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(81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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(54) **Title:** PROCESS AND ADSORBENT FOR REMOVAL OF DIOLEFINS AND OTHER CONTAMINANTS FROM LIQUEFIED PETROLEUM GAS

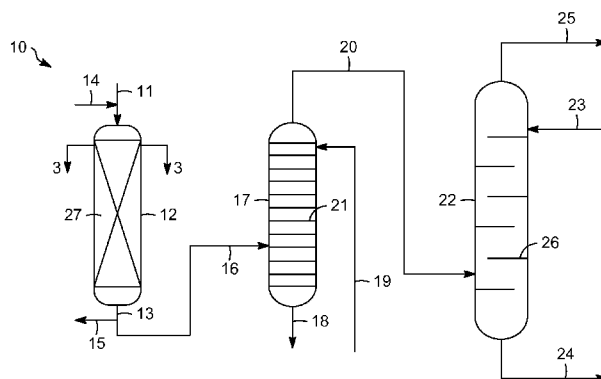


FIG. 1

(57) **Abstract:** A process and an apparatus for reducing the diolefin and oxygenate content of liquefied petroleum gas are disclosed. A first conduit is in fluid communication with a liquefied hydrocarbon source and a vessel. The vessel includes a solid adsorbent disposed on a support. The adsorbent is suitable for adsorbing diolefins and oxygenates. A second conduit is in fluid communication with the vessel for receiving the liquefied hydrocarbons of reduced diolefin and oxygenate content from the vessel. A steam inlet conduit is in fluid communication with a steam source and the vessel for treating the solid adsorbent containing adsorbed diolefins and oxygenates with steam to desorb the diolefins and oxygenates from the solid adsorbent. An amine absorber unit for reducing the hydrogen disulfide content of the liquefied hydrocarbon can be in fluid communication with the vessel.

PROCESS AND ADSORBENT FOR REMOVAL OF DIOLEFINS AND
OTHER CONTAMINANTS FROM LIQUEFIED PETROLEUM GAS

PRIORITY CLAIM OF EARLIER NATIONAL APPLICATION

[0001] This application claims priority to U.S. Application No. 14/100,971 filed

5 December 9, 2013.

BACKGROUND

[0002] This invention generally relates to a pretreatment process for liquefied petroleum gas. One of the products of fluid catalytic cracking (FCC) is liquefied petroleum gas (LPG). LPG, which generally comprises 3 and 4 carbon alkanes and alkenes, often contains
10 impurities in the form of sulfur containing compounds such as hydrogen sulfide and mercaptans. In the oil refining industry, it is conventional practice to treat sour hydrocarbon streams to remove these sulfur species. Extraction processes are typically used when treating light hydrocarbons for hydrogen sulfide and mercaptan removal. Mercaptans have
15 traditionally been removed from hydrocarbon streams because of their malodorous scent and contribution to product total sulfur.

[0003] In a typical configuration, a liquid LPG stream is fed to an amine absorber column to be contacted with an amine, such as diethanolamine (DEA) or methyldiethanol amine (MDEA), to absorb acid gases such as hydrogen sulfide and carbon dioxide. The LPG lean of hydrogen sulfide and other acid gases is then sent on for further treating to remove mercaptan
20 sulfur compounds before it is sent to product storage or a downstream processing unit.

[0004] LPG derived from high severity, high propylene FCC units contains higher concentrations of diolefins and other impurities (such as oxygenates), which have been found to contribute to foaming in the amine absorber. Removal of these materials is envisioned as a pretreatment solution to eliminate these impurities and resolve foaming issues that would
25 otherwise occur during the amine absorption process. However, modification of the upstream process can have a strong impact on the overall process and on the operating costs.

[0005] Therefore, a process is needed to remove impurities upstream of the amine absorber without disturbing the overall LPG treating operation.

SUMMARY

[0006] One embodiment of the present disclosure relates to the adsorption of the diolefin and oxygenate impurities in a pretreatment vessel containing a packing material such as a monolith washcoated with an appropriate adsorbent material. Monoliths, or monolithic structures, are a solid structure that includes a number of channels, often parallel with each other. The cross-sectional shape of the channel may be circular, hexagonal, square, triangular or sinusoidal. Monoliths are useful structures for a number of applications as they can be coated with materials such as catalysts or adsorbents. Some applications of monoliths include automobile catalytic converters, catalytic combustion, electrochemical reactors, biochemical reactors and the like. In order to coat, or washcoat, the honeycomb-like structure of the monolith, a slurry will be prepared containing the adsorbent material as well as a binder to promote adherence of the adsorbent to the internal walls of the channels of the monolith.

