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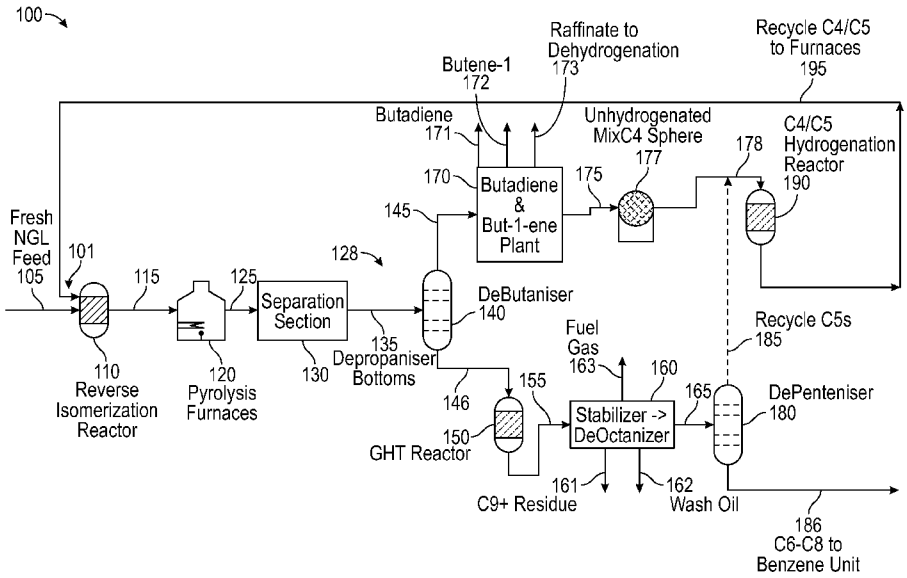

FIG. 1

(57) **Abstract:** Systems and methods for producing light olefins from a natural gas liquid (NGL) or other C5 stream are provided. The method may include supplying a NGL or other C5 stream to a reverse isomerization unit to produce a n-pentane enriched NGL stream and supplying the n- pentane enriched NGL stream to a liquid furnace to produce a pyrolyzed product stream. The method may also include separating the C2 hydrocarbons, the C3 hydrocarbons, the C4 hydrocarbons, the C5 hydrocarbons, and the C6+ hydrocarbons in the pyrolyzed product stream in a separation train and supplying the separated C5 hydrocarbons, or a portion thereof, to a hydrogenation reactor to produce a saturated C5 hydrocarbon stream, followed by recycling the saturated C5 hydrocarbon stream to the reverse isomerization unit.

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METHODS AND SYSTEMS TO IMPROVE LIGHT OLEFIN YIELD AND FEEDSTOCK UTILIZATION FROM C5 RAFFINATE STREAMS

TECHNICAL FIELD

[0001] The present disclosure generally relates to systems and methods for increasing light olefin yield and feedstock utilization from natural gas liquids (NGLs) or other C5 streams. More specifically, the present disclosure relates to, among other embodiments, systems and methods for improving ethylene production from NGL feed streams by hydrogenating C5 raffinate streams followed by recycling the saturated C5 raffinate streams to a reverse isomerization reactor to increase the n-C5 feed to furnaces. Hydrogenation can be performed independently or together with a C4 stream.

BACKGROUND

[0002] Ethylene is a desirable industrial compound having a worldwide production greater than that of any other organic compound. Accordingly, ethylene is widely used in the chemical industry, particularly as a feedstock for the production of polyethylene. In addition to other production methods, ethylene may be generated by the pyrolysis of natural gas liquids (NGLs) and/or other C5 streams in liquid furnaces or crackers. The major component of NGLs is mixed pentanes, typically around 50% n-C5 and 43% i-C5, with specific compositions that vary from well to well. Pyrolysis liquid furnaces may be used to crack NGL feedstocks to high value olefins, such as ethylene, propylene, benzene, butadiene, and C5 raffinate. Particularly desirable are lighter olefins which are in greater demand, therefore enhancement of light olefin yield from pyrolysis liquid furnaces enhances the overall profitability of the process. In recent years, the modern chemical industry has been focused on minimizing carbon loss and maximizing productivity in an energy sustainable matter. Accordingly, methods and systems capable of

increasing the efficiency of light olefin production, particularly ethylene production, and improving feedstock utilization of NGL-derived streams is desirable.

SUMMARY

[0003] To address these shortcomings in the art, Applicant has developed systems and methods for increasing light olefin yields from pyrolysis of NGL streams or other C5 streams in liquid furnaces by upgrading the feedstock before injection into the liquid furnace, according to the exemplary embodiments disclosed herein. In particular, among other exemplary embodiments, Applicant has developed systems and methods for downstream recycling or pre-processing of NGL hydrocarbon feedstocks using one or more hydrogenation reactors, that perform independently or together with a C4 stream, and reverse isomerization reactors to provide a n-C5 rich feedstock stream to pyrolysis furnaces, thereby enhancing the overall productivity of light olefins, particularly ethylene.

[0004] Systems and methods for the producing light olefins from a natural gas liquid (NGL) stream are provided. In certain embodiments, the method for producing light olefins from a NGL stream may comprise: supplying a natural gas liquid (NGL) stream to a reverse isomerization unit to produce a n-pentane enriched NGL stream; supplying the n-pentane enriched NGL stream to a liquid furnace or one or more pyrolysis furnaces to produce a pyrolyzed product stream, the pyrolyzed product stream comprising C2 hydrocarbons, C3 hydrocarbons, C4 hydrocarbons, C5 hydrocarbons, and C6+ hydrocarbons; separating the C2 hydrocarbons, the C3 hydrocarbons, the C4 hydrocarbons, the C5 hydrocarbons, and the C6+ hydrocarbons in the pyrolyzed product stream in a separation train; supplying the separated C5 hydrocarbons, or a portion thereof, to a first hydrogenation reactor to produce a saturated or hydrogenated C5 hydrocarbon stream; recycling the saturated or hydrogenated C5 hydrocarbon stream to the reverse isomerization unit.

