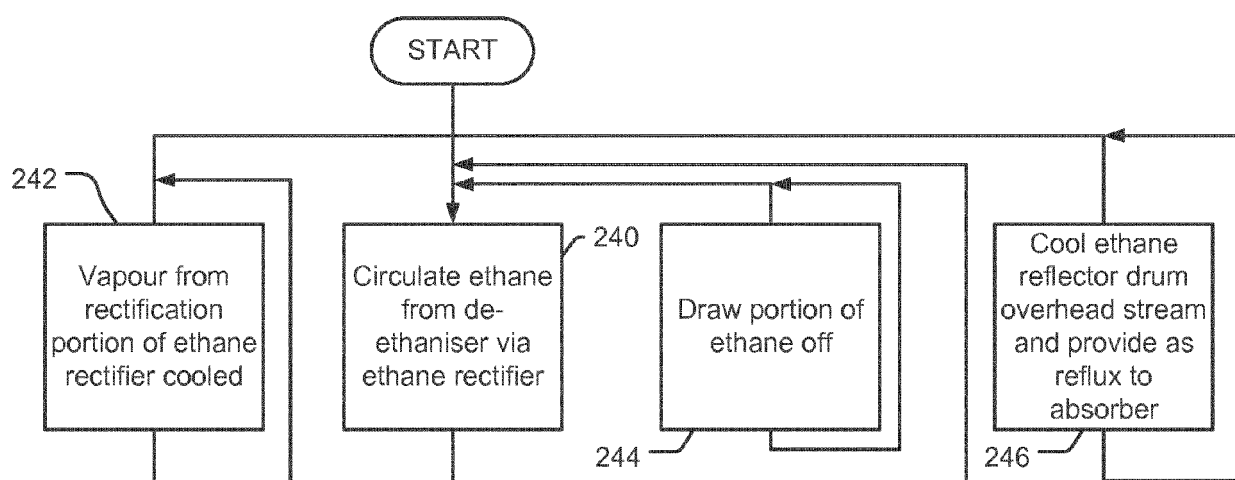


Figure 4



EUROPEAN SEARCH REPORT

Application Number
EP 17 16 4141

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 196 43 152 A1 (LINDE AG [DE]) 23 April 1998 (1998-04-23)	15	INV. F25J3/02
Y	* column 2, line 56 - column 3, line 28; figure *	1,2,4, 6-9, 12-14 3,5,10, 11	
A			
X	US 2010/011810 A1 (MAK JOHN [US] ET AL) 21 January 2010 (2010-01-21)	15	
Y	* figure 3 *	1,2,4, 6-9, 12-14 3,5,10, 11	
A			
X	US 2007/012072 A1 (QUALLS WESLEY [US] ET AL) 18 January 2007 (2007-01-18)	15	TECHNICAL FIELDS SEARCHED (IPC) F25J
A	* figures 2b,3b,4b,5b,6b,7b *	1,6,12, 14	
X	US 2011/048067 A1 (FISCHER BEATRICE [FR] ET AL) 3 March 2011 (2011-03-03)	15	
A	* paragraph [0030]; figure 1 *	1,12	
X	US 2 577 701 A (HARVEY DEMING PHILIP ET AL) 4 December 1951 (1951-12-04)	15	
A	* figures 1,2 *	3,12	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 29 September 2017	Examiner Göritz, Dirk
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 17 16 4141

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 19643152 A1	23-04-1998	NONE	
US 2010011810 A1	21-01-2010	AU 2006269696 A1 CA 2614414 A1 EA 200800270 A1 EP 1904800 A1 PE 04082007 A1 US 2010011810 A1 WO 2007008254 A1	18-01-2007 18-01-2007 28-04-2008 02-04-2008 25-04-2007 21-01-2010 18-01-2007
US 2007012072 A1	18-01-2007	AU 2006269366 A1 CN 101506605 A EA 200800296 A1 JP 5256034 B2 JP 5686755 B2 JP 2009503127 A JP 2012141128 A KR 20080033937 A KR 20130036345 A MY 152617 A PE 04672007 A1 PE 05302010 A1 US 2007012072 A1 US 2012042690 A1 WO 2007008638 A2	18-01-2007 12-08-2009 30-06-2008 07-08-2013 18-03-2015 29-01-2009 26-07-2012 17-04-2008 11-04-2013 31-10-2014 14-06-2007 20-08-2010 18-01-2007 23-02-2012 18-01-2007
US 2011048067 A1	03-03-2011	BR PI0818214 A2 EP 2205920 A2 FR 2923001 A1 RU 2010121144 A US 2011048067 A1 WO 2009087308 A2	14-06-2016 14-07-2010 01-05-2009 10-12-2011 03-03-2011 16-07-2009
US 2577701 A	04-12-1951	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 4617039 A [0002]