[0007] It is therefore an advantage of the invention to provide a process to remove contaminants upstream of an amine absorber without disturbing an overall liquefied petroleum gas treating operation.

[0008] These and other features, aspects, and advantages of the present invention will become better understood upon consideration of the following detailed description, drawings and appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a schematic of an LPG treatment unit comprising an LPG pretreatment vessel containing the monolith, an amine absorber, and a mercaptan extractor.

[0010] FIG. 2 is an alternate embodiment of the LPG treatment unit comprising a second LPG pretreatment vessel containing the monolith.

[0011] FIG. 3 is a cross-section taken along the line 3-3 of FIG. 1.

[0012] FIG. 4 is an enlarged view of FIG. 3.

[0013] Like reference numerals will be used to refer to like parts from Figure to Figure in the following description of the drawings.

DETAILED DESCRIPTION

[0014] A general understanding of the process and apparatus of this invention can be obtained by reference to the Figures. The Figures have been simplified by the deletion of a

large number of apparatuses customarily employed in a process of this nature, such as vessel internals, temperature and pressure controls systems, flow control valves, circulation pumps, etc. which are not specifically required to illustrate the performance of the invention.

Furthermore, the illustration of the process of this invention in the embodiment of a specific drawing is not intended to limit the invention to specific embodiments set out herein. Lastly, although a process for pretreatment of LPG is illustrated by way of an example, other LPG pretreatment schemes are contemplated.

[0015] FIG. 1 illustrates a unit operation 10 for the treatment of a liquefied petroleum gas (LPG) stream. Referring to FIG.1, a hydrocarbon liquid stream such as LPG containing diolefins and oxygenates in addition to mercaptan sulfur and hydrogen sulfide is fed through a line 11 to a pretreatment vessel 12. The pretreatment vessel 12 contains a packing material 27 which comprises an adsorbent 34 deposited on a solid support 33 as depicted in Figures 3-4 in greater detail. The hydrocarbon stream can pass over the packing material 27 and exit the pretreatment vessel 12 through a line 13.

[0016] Over time, the packing material 27 in the pretreatment vessel 12 will have adsorbed a significant amount of the diolefin and oxygenate impurities and will need to be regenerated. This regeneration process can be accomplished by contacting the packing material with a regenerative gas such as steam. A steam source is in fluid communication with the pretreatment vessel 12 by way of a steam inlet conduit 14. Steam that has contacted the packing material 27 can then exit the vessel by way of a steam outlet conduit 15.

[0017] After exiting the pretreatment vessel 12, the hydrocarbon stream with a reduced diolefin and oxygenate content can be sent to an amine absorber vessel 17 to reduce the amount of hydrogen sulfide in the hydrocarbon stream. The hydrocarbon stream enters the amine absorber 17 through a line 16. Amines such as diethanolamine (DEA), methyldiethanolamine (MDEA), or others are fed to the amine absorber vessel 17 through a line 19. The amine absorber vessel 17 contains a series of liquid-liquid contacting trays 21. The line 16 delivering the hydrocarbon stream has an inlet distributor that is above the bottom feed tray of vessel 17. Amine enters at the top tray of vessel 17 via line 19 to allow counter-current contact of the amine descending down and the hydrocarbon ascending up the vessel 17. The amine in vessel 17 reacts with hydrogen sulfide to yield amine sulfide salts. Typically, hydrogen sulfide content of a hydrocarbon stream is reduced down to 50 wppm or less. An amine effluent stream rich in acid gas exits the bottom of the amine absorber vessel 17 through a line 18 while the hydrocarbon effluent stream exits the top of the amine

absorber vessel 17 through a line 20 with a substantially reduced concentration of hydrogen sulfide. Additionally, carbon dioxide or other acid gases that are possibly present in the feed stream in the line 16 also react with the amines and are absorbed into the amine effluent stream leaving the amine absorber vessel 17 through the line 18.

