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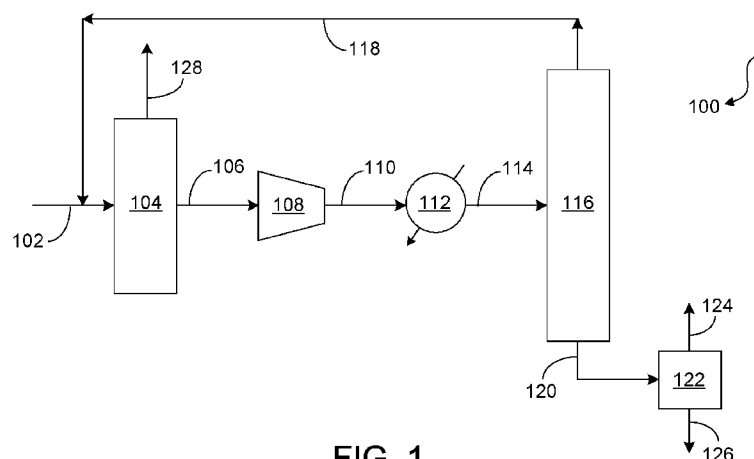


FIG. 1

(57) Abstract: Embodiments of methods and apparatuses for recovery of ethylene from FCC absorber off-gas comprising a heavy cut comprising ethylene, ethane and heavier hydrocarbons and a light cut comprising hydrogen, nitrogen and methane. An exemplary method includes passing the FCC absorber off-gas to an adsorption zone containing an adsorbent selective for the adsorption of the light cut, the adsorption zone adsorbing at least a portion of the light cut and recovering an adsorption zone effluent stream comprising the heavy cut. The adsorption zone effluent is passed to a demethanizer column to provide an overhead stream comprising hydrogen, nitrogen, methane, ethylene and ethane and a net bottoms stream comprising ethylene, ethane and the heavier hydrocarbons.

PROCESSES AND APPARATUSES FOR RECOVERY
OF ETHYLENE FROM HYDROCARBONS

STATEMENT OF PRIORITY

[0001] This application claims priority to U.S. Provisional Application No. 62/175600
5 which was filed June 15, 2015, the contents of which are hereby incorporated by reference
in its entirety.

TECHNICAL FIELD

[0002] The technical field generally relates to processes and apparatuses for recovery of
ethylene. More particularly, the technical field relates to processes and apparatuses for
10 recovery of ethylene from FCC absorber off-gas.

BACKGROUND

[0003] In a typical Fluid Catalytic Cracking (FCC) refinery, the FCC absorber off-gases
contributes to one-third of the refinery fuel gas production. The absorber off-gases typically
contain 15 to 20 mol% ethylene and ethane. These components are valuable products.
15 Mixtures of ethylene and ethane can be good feed sources for ethane cracking facility for
ethylene production. Currently most ethylene and ethane in FCC off-gas is burned instead
of recovered. Removal of ethylene and heavier components has a very large economic
benefit.

[0004] Conventionally, the primary method of recovering the FCC fuel gas ethylene and
20 ethane is through a cold box where the FCC absorber off-gas is cooled to very low
temperatures of around -120°C and then light ends are separated out through a series of
distillation columns. However, the cold boxes are capitally intensive. Further, the cold
boxes also face the problem of potential explosions from trace NO in the FCC fuel gas. NO
in the FCC absorber off-gas condenses within the cold box, followed by subsequent reaction
25 with oxygen to form heavier NO_x compounds that subsequently react with dienes to form
gums, which may explode when the cold box is warmed up. This condensation of NO is
caused by the extremely low temperatures found in a cold box in the range of -100°C to
 -120°C . This safety problem discourages companies from mixing FCC fuel gas within

existing product recovery systems even when there is extra capacity in these recovery section.

[0005] US 5,245,099 describes pressure swing adsorption (PSA) recovery of ethylene from FCC fuel gas. However, since the PSA cannot totally purify the ethylene and

5 substantial methane (around 15%) is still present, this stream would require further purification at the ethylene cracker demethanizer column if it was sent as is. The ethylene cracker demethanizer column runs very cold (-100°C) and is integrated with the cold box.

This would mean that small amounts of NO present in the feed would get very cold and condense out and still end up in the cold box with the possibility of explosive NO_x gum

10 formation if PSA recovery of ethylene from FCC Fuel gas was practiced as described in US 5,245,099.

[0006] Accordingly, it is desirable to provide apparatuses and processes for recovery of ethylene from FCC absorber off-gas in a safer and a cost-effective manner. Furthermore, other desirable features and characteristics of the present subject matter will become

15 apparent from the subsequent detailed description of the subject matter and the appended claims, taken in conjunction with the accompanying drawings and this background of the subject matter.

BRIEF SUMMARY

[0007] Various embodiments contemplated herein relate to processes and apparatuses
20 for recovery of ethylene. The exemplary embodiments taught herein recover ethylene from FCC absorber off-gas.