[0005] In some embodiments of the method, recycling the saturated or hydrogenated C5 hydrocarbon stream to the reverse isomerization unit increases light olefin yield, particularly ethylene and/or propylene yield at the liquid furnace or one or more liquid furnaces. In some embodiments, the NGL stream may be formed from the combination of a fresh natural gas liquid feed and the saturated or hydrogenated C5 hydrocarbon stream produced at the first hydrogenation reactor. In some embodiments of the method, the method may also include supplying the separated C4 hydrocarbons, or a portion thereof, to a second hydrogenation reactor to produce a saturated or hydrogenated C4 hydrocarbon stream and recycling the saturated or hydrogenated C4 hydrocarbon stream to the reverse isomerization unit.

[0006] In some embodiments, the method may further include supplying the separated C4 hydrocarbons, or a portion thereof, to the first hydrogenation reactor to produce a combined saturated or hydrogenated C4 hydrocarbon and saturated or hydrogenated C5 hydrocarbon stream. In some embodiments, the method may further include recycling the combined saturated or hydrogenated C4 and C5 hydrocarbon stream to the reverse isomerization unit. In some embodiments, the NGL stream may be formed from the combination of a fresh natural gas liquid feed and the combined saturated or hydrogenated C4 and C5 hydrocarbon stream produced at the first hydrogenation reactor. In some embodiments of the method, the NGL stream may be formed from the combination of a fresh natural gas liquid feed, the saturated or hydrogenated C5 hydrocarbon stream produced at the first hydrogenation reactor, and the saturated or hydrogenated C4 hydrocarbon stream produced at the second hydrogenation reactor.

[0007] In some embodiments, the method may further include supplying the C4 hydrocarbons separated from the pyrolyzed product stream to a butadiene and but-1-ene processing unit to produce a butadiene stream, a butene-1 stream, and a C4 raffinate stream; supplying the C4

raffinate stream to the first hydrogenation reactor or the second hydrogenation reactor to produce a saturated or hydrogenated C4 hydrocarbon stream; and supplying the saturated or hydrogenated C4 hydrocarbon stream to the reverse isomerization unit. In some embodiments, the method may further include separating, at a debutanizer unit, C4 hydrocarbons from the pyrolyzed product stream, or a portion thereof, to produce a separated C4 hydrocarbon stream; and supplying the separated C4 hydrocarbon stream to the butadiene and but-1-ene processing unit.

[0008] In some embodiments, the method may further include supplying the pyrolyzed product stream to a product recovery section of the separation train operable to separate propylene and ethylene, and/or C2 and C3 hydrocarbons, from the pyrolyzed product stream to produce a C4+ hydrocarbon stream; supplying the C4+ hydrocarbon stream to a debutanizer to produce a separated C4 hydrocarbon stream and a C5+ hydrocarbon stream; supplying the C5+ hydrocarbon stream to a depentanizer to produce a separated C5 hydrocarbon stream (*i.e.*, a C5 raffinate stream) and a C6+ hydrocarbon stream; and supplying the separated C5 hydrocarbon stream to the first hydrogenation reactor. In some embodiments, the method may further include supplying the C5+ hydrocarbon stream or the separated C5 hydrocarbon stream to a gas hydro treatment reactor to prior to supplying the C5 hydrocarbon stream to the first hydrogenation reactor. In some embodiments, the reverse isomerization unit is operated at a temperature of from about 240°C to about 440°C and at a pressure of from about 15 bar to about 30 bar.

[0009] The present disclosure also provides a method for producing light olefins from a NGL stream that may comprise: hydrogenating a recycled C5 stream to produce a saturated recycled C5 stream, the recycled C5 stream derived from the pyrolysis of a natural gas liquid stream; isomerizing the hydrogenated recycled C5 stream and iso-C5 from a fresh natural gas liquid stream to produce an isomerized hydrocarbon stream; and pyrolyzing the isomerized hydrocarbon stream

to produce one or more light olefins and one or more additional pyrolyzed products. In some embodiments, the method may also include hydrogenating a recycled C4 stream and a recycled C5 stream to produce a hydrogenated recycled mixed C4 and C5 stream, the recycled C4 stream and the recycled C5 stream derived from the pyrolysis of a natural gas liquid stream; isomerizing the hydrogenated recycled mixed C4 and C5 stream and a fresh natural gas liquid stream to produce an isomerized hydrocarbon stream; and pyrolyzing the isomerized hydrocarbon stream to produce one or more light olefins and one or more pyrolyzed products.

[0010] In some embodiments, the recycled C5 stream may be separated from the one or more pyrolyzed products. In some embodiments, the recycled C4 stream may be separated from the one or more pyrolyzed products. In some embodiments, the method may also include separating the one or more light olefins from the one or more pyrolyzed products. In some embodiments, the method may also include feeding the one or more additional pyrolyzed products to a debutanizer to produce the recycled C4 stream and a debutanized hydrocarbon stream. In some embodiments, the method may also include feeding the debutanized hydrocarbon stream to a gas hydrotreatment (GHT) reactor to produce a treated debutanized hydrocarbon stream; and feeding the treated debutanized hydrocarbon stream to a depentanizer to produce the recycled C5 stream. In some embodiments, the recycled C5 stream is a pentene-rich stream and the hydrogenated recycled C5 stream is a pentane-rich stream. In some embodiments, the recycled C4 stream is a butene-rich stream and the hydrogenated recycled mixed C4 and C5 stream is a pentane-rich and butane-rich stream.