5 [0018] The hydrocarbon effluent from the amine absorber vessel 17 enters an extraction vessel 22 through the line 20. The purpose of this vessel is to remove mercaptan sulfur compounds from the hydrocarbon stream. An alkaline solution rich in mercaptans is withdrawn from the extraction vessel 22 through a line 24. Fresh or regenerated alkaline in a line 23 is continuously fed to the extraction vessel 22. Mercaptans in the extraction vessel 22
10 react with the an alkaline solution (e.g., sodium hydroxide) to yield sodium mercaptides and water. The lower density hydrocarbons rise to the top of the extraction vessel 22 while the aqueous alkaline containing dissolved mercaptides flows to the bottom of the extraction vessel 22. Treated hydrocarbon substantially devoid of mercaptans and mercaptides exits the extraction vessel 22 via a product line 25. Alkaline rich in mercaptides is withdrawn through
15 a line 24.

[0019] FIG. 2 shows an alternate embodiment of the LPG treatment unit 40 comprising a second pretreatment vessel 28 which also contains the packing material 27. The advantage of a second pretreatment vessel 28 is the ability to direct the hydrocarbon stream from line 11 into either the first pretreatment vessel 12 through the line 37 or the second pretreatment
20 vessel 28 through the line 36. A control valve 32 can be used to determine to which downstream line the hydrocarbon stream in line 11 flows. Furthermore, a steam source is in fluid communication with both the first pretreatment vessel 12 by way of steam inlet conduit 14 and the second pretreatment vessel 28 by way of steam inlet conduit 29. Steam outlet conduit 15 and steam outlet conduit 30 allow for steam to leave pretreatment vessel 12 and
25 pretreatment vessel 28, respectively.

[0020] FIG. 3 is a cross-section taken along the line 3-3 of FIG. 1. FIG. 3 shows the internals of a pretreatment vessel 12 according to the invention in greater detail. The pretreatment vessel 12 contains a packing material 27 that extends across the entire cross-sectional area of the pretreatment vessel 12 and contacts the inner wall of the pretreatment
30 vessel 12. The packing material, as seen in greater detail in FIG. 4, is comprised primarily of an adsorbent 34 disposed on a solid support 33. In one embodiment of the present invention, the support material is a monolithic support comprised of cordierite. In another embodiment, the monolithic support is comprised of straight parallel microcells. Regarding the adsorbent,

the material must be capable of adsorbing diolefins and oxygenates from the hydrocarbon stream. Examples of adsorbents that are suitable for the present invention include zeolites such as ZSM-5, ZSM-11, ZSM-12, ZSM-23, ZSM-35, ZSM-38, ZSM-48, metal organic frameworks, and alumina.

5 [0021] If a monolithic form of support is desired, the adsorbent is applied to the monolithic form as a thin film or coating deposited on the monolith. The inert monolithic carrier can be comprised of any inert material which provides the structural support for the adsorbent. Usually this material can be any refractory material such as ceramic or metallic materials. It is desirable that the carrier material be unreactive with the adsorbent and
10 adsorbent components and not be degraded by the hydrocarbon to which it is exposed. Examples of suitable ceramic support materials include sillimanite, petalite, cordierite, mullite, zircon, zircon mullite, spodumene, alumina-titanate, etc. Metallic materials which are within the scope of this invention include metals and alloys that have an oxide layer such as steel having an alumina layer protecting the steel substrate against oxidation attack. Suitable
15 monoliths may be obtained from Corning Incorporated of Corning, New York and from Lexco, Inc. of Hudson, Ohio.

[0022] The support material 33 can best be utilized in any rigid unitary configuration which provides a plurality of pores or channels extending in the direction of gas flow. It is preferred that the configuration be a honeycomb configuration. The honeycomb structure can
20 be used advantageously in either unitary form, or as an arrangement of multiple modules. The honeycomb structure is usually oriented such that hydrocarbon flow is generally in the same direction as the cells or channels of the honeycomb structure. The adsorbent is deposited onto the support material 33 by any convenient way well known in the art. A preferred method involves preparing a slurry of the adsorbent and a binder, and coating the monolithic
25 honeycomb carrier with the slurry. The adsorbent should be 10 to 30 wt% of the slurry and preferably 20 to 25 wt% of the slurry. The binder may comprise an alumina, silica or a zirconia.