[0008] In accordance with an exemplary embodiment, a process is provided for the concentration and recovery of a heavy cut comprising ethylene, ethane and heavier hydrocarbons from a hydrocarbon feed stream comprising a light cut and the heavy cut, the
25 light cut comprising hydrogen, nitrogen and methane. The process includes passing the hydrocarbon feed stream to an adsorption zone containing an adsorbent selective for the adsorption of the light cut, the adsorption zone adsorbing at least a portion of the light cut and recovering an adsorption zone effluent stream comprising the heavy cut. The adsorption zone effluent is passed to a demethanizer column to provide an overhead stream comprising

hydrogen, nitrogen, methane, ethylene and ethane and a net bottoms stream comprising ethylene, ethane and the heavier hydrocarbons.

[0009] In accordance with another exemplary embodiment, a process is provided for the concentration and recovery of a heavy cut comprising ethylene, ethane and heavier

5 components from a hydrocarbon feed stream comprising a light cut and the heavy cut, the light cut comprising hydrogen, nitrogen and methane. The process includes passing the hydrocarbon feed stream to an adsorption zone containing an adsorbent selective for the adsorption of the light cut, the adsorption zone adsorbing at least a portion of the light cut and recovering an adsorption zone effluent stream comprising the heavy cut. The adsorption
10 zone effluent stream is compressed to provide a compressed adsorption zone effluent stream. The compressed adsorption zone effluent stream is cooled to provide a cooled adsorption zone effluent stream. The cooled adsorption zone effluent is passed to a demethanizer column to provide an overhead stream comprising hydrogen, nitrogen, methane, ethylene and ethane and a net bottoms stream comprising ethylene, ethane and the
15 heavier hydrocarbons. Further, the overhead stream is recycled to the adsorption zone.

[0010] In accordance with yet another exemplary embodiment, an apparatus is provided for the concentration and recovery of a heavy cut comprising ethylene, ethane and heavier hydrocarbons from a hydrocarbon feed stream comprising a light cut and the heavy cut, the light cut comprising hydrogen, nitrogen and methane. The apparatus includes an adsorption

20 zone comprising an adsorbent selective for the adsorption of the light cut, the adsorption zone configured to adsorb at least a portion of the light cut and recover an adsorption zone effluent stream comprising the heavy cut. A compressor is in fluid communication with the adsorption zone and is configured to compress the adsorption zone effluent stream to provide a compressed adsorption zone effluent stream. A cooling zone is in fluid
25 communication with the compressor and configured to cool the compressed adsorption zone effluent stream to provide a cooled adsorption zone effluent stream. A demethanizer column is in fluid communication with the cooling zone and is configured to separate an overhead stream comprising, hydrogen, nitrogen, methane, ethylene and ethane from the cooled adsorption zone effluent stream to provide a net bottoms stream comprising ethylene,
30 ethane and the heavier hydrocarbons. A recycle line extends from top of the demethanizer column to the adsorption zone for recycling the overhead stream to the adsorption zone.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The various embodiments will hereinafter be described in conjunction with the following FIGURES, wherein like numerals denote like elements.

5 [0012] FIG. 1 is a schematic diagram of a process and an apparatus for recovery of ethylene in accordance with an exemplary embodiment.

[0013] FIG. 2 is a schematic diagram of a process and an apparatus for recovery of ethylene in accordance with another exemplary embodiment.

DEFINITIONS

10 [0014] As used herein, the term “stream” can include various hydrocarbon molecules and other substances.

[0015] The notation “C_x” means hydrocarbon molecules that have “x” number of carbon atoms, C_x⁺ means hydrocarbon molecules that have “x” and/or more than “x” number of carbon atoms, and C_x⁻ means hydrocarbon molecules that have “x” and/or less than “x” number of carbon atoms.

15 [0016] As used herein, the term “zone” can refer to an area including one or more equipment items and/or one or more sub-zones. Equipment items can include one or more reactors or reactor vessels, heaters, exchangers, pipes, pumps, compressors, controllers and columns. Additionally, an equipment item, such as a reactor, dryer, or vessel, can further include one or more zones or sub-zones.

20 [0017] As used herein, the term “overhead stream” can mean a stream withdrawn at or near a top of a vessel, such as a column.

[0018] As used herein, the term “bottom stream” can mean a stream withdrawn at or near a bottom of a vessel, such as a column.

25 [0019] As depicted, process flow lines in the FIGURES can be referred to interchangeably as, e.g., lines, pipes, feeds, gases, products, discharges, parts, portions, or streams.

[0020] The term “communication” means that material flow is operatively permitted between enumerated components.

[0021] The term “downstream communication” means that at least a portion of material flowing to the subject in downstream communication may operatively flow from the object with which it communicates.

[0022] The term “upstream communication” means that at least a portion of the material flowing from the subject in upstream communication may operatively flow to the object with which it communicates.

[0023] The term “column” means a distillation column or columns for separating one or more components of different volatilities.