[0011] The present disclosure provides a system for producing light olefins from a natural gas liquid stream. The system may include: a reverse isomerization unit operable to receive a natural gas liquid (NGL) stream, the reverse isomerization unit further operable to isomerize the NGL

stream to produce a n-pentane enriched NGL stream; a liquid furnace or one or more pyrolysis furnaces operable to receive the n-pentane enriched NGL stream, the liquid furnace or the one or more pyrolysis furnaces further operable to pyrolyze the n-pentane enriched NGL stream to produce a pyrolyzed product stream, the pyrolyzed product stream comprising C2 hydrocarbons, C3 hydrocarbons, C4 hydrocarbons, C5 hydrocarbons, and C6+ hydrocarbons; a separation train operable to separate the C2 hydrocarbons, the C3 hydrocarbons, the C4 hydrocarbons, the C5 hydrocarbons, and the C6+ hydrocarbons in the pyrolyzed product stream; and a first hydrogenation reactor operable to receive the separated C5 hydrocarbons, or a portion thereof, the first hydrogenation reactor further operable to hydrogenate the separated C5 hydrocarbons, or a portion thereof, to produce a saturated or hydrogenated C5 hydrocarbon stream; the reverse isomerization unit further operable to receive the saturated or hydrogenated C5 hydrocarbon stream.

[0012] In some embodiments of the system, recycling the saturated or hydrogenated C5 hydrocarbon stream to the reverse isomerization unit increases light olefin yield, particularly ethylene and/or propylene yield, at the liquid furnace. In some embodiments of the system, the NGL stream may be formed from the combination of a fresh natural gas liquid feed and the saturated or hydrogenated C5 hydrocarbon stream produced at the first hydrogenation reactor. In some embodiments, the system may further include a second hydrogenation reactor operable to receive the separated C4 hydrocarbons, or a portion thereof. The second hydrogenation reactor may be further operable to hydrogenate the separated C4 hydrocarbons, or a portion thereof, to produce a saturated or hydrogenated C4 hydrocarbon stream. The reverse isomerization unit may be operable to receive the saturated or hydrogenated C4 hydrocarbon stream produced by the second hydrogenation reactor.

[0013] In some embodiments of the system, the first hydrogenation reactor may be configured to receive the separated C4 hydrocarbons, or a portion thereof. The first hydrogenation reactor may be further operable to hydrogenate the separated C4 hydrocarbons, or a portion thereof, to produce a combined saturated or hydrogenated C4 hydrocarbon and a saturated or hydrogenated C5 hydrocarbon stream. The reverse isomerization unit may be configured to receive the combined saturated or hydrogenated C4 and C5 hydrocarbon stream. In some embodiments of the system, the NGL stream may be formed from the combination of a fresh natural gas liquid feed and the combined saturated or hydrogenated C4 and C5 hydrocarbon stream produced at the first hydrogenation reactor. In some embodiments of the system, the NGL stream may be formed from the combination of a fresh natural gas liquid feed, the saturated or hydrogenated C5 hydrocarbon stream produced at the first hydrogenation reactor, and the saturated or hydrogenated C4 hydrocarbon stream produced at the second hydrogenation reactor.

[0014] In some embodiments, the system may also a butadiene and but-1-ene processing unit operable to receive the C4 hydrocarbons separated from the pyrolyzed product stream. The butadiene and but-1-ene processing unit may be further operable to produce a butadiene stream, a butene-1 stream, and a C4 raffinate stream. The first hydrogenation reactor or the second hydrogenation reactor may be operable to receive the C4 raffinate stream and produce a saturated (hydrogenated) C4 hydrocarbon stream. The reverse isomerization unit may be operable to receive the saturated (hydrogenated) C4 hydrocarbon stream produced by the first or second hydrogenation reactors.

[0015] In some embodiments, the system may further include a debutanizer unit operable to receive the pyrolyzed product stream, or a portion thereof. The debutanizer unit may be further operable to separate C4 hydrocarbons from the pyrolyzed product stream to produce a separated

C4 hydrocarbon stream. The butadiene and but-1-ene processing unit may also be operable to receive the separated C4 hydrocarbon stream produced by the debutanizer unit.

[0016] In some embodiments, the separation train of the system may include a product recovery section configured to receive the pyrolyzed product stream produced by the liquid furnace, the product recovery section further configured to separate propylene and ethylene (C2 and C3 hydrocarbons) from the pyrolyzed product stream to produce a C4+ hydrocarbon stream; a debutanizer configured to receive the C4+ hydrocarbon stream produced by the product recovery section, the debutanizer further configured to debutanize the C4+ hydrocarbon stream to produce a separated C4 hydrocarbon stream and a C5+ hydrocarbon stream; and a depentanizer configured to receive the C5+ hydrocarbon stream produced by the debutanizer, the depentanizer further configured to depentenize the C5+ hydrocarbon stream to produce a separated C5 hydrocarbon (raffinate) stream and a C6+ hydrocarbon stream. In such embodiments, the first hydrogenation reactor may be operable to receive the separated C5 hydrocarbon stream produced by the depentanizer.

[0017] In some embodiments of the system, the product recovery section may include a de-ethanizer operable to receive the pyrolyzed product stream, or a portion thereof, and produce a separated C2 hydrocarbon stream; and a depropanizer operable to receive the pyrolyzed products stream, or a portion thereof, and produce a separated C3 hydrocarbon stream. The separated C2 hydrocarbon stream may comprise ethylene and the separated C3 hydrocarbon stream may comprise propylene. The de-ethanizer may be configured to produce a C3+ hydrocarbon stream and the depropanizer may be configured to receive the C3+ hydrocarbon stream produced by the de-ethanizer and produce a separated C3 hydrocarbon stream and a C4+ hydrocarbon stream. In some embodiments, the system may further include a gas hydro treatment reactor configured to

receive the C5+ hydrocarbon stream produced by the debutanizer or the separated C5 hydrocarbon stream (*i.e.*, the C5 raffinate stream) produced by the depentanizer prior to supplying the C5 hydrocarbon stream to the first hydrogenation reactor. In some embodiments of the system, the reverse isomerization unit is operated at a temperature of from about 240°C to about 440°C and at a pressure of from about 15 bar to about 30 bar.