[0023] The slurry can be prepared by means known in the art. An inorganic slurry can be prepared by combining the appropriate amount of the adsorbent and binder with water and a
30 peptizing agent that may be an acid such as nitric acid. Twenty five to thirty five parts of water to one part of acid will be sufficient. Alternatively, sols of alumina, silica or zirconia may be mixed with the adsorbent and a peptizing agent acid to provide the inorganic slurry. Additionally, inorganic salts such as aluminum chloride, and/or hydrolysis products or

hydroxides of aluminum, silica or zirconium may be mixed with the adsorbent to provide the slurry. An organic slurry can include an organic polymer such as Methocel, organic salts of aluminum such as co-alkyl aluminum, silica or zirconium or organic silicates that are hydrolyzable to silica may be mixed with the adsorbent. Mixtures of the described binders are also contemplated.; organic silicates that are hydrolyzable to silica; and mixtures thereof.

[0024] This mixture is then blended by using means such as sonification, milling, or another suitable method to provide the slurry. This slurry may be used to wash coat a monolithic honeycomb by dipping the honeycomb into the slurry and removing the excess slurry by draining or blowing out the channels. The desired slurry of adsorbent material may be deposited onto the support in any suitable manner well known in the art. In some embodiments, the adsorbent material 34 is disposed on the solid support 33 by brushing or spraying the liquid slurry of adsorbent onto the walls of the support.

[0025] The coated support is heated to 100 to 120°C to dry the coated support. The dried support should then be calcined at over 600°C to bond the adsorbent to the support or to decompose the organic material from the support. If the desired loading of support is not achieved, the above process may be repeated as many times as required to achieve the desired loading.

[0026] The process of disposing of the adsorbent material 34 onto the solid support 33 leaves channels 35 through which the hydrocarbon stream may flow. The channels 35 allow for the hydrocarbon stream to contact the adsorbent material 34 within the pretreatment vessel 12. This arrangement assures adequate contact between the hydrocarbon and the adsorbent in order to efficiently adsorb diolefins and oxygenate contaminants from the hydrocarbon stream.

[0027] In general, the pretreatment vessel 12 may have a diameter of 30 cm (1 foot) to 762 cm (25 feet). Preferably, the diameter is 61 cm (2 feet) to 457 cm (15 feet). More preferably, the diameter is 91 cm (3 feet) to 366 cm (12 feet). Ideally, the diameter is 107 cm (3.5 feet) to 305 cm (10 feet). In general, the pretreatment vessel 12 may have a height of 152 cm (5 feet) to 76.2 m (250 feet). Preferably, the height is 305 cm (10 feet) to 45.7 m (150 feet). More preferably the height is 457 cm (15 feet) to 30.5 m (100 feet). Ideally, the height is 610 cm (20 feet) to 15.2 m (50 feet).

[0028] In some embodiments of the present invention, the microcells of the solid support have 650 to 3900 cells per cm² (100 to 600 cells per square inch). Preferably, the microcells of the solid support have 1300 to 2600 cells per cm² (200 to 400 cells per square inch).

Ideally the microcells of the solid support have 1950 to 3250 cells per cm² (300 to 500 cells per square inch).

[0029] Although the invention has been described in considerable detail with reference to certain embodiments, one skilled in the art will appreciate that the present invention can be practiced by other than the described embodiments, which have been presented for purposes of illustration and not of limitation. Therefore, the scope of the appended claims should not be limited to the description of the embodiments contained herein.

SPECIFIC EMBODIMENTS

[0030] 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.

[0031] A first embodiment of the invention is a process for reducing the diolefin and oxygenate content of a liquefied C₂-C₅ hydrocarbon, the process comprising feeding the liquefied hydrocarbon to a vessel containing a solid adsorbent disposed on a support thereby adsorbing the diolefins and oxygenates on the adsorbent. 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 treating the solid adsorbent containing adsorbed diolefins and oxygenates with steam to separate the adsorbed diolefins and oxygenates from the solid adsorbent. 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 solid adsorbent is a zeolite. 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 solid adsorbent is a metal organic framework. 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 solid adsorbent is alumina. 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 support is a monolithic support. 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 monolithic support is cordierite. 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 monolithic support comprises straight parallel microcells. 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 solid adsorbent is disposed on the microcells of the monolithic support by forming a slurry comprising the adsorbent and wash coating the microcells with the slurry. An embodiment of the invention is one, any or all of prior
5 embodiments in this paragraph up through the first embodiment in this paragraph, further comprising passing the liquefied hydrocarbon of reduced diolefin and deoxygenate content to an amine absorber unit, wherein the amine absorber unit reduces the hydrogen disulfide content of the liquefied hydrocarbon.