[0024] The term “predominant” means a majority, suitably at least 80 wt% and preferably at least 90 wt%.

DETAILED DESCRIPTION

[0025] The following detailed description is merely exemplary in nature and is not intended to limit the various embodiments or the application and uses thereof. Furthermore, there is no intention to be bound by any theory presented in the preceding background or the following detailed description.

[0026] An embodiment of a process for recovery of ethylene is addressed with reference to a process and apparatus 100 for recovery of ethylene from FCC absorber off gas as shown in FIG. 1. The apparatus and method 100 includes an adsorption zone 104, a compressor 108, a cooler 112, a demethanizer column 116 and a C₂ splitter 122. For the purpose of the explanation of the instant embodiment, the adsorption zone 104 is a pressure swing adsorption zone 104.

[0027] In accordance with the process and as shown in FIG. 1, a first hydrocarbon feed 102 is provided to the pressure swing adsorption zone 104. The first hydrocarbon feed 102 includes a heavy cut and a light cut. The heavy cut may include hydrocarbons such as ethylene, ethane, propane, propylene and other heavier hydrocarbons. The light cut may include methane and lighter gases such as hydrogen and nitrogen. Exemplary compositions of the FCC absorber off-gas which can be the hydrocarbon feed 102 of the present invention are shown in Table 1 below.

TABLE 1:
FCC fuel gas composition data for two FCC streams

	Stream #	25	31
	Description	FCCU1 (Total)	FCCU3
Component	LHV	mol%	mol%
Hydrogen	274	12.35	28.88
Methane	909	34.46	31.04
Ethane	1619	14.48	12.71
Ethylene	1499	13.95	13.96
Propane	2315	1.34	0.52
Propylene	2162	4.25	1.93
Iso-Butane	3011	1.35	0.25
n-Butane	3011	0.31	0.06
1-Butene	2876	0.46	0.09
Iso-Butene	2876	0.47	0.11
Trans-Butene	2876	0.43	0.09
Cis-Butene	2876	0.29	0.06
Butadiene	2876	0	0
iso-Pentane	3704	0.4	0.07
n-Pentane	3704	0.03	0
C6+	4404	0.08	0.06
Nitrogen	0	11.2	6.51

Carbon Dioxide	0	2.91	1.8
Carbon Monoxide	321	0.62	0.64
Hydrogen Sulfide	---	0.63	1.2
Pressure, kPa (psig)	---	1793 (260)	1793 (260)

[0028] A number of unit operations (not shown) may be performed on the hydrocarbon feed 102 prior to passing through the pressure swing adsorption zone 104 to remove undesirable impurities. The unit operations may include, but are not limited to: passing the hydrocarbon feed 102 through at least one of an amine absorber unit, a drier, an acetylene converter and one or more treaters.

[0029] Referring back to FIG. 1, the pressure swing adsorption zone 104 includes an adsorbent selective for the adsorption of the light cut. Examples of an adsorbent selective for the adsorption of the light cut include, but are not limited to, a silica gel adsorbent. The pressure swing adsorption zone 104 adsorbs at least a portion of hydrogen, nitrogen and methane present in the light cut. In an exemplary embodiment, at least 80 wt% of nitrogen and hydrogen present in the light cut is adsorbed. Further, at least 70 wt% of methane present in the light cut is adsorbed in the pressure swing adsorption zone 104. In another exemplary embodiment, at least 75 wt% of methane present in the light cut is adsorbed in the pressure swing adsorption zone 104. The portion of the light cut being adsorbed in the pressure swing adsorption zone 104 may be rejected as light ends 128.

[0030] An adsorption zone effluent stream 106 including the heavy cut is withdrawn from the pressure swing adsorption zone 104. The adsorption zone effluent stream 106 may further include the remaining amount of the light cut not adsorbed by the pressure swing adsorption zone 104. The adsorption zone effluent stream 106 may have a pressure in the range of 0.2 to 2.1 bar (g). The adsorption zone effluent stream 106 is compressed in the compressor 108 to provide a compressed adsorption zone effluent stream 110. In accordance with an embodiment, the compressor 108 may be a two-stage compressor. In one example, the compressed adsorption zone effluent stream 110 may have a pressure of at least 28 bar (g). In another example, the compressed adsorption zone effluent stream 110 may have a pressure of at least 50 bar (g). The compressed adsorption zone effluent stream

110 is passed to the cooler 112 for cooling the compressed adsorption zone effluent stream 110. In an exemplary embodiment, the compressed adsorption zone effluent stream 110 is cooled to a temperature of at least 22°F (−30°C) in the cooler 112. In another exemplary embodiment, the compressed adsorption zone effluent stream 110 is cooled to a temperature of at least 4°F (−20°C) in the cooler 112.