[0018] The present disclosure also provides a system for producing light olefins from a NGL stream that may comprise: a hydrogenation reactor operable to receive a recycled C5 stream derived from the pyrolysis of a natural gas liquid stream and operable to hydrogenize the recycled C5 stream to produce a hydrogenated recycled C5 stream; a reverse isomerization reactor operable to receive a fresh natural gas liquid stream and the hydrogenated recycled C5 stream, the reverse isomerization reactor further operable to isomerize the combined fresh natural gas liquid stream and the hydrogenated recycled C5 stream to produce an isomerized hydrocarbon stream; and one or more pyrolysis furnaces operable to receive the isomerized hydrocarbon stream and pyrolyze the isomerized hydrocarbon stream to produce one or more light olefins and one or more pyrolyzed products.

[0019] In some embodiments of the system, the hydrogenation reactor may be further operable to receive a recycled C4 stream derived from the pyrolysis of a natural gas liquid stream and hydrogenize the combined recycled C4 and C5 streams to produce a hydrogenated recycled mixed C4 and C5 stream. The reverse isomerization reactor may be operable to receive the fresh natural gas liquid stream and the hydrogenated recycled mixed C4 and C5 stream. The reverse isomerization reactor may be further operable to isomerize the combined fresh natural gas liquid stream and the hydrogenated recycled mixed C4 and C5 stream to produce the isomerized hydrocarbon stream. In some embodiments, the system may further include one or more separators

operable to separate the one or more light olefins from the one or more pyrolyzed products. In some embodiments, the system may further include a debutanizer operable to receive the one or more additional pyrolyzed products and produce the recycled C4 stream and a debutanized hydrocarbon stream.

[0020] In some embodiments, the system may further include a gas hydro treatment (GHT) reactor operable to receive the debutanized hydrocarbon stream from the debutanizer and produce a treated debutanized hydrocarbon stream. In some embodiments, the system may further include a depentanizer operable to receive the treated debutanized hydrocarbon stream and produce the recycled C5 stream and a C6-C8 stream. In some embodiments, the recycled C5 stream may be a pentene-rich stream and the hydrogenated recycled C5 stream may be a pentane-rich stream. In some embodiments of the system, the recycled C4 stream may be a butene-rich stream. In some embodiments of the system, the hydrogenated recycled mixed C4 and C5 stream may be a pentane-rich and butane-rich stream.

[0021] Still other aspects and advantages of these exemplary embodiments and other embodiments, are discussed in detail herein. Moreover, it is to be understood that both the foregoing information and the following detailed description provide merely illustrative examples of various aspects and embodiments, and are intended to provide an overview or framework for understanding the nature and character of the claimed aspects and embodiments. Accordingly, these and other objects, along with advantages and features of the present disclosure, will become apparent through reference to the following description and the accompanying drawings. Furthermore, it is to be understood that the features of the various embodiments described herein are not mutually exclusive and may exist in various combinations and permutations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The accompanying drawings, which are included to provide a further understanding of the embodiments of the present disclosure, are incorporated in and constitute a part of this specification, illustrate embodiments of the present disclosure, and together with the detailed description, serve to explain principles of the embodiments discussed herein. No attempt is made to show structural details of this disclosure in more detail than may be necessary for a fundamental understanding of the embodiments discussed herein and the various ways in which they may be practiced. According to common practice, the various features of the drawings discussed below are not necessarily drawn to scale. Dimensions of various features and elements in the drawings may be expanded or reduced to more clearly illustrate embodiments of the disclosure.

[0023] **FIG. 1** is a graphical representation of a system and method for producing light olefins from a NGL stream that includes feeding unhydrogenated C4 and C5 hydrocarbon streams separated from a pyrolysis product stream to a single hydrogenation reactor, followed by recycling the hydrogenated C4/C5 hydrocarbon stream to a reverse isomerization reactor, according to an exemplary embodiment of the present disclosure.

[0024] **FIG. 2** is a graphical representation of a system and method for producing light olefins from a NGL stream that includes feeding an unhydrogenated C5 hydrocarbon stream separated from a pyrolysis product stream to a hydrogenation reactor, followed by recycling the hydrogenated C5 hydrocarbon stream to a reverse isomerization reactor, according to an exemplary embodiment of the present disclosure.

DETAILED DESCRIPTION

[0025] The present disclosure describes various embodiments related to processes, methods, and systems for integrating petrochemical and refinery operations. Further embodiments may be described and disclosed.

[0026] In the following description, numerous details are set forth in order to provide a thorough understanding of the various embodiments. In other instances, well-known processes, devices, and systems may not have been described in particular detail in order not to unnecessarily obscure the various embodiments. Additionally, illustrations of the various embodiments may omit certain features or details in order to not obscure the various embodiments.

[0027] The description may use the phrases "in some embodiments," "in various embodiments," "in an embodiment," or "in embodiments," which may each refer to one or more of the same or different embodiments. Furthermore, the terms "comprising," "including," "having," and the like, as used with respect to embodiments of the present disclosure, are synonymous.

[0028] The term "about" is defined as being close to as understood by one of ordinary skill in the art. In one non-limiting embodiment, the terms are defined to be within 10%, preferably within 5%, more preferably within 1%, and most preferably within 0.5%.

[0029] The terms "reducing," "reduced," or any variation thereof, when used in the claims and/or the specification includes any measurable decrease or complete inhibition to achieve a desired result.