[0032] A second embodiment of the invention is an apparatus for reducing the diolefin and oxygenate content of a liquefied C₂-C₅ hydrocarbon, the apparatus comprising a first
10 conduit in fluid communication with a liquefied hydrocarbon source and a vessel, the vessel comprising solid adsorbent disposed on a support, the adsorbent suitable for adsorbing diolefins and oxygenates; and a second conduit in fluid communication with the vessel for receiving the liquefied hydrocarbons of reduced diolefin and oxygenate content from the
15 vessel. 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 a steam inlet conduit in fluid communication with a steam source and the vessel for treating the solid adsorbent containing adsorbed diolefins and oxygenates with steam to desorb the diolefins and oxygenates from the solid adsorbent; and a steam outlet conduit in fluid communication
20 with the vessel for removing steam from the vessel. 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 solid adsorbent is a zeolite. 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 solid adsorbent is a metal organic framework. An embodiment of the
25 invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, wherein the solid adsorbent is selected from alumina and cordierite. 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 support is a monolithic support. An embodiment of the invention is one, any or all of prior embodiments
30 in this paragraph up through the second embodiment in this paragraph, wherein the monolithic support comprises straight parallel microcells. 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 an amine absorber unit for reducing the hydrogen disulfide

content of the liquefied hydrocarbon, the amine absorber unit being in fluid communication with the vessel.

[0033] A third embodiment of the invention is an apparatus for reducing the diolefin and oxygenate content of a liquefied C₂-C₅ hydrocarbon, the apparatus comprising a first conduit in fluid communication with a liquefied hydrocarbon source and a vessel, the vessel comprising solid adsorbent disposed on a support, the adsorbent suitable for adsorbing diolefins and oxygenates; a second conduit in fluid communication with the vessel for receiving the liquefied hydrocarbons of reduced diolefin and oxygenate content from the vessel; and a second vessel in fluid communication with the liquefied hydrocarbon source, the steam inlet conduit and the steam outlet conduit, the second vessel comprising the solid adsorbent disposed on a support thereby to adsorb the diolefins and oxygenates. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph, wherein the liquefied hydrocarbon source can be passed to either the first vessel or the second vessel to allow for the vessel that is not in contact with the liquefied hydrocarbon to be regenerated by contacting the solid adsorbent in the vessel with steam.

[0034] Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The preceding preferred specific embodiments are, therefore, to be construed as merely illustrative, and not limitative of the remainder of the disclosure in any way whatsoever.

[0035] In the foregoing, all temperatures are set forth in degrees Celsius and, all parts and percentages are by weight, unless otherwise indicated.

[0036] From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention and, without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions.

CLAIMS:

1. A process for reducing the diolefin and oxygenate content of a liquefied C₂-C₅ hydrocarbon, the process comprising feeding the liquefied hydrocarbon to a vessel containing a solid adsorbent disposed on a support thereby adsorbing the diolefins and oxygenates on the
5 adsorbent.

2. The process of claim 1, further comprising treating the solid adsorbent containing adsorbed diolefins and oxygenates with steam to separate the adsorbed diolefins and oxygenates from the solid adsorbent.

3. The process of claim 1, wherein the solid adsorbent is a zeolite.

10 4. The process of claim 1, wherein the solid adsorbent is a metal organic framework.

5. The process of claim 1, wherein the solid adsorbent is alumina.

6. The process of claim 1, wherein the support is a monolithic support.

7. The process of claim 6, wherein the monolithic support is cordierite.

8. The process of claim 6, wherein the monolithic support comprises straight parallel
15 microcells.

9. The process of claim 6, wherein the solid adsorbent is disposed on the microcells of the monolithic support by forming a slurry comprising the adsorbent and wash coating the microcells with the slurry.