[0031] A cooled adsorption zone effluent stream 114 is withdrawn from the cooler 112 and passed to the demethanizer column 116. In the demethanizer column 116, the C₂[−] hydrocarbon product is fractionated, such as by conventional distillation, to provide an overhead stream 118 and a demethanized net bottoms stream 120. The overhead stream 118 includes ethylene, ethane and a remaining amount of methane, hydrogen and nitrogen that is not absorbed by the pressure swing adsorption zone 104. The overhead stream 118 is recycled to an inlet of the pressure swing adsorption zone 104. In various embodiments, the overhead stream 118 may pass through the cooler 112 prior to being recycled to the inlet of the pressure swing adsorption zone 104. The demethanizer column 116 operates at significantly warmer temperatures of at least 40°F (−40°C) in contrast to conventional teachings. In one example, the demethanizer column 116 operates at a temperature of at least −49°F (−45°C) temperature. According to the present invention, it was unexpectedly discovered that for the overhead stream 118, the demethanizer column 116 can be operated at a demethanizing temperature of greater than 40°F (−40°C), rather than the traditional cryogenic demethanizer column temperature of 40°F (−95°C). Thus, the overall ethylene separation objectives can be met without using an ethylene refrigerant system, without a significant loss of ethylene product, without significant increases in ethylene recycle, and without considerable increases in operating cost and capital cost. This permits the demethanizer column zone to be cooled with a propylene refrigerant (less than −49°C) rather than an ethylene refrigerant-based cooling system (less than −100°C) for recovering ethylene. Further, the capital cost of the cold box system is less than half of the cold box system in a traditional fractionation system design. Since traditional fractionation systems often use turbo-expanders to reach very cold temperatures, the proposed system avoids such costly and often unreliable equipment. Moreover, there is no safety issue as the instant process can separate trace NO out, which is a safety hazard for cold box.

[0032] Turning back to FIG. 1, the net bottoms stream 120 is withdrawn from the bottom of the demethanizer column 116. The net bottoms stream 120 includes ethylene, ethane and the heavier hydrocarbons. In an embodiment, the net bottoms stream 120 includes less than 1 wt% of the light cut present in the hydrocarbon feed stream 102. In another embodiment, the net bottoms stream 120 includes less than 0.03 wt% of the light cut present in the hydrocarbon feed stream 102. The net bottoms stream 120 predominantly includes ethylene and ethane. In accordance with an exemplary embodiment, the net bottoms stream 120 includes at least 85 wt% of ethylene present in the hydrocarbon feed stream 102. In accordance with another exemplary embodiment, the net bottoms stream 120 includes at least 90 wt% of ethylene present in the hydrocarbon feed stream 102.

[0033] The C₂ splitter 122 is in downstream communication with the demethanizer column 116 and is configured to recover ethylene from the net bottoms streams 120. In an exemplary embodiment, a deethanizer column (not shown) may also be present between the demethanizer column 116 and the C₂ splitter 122. In such a scenario, the net bottoms stream 120 is fractionated, such as by conventional distillation, to separate a deethanizer overhead stream comprising predominantly ethane and ethylene from a deethanized C₃⁺ bottoms stream (which may be removed from the system) and subsequently sending the deethanizer overhead stream to the C₂ splitter. The net bottoms streams 120 is sent to the C₂ splitter 122 to recover a high purity ethylene product stream (greater than 99.5 mol%).

The C₂ splitter 122 produces an overhead stream 124 including high purity ethylene stream and an ethane rich bottoms stream 126. The ethane rich bottoms stream 126, can be flashed and used to cool demethanizer feed, or a portion thereof can advantageously be recycled to the demethanizer column 116, or can alternatively be used as fuel. If the ethane is recycled back to the demethanizer column 116, the demethanizer column 116 can be changed from a refluxed and reboiled distillation column to a reboiled absorber and can be used to absorb ethylene and heavier material in the demethanizer, thus avoiding the need for a condenser and propylene refrigerant. Conditions on the C₂ splitter 122 are determined as dictated by the state of the art for these separations. The C₂ splitter 122 can include one or more reboilers, one or more side condensers and can also include pumps, drums, control valves, and other typical processing equipment that are standard in the industry.

[0034] Referring to FIG. 2, another version of the exemplary apparatus 100 is depicted with the apparatus and method 100 includes the pressure swing adsorption zone 104, an intermediate compressor 230, the compressor 108, the cooler 112, the demethanizer column 116 and the C₂ splitter 122 as described above. Many of the elements in FIG. 2 have the same configuration as in FIG. 1 and bear the same respective reference number and have similar operating conditions. Further, the temperature and pressure of various streams are similar to the corresponding streams in FIG. 1, unless specified otherwise. The hydrocarbon feed 102 passes through the compressor 108 to provide a compressed adsorption zone effluent stream 210. The compressed adsorption zone effluent stream 210 is passed to the cooler 112 for cooling.