[0030] The use of the words "a" or "an" when used in conjunction with any of the terms "comprising," "including," "containing," or "having," in the claims or the specification may mean "one," but it is also consistent with the meaning of "one or more," "at least one," and "one or more than one." The terms "wt.%", "vol.%", or "mol.%" refers to a weight, volume, or molar percentage of a component, respectively, based on the total weight, the total volume of material, or total moles, that includes the component. In a non-limiting example, 10 grams of component in 100 grams of the material is 10 wt.% of component.

[0031] The words "comprising" (and any form of comprising, such as "comprise" and "comprises"), "having" (and any form of having, such as "have" and "has"), "including" (and any form of including, such as "includes" and "include") or "containing" (and any form of containing, such as "contains" and "contain") are inclusive or open-ended and do not exclude additional, unrecited elements or method steps.

[0032] Disclosed here are systems and methods for increasing light olefin yields from the pyrolysis of NGL streams in liquid furnaces by upgrading the feedstock before injection into the liquid furnace. In particular, prior to being fed to one or more pyrolysis furnaces, a fresh NGL stream may be mixed or combined with a n-C5 rich feedstock stream produced by one or more hydrogenation reactors from a recycled C5 hydrocarbon stream separated from a pyrolyzed product stream.

[0033] Pre-processing of NGL hydrocarbon feedstocks using one or more hydrogenation reactors and reverse isomerization reactors provides a n-C5 rich feedstock stream to pyrolysis furnaces, thereby enhancing the overall productivity of light olefins, particularly ethylene.

[0034] **FIG. 1** is a graphical representation of an exemplary system **100** and method for producing ethylene and other light olefins from a natural gas liquid feed stream **105** that includes feeding unhydrogenated C4 and C5 hydrocarbon streams **178**, **185** separated from a pyrolysis product stream **125**, by a separation train **128**, to a single hydrogenation reactor **190**, followed by recycling the hydrogenated C4/C5 hydrocarbon stream **195** to a reverse isomerization reactor **110**, according to an exemplary embodiment of the present disclosure. As depicted in **FIG. 1**, system **100** may include one or more reverse isomerization reactors, such as reverse isomerization reactor **110**. Reverse isomerization reactor **110** may be operable to receive a natural gas liquid (NGL)

stream **101**, such as fresh NGL feed stream **105** and isomerize the NGL feed stream **101** to produce an isomerized hydrocarbon stream **115** or n-pentane enriched NGL stream **115**.

[0035] As depicted in **FIG. 1**, the reverse isomerization reactor **110** may be fluidly coupled with one or more pyrolysis furnaces, such as liquid furnace **120**. Liquid furnace **120** may be operable to receive the isomerized hydrocarbon stream **115** or the n-pentane enriched NGL stream **115** produced by the reverse isomerization reactor **110**. Liquid furnace **120** may also be operable to pyrolyze the isomerized hydrocarbon stream **115** or the n-pentane enriched NGL stream **115** to produce a pyrolyzed product stream **125**. The pyrolyzed product stream **125** may comprise C2 hydrocarbons, C3 hydrocarbons, C4 hydrocarbons, C5 hydrocarbons, and C6+ hydrocarbons, among other hydrocarbons and chemical components. As used herein, the term "C6+ hydrocarbons," refers to hydrocarbons having six (6) or more carbon atoms. Similar terms, such as "C3+ hydrocarbons," "C4+ hydrocarbons," and "C5+ hydrocarbons," also refers to hydrocarbons having three (3) or more carbon atoms, four (4) or more carbons atoms, and five (5) or more carbon atoms, respectively.

[0036] System **100** may further include a separation train **128** operable to separate the C2 hydrocarbons, the C3 hydrocarbons, the C4 hydrocarbons, the C5 hydrocarbons, and the C6+ hydrocarbons in the pyrolyzed product stream **125**. Accordingly, separation train **128** is fluidly coupled to pyrolysis furnace **120** and operable to receive the pyrolyzed product stream **125** produced by pyrolysis furnace **120**. As depicted in **FIG. 1**, the separation train **128** in system **100** may include a product separation section **130**, a debutanizer **140**, a dependanizer **180**, a butadiene and but-1-ene processing unit **170**, and a stabilizer/deoctanizer **160**. The product separation section **130** of separation train **128** may be fluidly coupled to the liquid furnace **120** and operable to receive the pyrolyzed product stream **125** produced by the liquid furnace **120**. Product

separation section **130** may include components operable to separate light olefin products produced by pyrolysis in the liquid furnace **120**, such as ethylene and propylene, as well as other C2 and C3 hydrocarbons. Accordingly, product separation section **130** may include a de-ethanizer and a depropanizer. After product separation, the resultant C4+ hydrocarbon stream **135** (*e.g.*, depropanizer bottoms stream) may be supplied to debutanizer **140**.

[0037] As depicted in **FIG. 1**, system **100** may include debutanizer **140** fluidly coupled with product separation section **130** and operable to receive the C4+ hydrocarbon stream **135** produced by product separation section **130**. Debutanizer **140** may be operable to separate C4 hydrocarbons from the C4+ hydrocarbon stream **135** to produce a separated C4 hydrocarbon stream **145** and a C5+ hydrocarbon stream **146**. Separation train **128** of system **100** may further include a butadiene and but-1-ene processing unit **170** fluidly coupled to debutanizer **140** and operable to receive separated C4 hydrocarbon stream **145**. Butadiene and but-1-ene processing unit **170** is further operable to process the separated C4 hydrocarbon stream **145** to produce a butadiene product stream **171**, a butene-1 product stream **172**, raffinate to dehydrogenation or other use **173**, and C4 raffinate stream **175**. Butadiene and but-1-ene processing unit **170** may be fluidly coupled to unhydrogenated mixC4 sphere **177** and C4/C5 hydrogenation reactor **190** or first hydrogenation reactor **190**.