10. An apparatus for reducing the diolefin and oxygenate content of a liquefied C₂-C₅ hydrocarbon, the apparatus comprising:
20

a first conduit in fluid communication with a liquefied hydrocarbon source and a vessel, the vessel comprising solid adsorbent disposed on a support, the adsorbent suitable for adsorbing diolefins and oxygenates;

25 a second conduit in fluid communication with the vessel for receiving the liquefied hydrocarbons of reduced diolefin and oxygenate content from the vessel.

a steam inlet conduit in fluid communication with a steam source and the vessel for treating the solid adsorbent containing adsorbed diolefins and oxygenates with steam to desorb the diolefins and oxygenates from the solid adsorbent; and

30 a steam outlet conduit in fluid communication with the vessel for removing steam from the vessel.

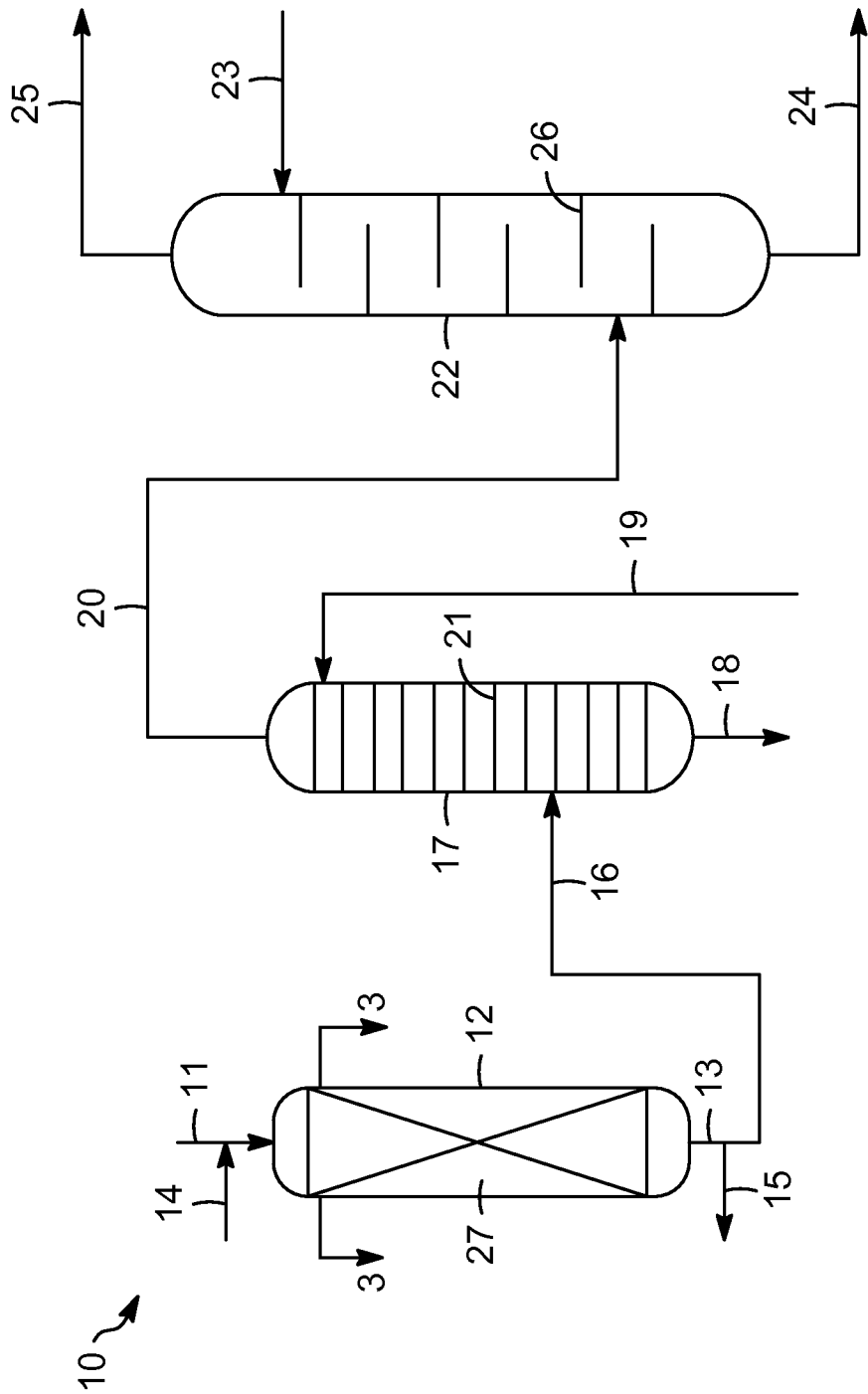


FIG. 1

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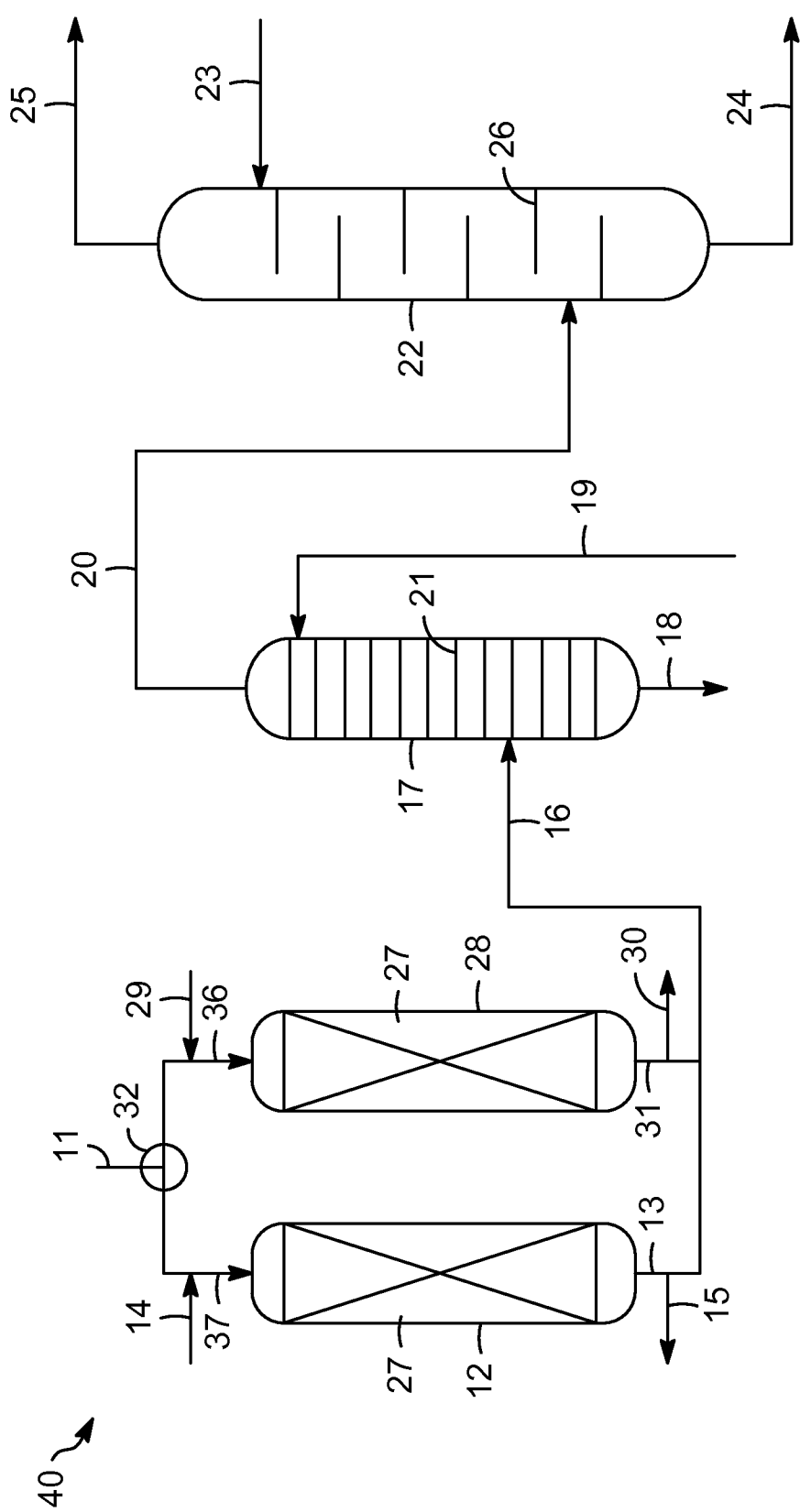
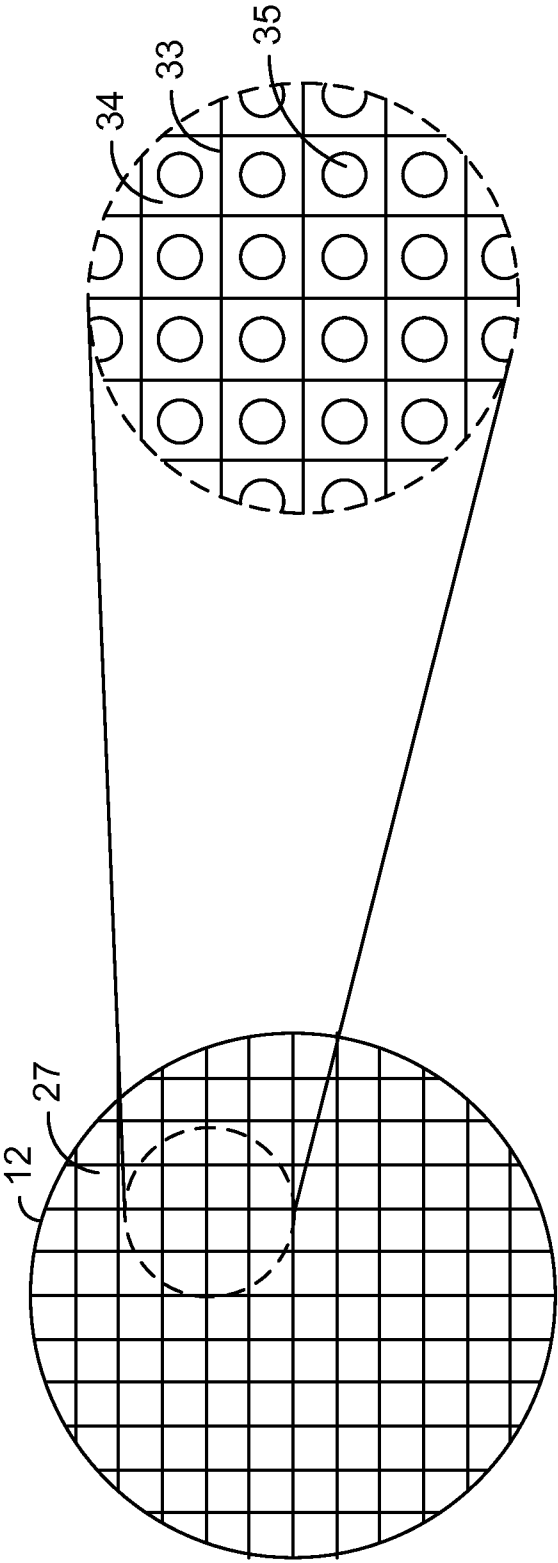


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/054004**A. CLASSIFICATION OF SUBJECT MATTER****C10G 25/09(2006.01)i, C10G 25/00(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)

C10G 25/09; C07C 011/16; C07C 007/12; C07C 2/64; B01J 20/34; C07C 7/12; C10G 25/00

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: diolefin, oxygenate, solid adsorbent, support, liquefied petroleum gas, LPG

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 8546631 B2 (JAN, D-Y. et al.) 01 October 2013 See abstract; and claims 1-20.	1-10
A	US 4404118 A (HERSKOVITS, L. E.) 13 September 1983 See abstract; column 5, lines 17-52; and claims 1-9.	1-10
A	US 2973396 A (ATKINSON, E. R. et al.) 28 February 1961 See column 1, line 15-column 2, line 57; and claims 1-9.	1-10
A	EP 0230700 B1 (UOP) 20 September 1989 See pages 3, 4; and claims 1-5.	1-10
A	US 3436436 A (TAKAO, S. et al.) 01 April 1969 See abstract; and claims 1-8.	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"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

11 December 2014 (11.12.2014)

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Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 8546631 B2	01/10/2013	US 2012-0157738 A1	21/06/2012
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