[0035] A cooled adsorption zone effluent stream 214 is withdrawn from the cooler 112 and passed to the demethanizer column 116. The demethanizer column 116 provides an overhead stream 218 and a net bottoms stream 220. The overhead stream 218 includes ethylene, ethane, methane, hydrogen and nitrogen. The net bottoms stream 220 includes ethylene, ethane and heavier hydrocarbons. The overhead stream 218 is sent to the pressure swing adsorption zone 104. The pressure swing adsorption zone 104 includes an adsorbent selective for the adsorption of the light cut. The pressure swing adsorption zone 104 adsorbs at least a portion of hydrogen, nitrogen and methane present in the light cut of the overhead stream 218. The portion of the light cut being adsorbed in the pressure swing adsorption zone 104 may be rejected as light ends 228. In an exemplary embodiment, at least 80 wt% of nitrogen and hydrogen present in the overhead stream 218 is adsorbed. Further, at least 70 wt% of methane present in the overhead stream 218 is adsorbed in the pressure swing adsorption zone 104. In another exemplary embodiment, at least 75 wt% of methane present in the light cut is adsorbed in the pressure swing adsorption zone 104. An adsorption zone effluent stream 206 including predominantly the heavy cut is withdrawn from the pressure swing adsorption zone 104 and subsequently passed through the intermediate compressor 230. A compressed stream 232 is obtained from the intermediate compressor 230 and subsequently passed to the compressor 108, the cooler 112, the demethanizer column 116 and C₂ splitter 122 in accordance with the process steps as discussed in detail with respect to FIG. 1.

EXAMPLE

[0036] The following is an example of the ethylene recovery using a combination of pressure swing adsorption and demethanizer column, in accordance with an exemplary embodiment, that is similarly configured to the apparatus and method 100 illustrated in FIG. 1. The example is provided for illustration purposes only and is not meant to limit the various embodiments of apparatuses and methods for naphtha hydrotreating in any way.

[0037] In an exemplary case study, the instant process was applied to a FCC unit. Based on the average FCC Units absorber off-gas availability of 2000 Mscfh (57,000 m³/hr) at 275 psig (1896 kPa) delivery pressure from the FCCU Vapor Recovery Units, +/-50% erected Gulf Coast cost estimate was conducted for this recovery scheme. The total estimated installed cost was 27MM\$. The individual cost contributions for major equipment are shown in Table 2 below. The estimated capital cost was one-quarter of the cost of a new cold box.

TABLE 2:

Major Equipment Costs for UOP PSA + Warm
Demethanizer column Ethylene Recovery Unit

	Capital Cost in MM\$ installed
Pressure Swing Adsorption	8.9
Compression	7.1
Refrigeration	5
Distillation	1.7
Other	3.8

Further, the estimated utilities were:

- 3.0MW for refrigeration
- 3.9MW for compression

- 0.15MW for pumps
- 15MMBtu/h for cooling water

[0038] Based on 0.05\$/kW-h and 8000 operating hours per year, the estimated total utilities cost was 2.9MM\$/year. In summary, the overall benefit was 30MM\$/year. The payout is less than 1 year.

SPECIFIC EMBODIMENTS

[0039] 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.

[0040] A first embodiment of the invention is a process for the concentration and recovery of a heavy cut comprising ethylene, ethane and heavier hydrocarbons from a hydrocarbon feed stream comprising a light cut and the heavy cut, the light cut comprising hydrogen, nitrogen and methane, the process comprising the following steps: a) passing the hydrocarbon feed stream to an adsorption zone containing an adsorbent selective for the adsorption of the light cut, the adsorption zone adsorbing at least a portion of the light cut and recovering an adsorption zone effluent stream comprising the heavy cut; and b) passing the adsorption zone effluent to a demethanizer column to provide an overhead stream comprising hydrogen, nitrogen, methane, ethylene and ethane and a net bottoms stream comprising ethylene, ethane and the heavier hydrocarbons. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising recycling the overhead stream to the adsorption zone. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising sending the net bottoms stream to a C₂ splitter for recovery of ethylene. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the adsorption zone adsorbs at least 70% of methane present in the light cut. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the adsorption zone adsorbs at least 80% of each of hydrogen and nitrogen present in the light cut. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up

through the first embodiment in this paragraph, wherein the demethanizer column operates at a demethanizing temperature at least -49°F (-45°C). An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the adsorption zone effluent stream is compressed prior to being passed to the demethanizer column. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the adsorption zone effluent stream is compressed to a pressure of at least 28 bar (g). An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the adsorption zone effluent stream is cooled subsequent to the compression and prior to being passed to the demethanizer column. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the adsorption zone effluent stream is cooled to a temperature of at least -22°F (-30°C). An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the net bottoms stream comprises less than 1 wt% of the light cut present in the hydrocarbon feed stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the net bottoms stream comprises at least 85 wt% ethylene present in the hydrocarbon feed stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the adsorbent selective for the adsorption of the light cut comprises a silica gel adsorbent.