[0038] System **100** may also include a gas hydrotreatment (GHT) reactor **150** fluidly coupled with debutanizer **140** such that the GHT reactor **150** is operable to receive the C5+ hydrocarbon stream **146** produced by debutanizer **140**. GHT reactor **150** is operable to hydrotreat the C5+ hydrocarbon stream **146** and produce hydrotreated C5+ hydrocarbon stream **155**. As depicted in **FIG. 1**, GHT reactor **150** is fluidly coupled with stabilizer/deoctanizer **160**. Stabilizer/deoctanizer **160** is operable to receive the hydrotreated C5+ hydrocarbon stream **155** produced by GHT reactor

150 and produce fuel gas stream **163**, C9+ residue stream **161**, wash oil stream **162**, and residual C5+ hydrocarbon stream **165**.

[0039] Separation train **128** of system **100** further includes depentanizer **180** fluidly coupled with stabilizer/deoctanizer **160** and operable to receive residual C5+ hydrocarbon stream **165** produced by stabilizer/deoctanizer **160**. Depentanizer **180** may be operable to separate C5 hydrocarbons from the residual C5+ hydrocarbon stream **165** to produce a separated C5 hydrocarbon stream **185** or C5 raffinate stream **185** and a C6+ hydrocarbon stream **186**. The separated C5 hydrocarbon stream or C5 raffinate stream **185** may be supplied to the C4/C5 hydrogenation reactor **190** in the form of combined C4/C5 raffinate stream **178** or combined separated C4/C5 stream **178**.

[0040] C4/C5 hydrogenation reactor **190** may be operable to receive C4 raffinate stream **175** or separated C4 stream **178** from unhydrogenated mixC4 sphere **177** as well as separated C5 hydrocarbon stream or C5 raffinate stream **185** in the form of combined separated C4/C5 stream **178**. C4/C5 hydrogenation reactor **190** is further operable to hydrogenate or saturate the combined separated C4/C5 stream **178** to produce a saturated or hydrogenated C4/C5 hydrocarbon stream **195**. C4/C5 hydrogenation reactor **190** is fluidly coupled to reverse isomerization reactor **110** such that combined saturated/hydrogenated C4/C5 hydrocarbon stream **195** may be supplied to reverse isomerization reactor **110** as either a separate feed stream to reverse isomerization reactor **110** or as part of a combined stream with fresh NGL feed stream **105** in the form of NGL stream **101**.

[0041] While **FIG. 1** depicts a single C4/C5 hydrogenation reactor **190**, in other embodiments of system **100**, C4/C5 hydrogenation reactor **190** may be replaced by any number of hydrogenation reactors configured to receive unhydrogenated C4 and C5 streams separated from pyrolyzed product stream **125**. In some embodiments, the single C4/C5 hydrogenation reactor **190** may be

replaced by a first hydrogenation reactor operable to receive and hydrogenate/saturate a separated C5 hydrocarbon stream or C5 raffinate stream and a second hydrogenation reactor operable to receive and hydrogenate/saturate a separated C4 hydrocarbon stream or C4 raffinate stream. The output streams of the first and second hydrogenation reactors may be combined to form saturated/hydrogenated C4/C5 hydrocarbon stream **195** and supplied to reverse isomerization reactor **110** either separately or as a combined feed stream with fresh NGL feed stream **105** to form NGL feed **101**.

[0042] **FIG. 2** is a graphical representation of an exemplary system **200** and method for producing ethylene and other light olefins from a natural gas liquid feed stream **205** that includes feeding unhydrogenated C5 hydrocarbon stream **285** separated from a pyrolysis product stream **225** by a separation train **228** to a C5 hydrogenation reactor **290**, followed by recycling the hydrogenated/saturated C5 hydrocarbon stream **295** to a reverse isomerization reactor **210**, according to an exemplary embodiment of the present disclosure. As depicted in **FIG. 2**, system **200** may include one or more reverse isomerization reactors, such as reverse isomerization reactor **210**. Reverse isomerization reactor **210** may be operable to receive a natural gas liquid (NGL) stream **201**, such as fresh NGL feed stream **205** and isomerize the NGL feed stream **201** to produce an isomerized hydrocarbon stream **215** or n-pentane enriched NGL stream **215**.

[0043] As depicted in **FIG. 2**, the reverse isomerization reactor **210** may be fluidly coupled with one or more pyrolysis furnaces, such as liquid furnace **220**. Liquid furnace **220** may be operable to receive the isomerized hydrocarbon stream **215** or the n-pentane enriched NGL stream **215** produced by the reverse isomerization reactor **210**. Liquid furnace **220** may also be operable to pyrolyze the isomerized hydrocarbon stream **215** or the n-pentane enriched NGL stream **215** to produce a pyrolyzed product stream **225**. The pyrolyzed product stream **225** may comprise C2

hydrocarbons, C3 hydrocarbons, C4 hydrocarbons, C5 hydrocarbons, and C6+ hydrocarbons, among other hydrocarbons and chemical components.

[0044] System **200** may further include a separation train **228** operable to separate the C2 hydrocarbons, the C3 hydrocarbons, the C4 hydrocarbons, the C5 hydrocarbons, and the C6+ hydrocarbons in the pyrolyzed product stream **225**. Accordingly, separation train **228** is fluidly coupled to pyrolysis furnace **220** and operable to receive the pyrolyzed product stream **225** produced by pyrolysis furnace **220**. As depicted in **FIG. 2**, the separation train **228** in system **200** may include a product separation section **230**, a debutanizer **240**, a dependanizer **280**, and a stabilizer/deoctanizer **260**. The product separation section **230** of separation train **228** may be fluidly coupled to the liquid furnace **220** and operable to receive the pyrolyzed product stream **225** produced by the liquid furnace **220**. Product separation section **230** may include components operable to separate light olefin products produced by pyrolysis in the liquid furnace **220**, such as ethylene and propylene, as well as other C2 and C3 hydrocarbons. Accordingly, product separation section **230** may include a de-ethanizer and a depropanizer. After product separation, the resultant C4+ hydrocarbon stream **235** (*e.g.*, depropanizer bottoms stream) may be supplied to debutanizer **240**.