[0041] A second embodiment of the invention is a process for the concentration and recovery of a heavy cut comprising ethylene, ethane and heavier hydrocarbons from a hydrocarbon feed stream comprising a light cut and the heavy cut, the light cut comprising hydrogen, nitrogen and methane, the process comprising the following steps a) passing the hydrocarbon feed stream to an adsorption zone containing an adsorbent selective for the adsorption of the light cut, the adsorption zone adsorbing at least a portion of the light cut and recovering an adsorption zone effluent stream comprising the heavy cut; b) compressing the adsorption zone effluent stream to provide a compressed adsorption zone effluent stream; c) cooling the compressed adsorption zone effluent stream to provide a cooled adsorption zone effluent stream; d) passing the cooled adsorption zone effluent to a

demethanizer column to provide an overhead stream comprising hydrogen, nitrogen, methane, ethylene and ethane and a net bottoms stream comprising ethylene, ethane and the heavier hydrocarbons; and e) recycling the overhead stream to the adsorption zone. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up
5 through the second embodiment in this paragraph further comprising sending the net bottoms stream to a C₂ splitter for recovery of ethylene. 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 demethanizer column operates at a demethanizing temperature at least 49°F (−45°C). An embodiment of the invention is one, any or all of prior
10 embodiments in this paragraph up through the second embodiment in this paragraph, wherein the net bottoms stream comprises less than 1 wt% of the light cut present in the hydrocarbon feed stream. 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 net bottoms stream comprises at least 85 wt% of ethylene present in the
15 hydrocarbon feed stream.

[0042] A third embodiment of the invention is an apparatus for the concentration and recovery of a heavy cut comprising ethylene, ethane and heavier hydrocarbons from a hydrocarbon feed stream comprising a light cut and the heavy cut, the light cut comprising hydrogen, nitrogen and methane, the apparatus comprising a) an adsorption zone
20 comprising an adsorbent selective for the adsorption of the light cut, the adsorption zone configured to adsorb at least a portion of the light cut and recover an adsorption zone effluent stream comprising the heavy cut; b) a compressor in fluid communication with the adsorption zone and configured to compress the adsorption zone effluent stream to provide a compressed adsorption zone effluent stream; c) a cooling zone in fluid communication
25 with the compressor and configured to cool the compressed adsorption zone effluent stream to provide a cooled adsorption zone effluent stream; d) a demethanizer column in fluid communication with the cooling zone and configured to separate an overhead stream comprising, hydrogen, nitrogen, methane, ethylene and ethane from the cooled adsorption zone effluent stream to provide a net bottoms stream comprising ethylene, ethane and the
30 heavier hydrocarbons; and e) a recycle line extending from top of the demethanizer column to the adsorption zone for recycling the overhead stream to the adsorption zone. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up

through the third embodiment in this paragraph further comprising a C₂ splitter in fluid communication with the demethanizer column configured to recover ethylene from the net bottoms streams.

[0043] Without further elaboration, it is believed that using the preceding description that one skilled in the art can utilize the present invention to its fullest extent and easily
5 ascertain the essential characteristics of this invention, without departing from the spirit and scope thereof, to make various changes and modifications of the invention and to adapt it to various usages and conditions. The preceding preferred specific embodiments are, therefore, to be construed as merely illustrative, and not limiting the remainder of the disclosure in any
10 way whatsoever, and that it is intended to cover various modifications and equivalent arrangements included within the scope of the appended claims.

CLAIMS

1. A process for the concentration and recovery of a heavy cut comprising ethylene, ethane and heavier hydrocarbons from a hydrocarbon feed stream comprising a light cut and the heavy cut, the light cut comprising hydrogen, nitrogen and methane, the
5 process comprising the following steps:

a) passing the hydrocarbon feed stream to an adsorption zone containing an adsorbent selective for the adsorption of the light cut, the adsorption zone adsorbing at least a portion of the light cut and recovering an adsorption zone effluent stream comprising the heavy cut; and

10 b) passing the adsorption zone effluent to a demethanizer column to provide an overhead stream comprising hydrogen, nitrogen, methane, ethylene and ethane and a net bottoms stream comprising ethylene, ethane and the heavier hydrocarbons.

2. The process of claim 1 further comprising recycling the overhead stream to the adsorption zone.

15 3. The process of claim 1 further comprising sending the net bottoms stream to a C2 splitter for recovery of ethylene.

4. The process of claim 1, wherein the adsorption zone adsorbs at least 70% of methane present in the light cut.

20 5. The process of claim 1, wherein the adsorption zone adsorbs at least 80% of each of hydrogen and nitrogen present in the light cut.

6. The process of claim 1, wherein the adsorption zone effluent stream is compressed prior to being passed to the demethanizer column.

7. The process of claim 6, wherein the adsorption zone effluent stream is cooled subsequent to the compression and prior to being passed to the demethanizer column.

25 8. The process of claim 1, wherein the net bottoms stream comprises less than 1 wt% of the light cut present in the hydrocarbon feed stream and comprises at least 85 wt% of ethylene present in the hydrocarbon feed stream.