[0045] As depicted in **FIG. 2**, system **200** may include debutanizer **240** fluidly coupled with product separation section **230** and operable to receive the C4+ hydrocarbon stream **235** produced by product separation section **230**. Debutanizer **240** may be operable to separate C4 hydrocarbons from the C4+ hydrocarbon stream **235** to produce a separated C4 hydrocarbon stream **245** and a C5+ hydrocarbon stream **246**. System **200** may also include a gas hydrotreatment (GHT) reactor **250** fluidly coupled with debutanizer **240** such that the GHT reactor **250** is operable to receive the C5+ hydrocarbon stream **246** produced by debutanizer **240**. GHT reactor **250** is operable to

hydrotreat the C5+ hydrocarbon stream **246** and produce hydrotreated C5+ hydrocarbon stream **255**. As depicted in **FIG. 2**, GHT reactor **250** is fluidly coupled with stabilizer/deoctanizer **260**. Stabilizer/deoctanizer **260** is operable to receive the hydrotreated C5+ hydrocarbon stream **255** produced by GHT reactor **250** and produce fuel gas stream **263**, C9+ residue stream **261**, wash oil stream **262**, and residual C5+ hydrocarbon stream **265**.

[0046] Separation train **228** of system **200** further includes dependanizer **280** fluidly coupled with stabilizer/deoctanizer **260** and operable to receive residual C5+ hydrocarbon stream **265** produced by stabilizer/deoctanizer **260**. Dependanizer **280** may be operable to separate C5 hydrocarbons from the residual C5+ hydrocarbon stream **265** to produce a separated C5 hydrocarbon stream **285** or C5 raffinate stream **285** and a C6+ hydrocarbon stream **286**. The separated C5 hydrocarbon stream or C5 raffinate stream **285** may be supplied to the C5 hydrogenation reactor **290** (*e.g.*, first hydrogenation reactor **290**).

[0047] C5 hydrogenation reactor **290** may be operable to receive the separated C5 hydrocarbon stream or C5 raffinate stream **285** produced by dependanizer **280** and hydrogenate or saturate the separated C5 hydrocarbon stream or C5 raffinate stream **285** to produce a saturated or hydrogenated C5 hydrocarbon stream **295**. The C5 hydrogenation reactor **290** is fluidly coupled to reverse isomerization reactor **210** such that the saturated/hydrogenated C5 hydrocarbon stream **295** may be supplied to reverse isomerization reactor **210** as either a separate feed stream to reverse isomerization reactor **210** or as part of a combined stream with fresh NGL feed **205** in the form of NGL stream **201**.

EXAMPLES

[0048] The examples provided below illustrate selected aspects of the various methods and systems for producing light olefins from a NGL stream and do no limit the scope of the disclosure in any manner.

Example 1

[0049] Hydrocarbon yields for system **100** depicted in **FIG. 1** are shown in **Table 1** as determined by simulation. As shown in **Table 1**, system **100** produced 9.93 tons per hour (T/hr) ethylene and 3.75 T/hr propylene at the furnace outlet from an exemplary NGL fresh feed comprising 9.48 T/hr isopentane and 13.35 T/hr.

Table 1

Flow (T/hr)	*NGL Fresh Feed*	*Furnace Outlet*	C5 from GHT
Methane	0.00	5.34	0.00
Ethane	0.01	0.00	0.00
Ethylene	0.00	**9.93**	0.00
Propylene	0.00	**3.75**	0.00
PROPANE	0.00	0.00	0.00
i-Butene	0.00	0.34	0.00
n-Butene	0.00	0.17	0.03
2-Butenes (cis & trans)	0.00	0.14	0.00
Butadiene	0.00	1.14	0.00
ISOBUTANE	0.00	0.01	0.00
n-BUTANE	0.01	0.02	0.01
ISOPENTANE	9.48	0.07	0.00
n-PENTANE	13.35	0.01	0.64
1-PENTENE	0.00	0.07	0.16
CYCLOPENTANE	0.27	0.01	0.15
2,2-DIMETHYLBUTANE	0.00	0.01	0.00
2,3-DIMETHYLBUTANE	0.00	0.00	0.00
CYCLOPENTENE	0.00	0.05	0.20
Isoprene	0.00	0.36	0.00
3-Methyl-1-Butene	0.00	0.00	0.00
2-Methyl-2-Butene	0.00	0.00	0.00
2-METHYL-BUTANE	0.01	0.00	0.31
2-Methyl-1-Butene	0.01	0.00	0.20
CyC5 diolefin	0.00	0.18	0.00
2-Pentene (cis &trans)	0.00	0.00	0.00
2-METHYLPENTANE	0.00	0.00	0.00

Flow (T/hr)	*NGL Fresh Feed*	*Furnace Outlet*	C5 from GHT
3-METHYLPENTANE	0.00	0.00	0.00
n-HEXANE	1.15	0.20	0.00
i-HEXENE	0.51	0.00	0.00
1-HEXENE	0.00	0.00	0.04
METHYLCYCLOPENTANE	0.06	0.20	0.00
CYCLOHEXANE	0.02	0.00	0.00
BENZENE	0.03	1.30	0.00
2-METHYLHEXANE	0.04	0.00	0.00
n-HEPTANE	0.02	0.01	0.00
METHYLCYCLOHEXANE	0.02	0.00	0.00
TOLUENE	0.01	0.37	0.00
EB+XY	0.00	0.12	0.00
Styrene	0.00	0.11	0.00
n-Octane	0.00	0.40	0.00
Fuel oil	0.00	0.71	0.00
Total Flow (T/hr)	25	25	1.76

Example 2

[0050] Hydrocarbon yields for system **200** depicted in **FIG. 2** are shown in **Table 2** as determined by simulation. As shown in **Table 2**, system **200** produced 11.99 tons per hour (T/hr) ethylene and 4.49 T/hr propylene at the furnace outlet from a NGL fresh feed comprising 9.48 T/hr isopentane and 13.35 T/hr. Accordingly, C5 hydrogenation of a recycled C5 hydrocarbon stream separated from a pyrolyzed product stream, according to the system and method depicted in **FIG. 2**, resulted in a 20% increase in ethylene yield and propylene yield as compared to the C4/C5 hydrogenation system **100** depicted in **FIG. 1** (Example 1).