9. An apparatus for the concentration and recovery of a heavy cut comprising ethylene, ethane and heavier hydrocarbons from a hydrocarbon feed stream comprising a

light cut and the heavy cut, the light cut comprising hydrogen, nitrogen and methane, the apparatus comprising:

- 5 a) an adsorption zone comprising an adsorbent selective for the adsorption of the light cut, the adsorption zone configured to adsorb at least a portion of the light cut and recover an adsorption zone effluent stream comprising the heavy cut;
- b) a compressor in fluid communication with the adsorption zone and configured to compress the adsorption zone effluent stream to provide a compressed adsorption zone effluent stream;
- 10 c) a cooling zone in fluid communication with the compressor and configured to cool the compressed adsorption zone effluent stream to provide a cooled adsorption zone effluent stream;
- d) a demethanizer column in fluid communication with the cooling zone and configured to separate an overhead stream comprising, hydrogen, nitrogen, methane, ethylene and ethane from the cooled adsorption zone effluent stream to provide a net
15 bottoms stream comprising ethylene, ethane and the heavier hydrocarbons; and
- e) a recycle line extending from top of the demethanizer column to the adsorption zone for recycling the overhead stream to the adsorption zone.

10. The apparatus of claim 9 further comprising a C2 splitter in fluid communication with the demethanizer column configured to recover ethylene from the net bottoms streams.

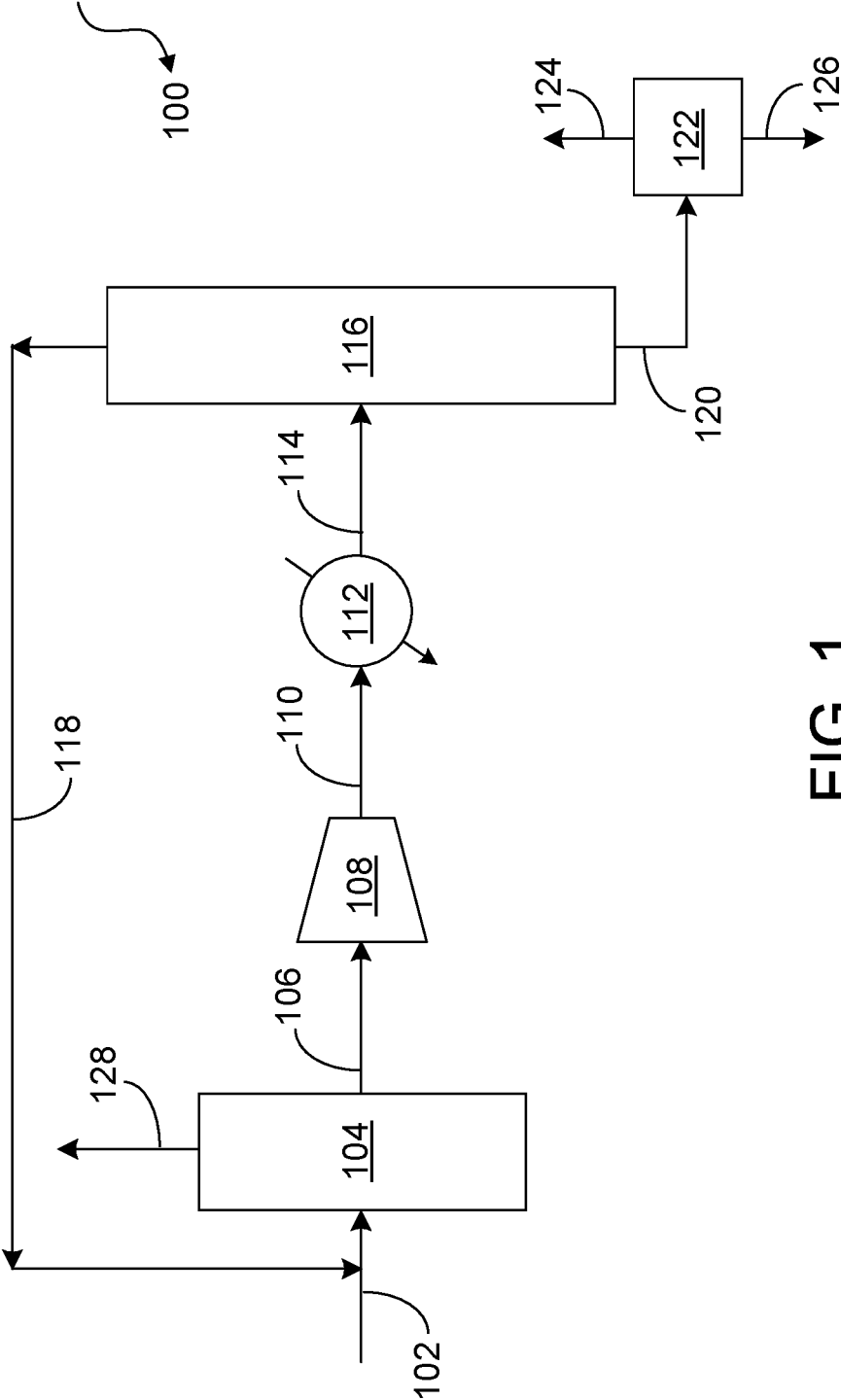


FIG. 1

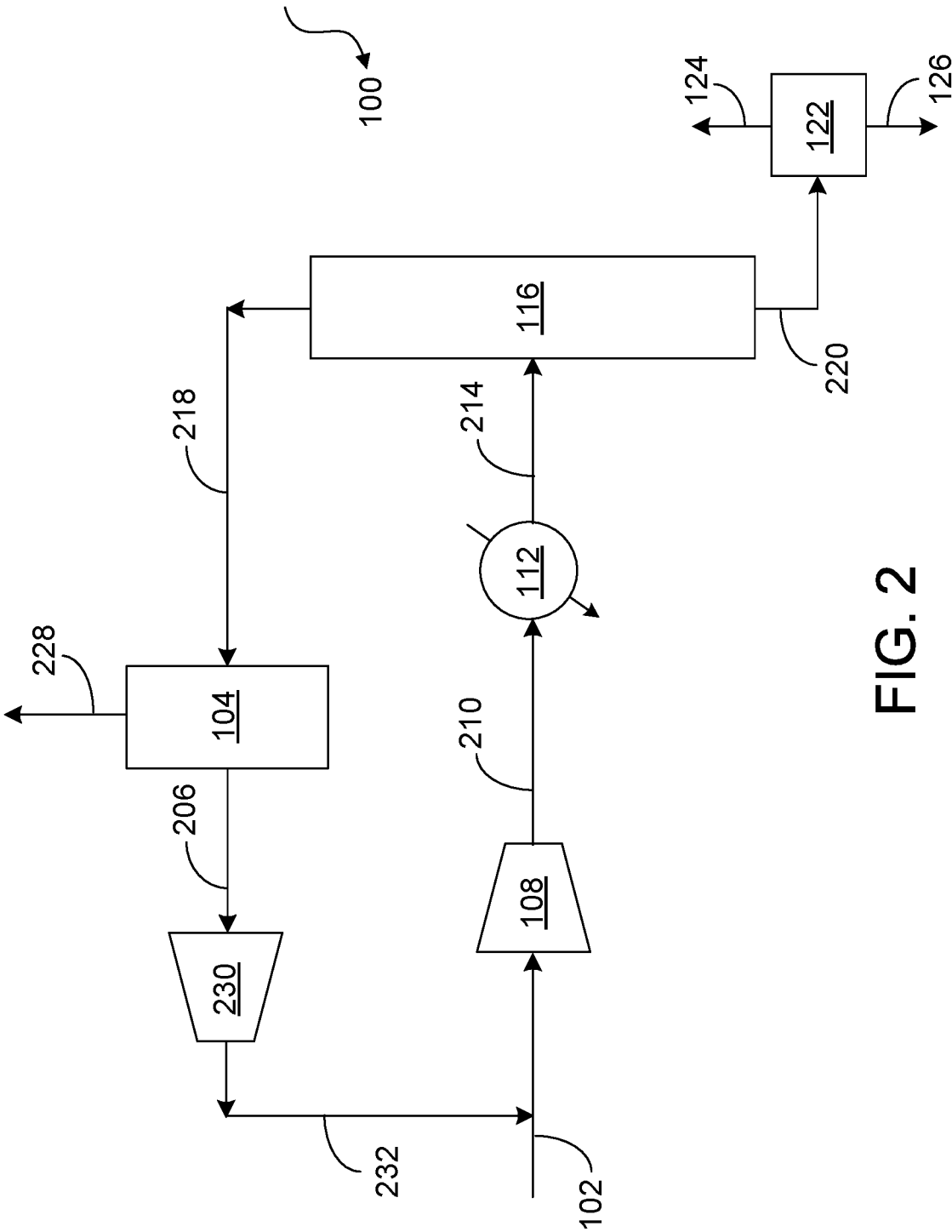


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2016/035427

A. CLASSIFICATION OF SUBJECT MATTER		
<i>C07C 7/12 (2006.01)</i> <i>C07C 11/04 (2006.01)</i> <i>B01D 53/04 (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)		
C07C 7/12, 11/04, B01D 53/04, 53/047, C07L 3/10,		
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)		
PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2011/068642 A2 (UOP LLC et al.) 09.06.2011, p. 5-11, claims, table 2	1-10
Y	WO 2012/166323 A2 (UOP LLC et al.) 06.12.2012, claims, examples, drawings	1-10
Y	US 5744687 A (THE BOC GROUP, INC.) 28.04.1998, drawings, col. 6-10	7, 9-10
Y	US 5993516 A (BG PLC) 30.11.1999, claims, examples	9-10
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents:	“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
“A” document defining the general state of the art which is not considered to be of particular relevance	“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
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“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	“&”	document member of the same patent family
“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		
Date of the actual completion of the international search	Date of mailing of the international search report	
01 August 2016 (01.08.2016)	13 October 2016 (13.10.2016)	
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37	Authorized officer E. Guseva Telephone No. 8-499-240-25-91	