Table 2

Flow (T/hr)	*NGL Fresh Feed*	*NGL from RI*	*Furnace Outlet*	*C5 from GHT*	*C5 Hydrogenation*
Methane	0.00	0.00	5.22	0.00	0.00
Ethane	0.01	0.00	0.00	0.00	0.00
Ethylene	0.00	0.00	**11.99**	0.00	0.00
Propylene	0.00	0.00	**4.49**	0.00	0.00
PROPANE	0.00	0.00	0.00	0.00	0.00

Flow (T/hr)	*NGL Fresh Feed*	*NGL from RI*	*Furnace Outlet*	*C5 from GHT*	*C5 Hydrogenation*
i-Butene	0.00	0.00	0.12	0.00	0.00
n-Butene	0.00	0.00	0.11	0.04	0.00
2-Butenes (cis & trans)	0.00	0.00	0.06	0.00	0.00
Butadiene	0.00	0.00	1.22	0.00	0.00
ISOBUTANE	0.00	0.00	0.00	0.00	0.00
n-BUTANE	0.01	0.00	0.01	0.01	0.04
ISOPENTANE	9.48	0.54	0.03	0.00	0.00
n-PENTANE	13.35	24.07	0.13	0.69	0.86
1-PENTENE	0.00	0.00	0.08	0.17	0.00
CYCLOPENTANE	0.27	0.29	0.01	0.16	0.37
2,2-DIMETHYLBUTANE	0.00	0.00	0.23	0.00	0.00
2,3-DIMETHYLBUTANE	0.00	0.00	0.00	0.00	0.00
CYCLOPENTENE	0.00	0.00	0.05	0.22	0.00
Isoprene	0.00	0.00	0.41	0.00	0.00
3-Methyl-1-Butene	0.00	0.00	0.00	0.00	0.00
2-Methyl-2-Butene	0.00	0.00	0.00	0.00	0.00
2-METHYL-BUTANE	0.01	0.00	0.00	0.34	0.56
2-Methyl-1-Butene	0.01	0.00	0.00	0.22	0.00
CyC5 diolefin	0.00	0.00	0.17	0.00	0.00
2-Pentene (cis & trans)	0.00	0.00	0.00	0.00	0.00
2-METHYLPENTANE	0.00	0.00	0.00	0.00	0.00
3-METHYLPENTANE	0.00	0.00	0.00	0.00	0.00
n-HEXANE	1.15	1.24	0.02	0.00	0.05
i-HEXENE	0.51	0.54	0.00	0.00	0.00
1-HEXENE	0.00	0.00	0.00	0.05	0.00
METHYLCYCLOPENTANE	0.06	0.07	0.16	0.00	0.00
CYCLOHEXANE	0.02	0.02	0.00	0.00	0.00
BENZENE	0.03	0.03	1.03	0.01	0.01
2-METHYLHEXANE	0.04	0.05	0.00	0.00	0.00
n-HEPTANE	0.02	0.02	0.00	0.00	0.00
METHYLCYCLOHEXANE	0.02	0.02	0.00	0.00	0.00
TOLUENE	0.01	0.01	0.27	0.00	0.00
EB+XY	0.00	0.00	0.06	0.00	0.00
Styrene	0.00	0.00	0.09	0.00	0.00
n-Octane	0.00	0.00	0.37	0.00	0.00
Fuel oil	0.00	0.00	0.55	0.00	0.00
Total Flow (T/hr)	**25**	**26.895**	**26.895**	**1.895**	**1.895**

[0051] When ranges are disclosed herein, ranges from any lower limit may be combined with any upper limit to recite a range not explicitly recited, as well as, ranges from any lower limit may

be combined with any other lower limit to recite a range not explicitly recited, in the same way, ranges from any upper limit may be combined with any other upper limit to recite a range not explicitly recited. Additionally, reference to values stated in ranges includes each and every value within that range, even though not explicitly recited. Thus, every point or individual value may serve as its own lower or upper limit combined with any other point or individual value or any other lower or upper limit, to recite a range not explicitly recited.

[0052] Other objects, features and advantages of the disclosure will become apparent from the foregoing figures, detailed description, and examples. It should be understood, however, that the figures, detailed description, and examples, while indicating specific embodiments of the disclosure, are given by way of illustration only and are not meant to be limiting. In further embodiments, features from specific embodiments may be combined with features from other embodiments. For example, features from one embodiment may be combined with features from any of the other embodiments. In further embodiments, additional features may be added to the specific embodiments described herein.

Claims

What is claimed is:

1. A method for producing light olefins from a natural gas liquid stream, the method comprising:

supplying a natural gas liquid (NGL) stream to a reverse isomerization unit to produce a n-pentane enriched NGL stream;

supplying the n-pentane enriched NGL stream to a liquid furnace to produce a pyrolyzed product stream, the pyrolyzed product stream comprising C2 hydrocarbons, C3 hydrocarbons, C4 hydrocarbons, C5 hydrocarbons, and C6+ hydrocarbons;

separating the C2 hydrocarbons, the C3 hydrocarbons, the C4 hydrocarbons, the C5 hydrocarbons, and the C6+ hydrocarbons in the pyrolyzed product stream in a separation train;

supplying the separated C5 hydrocarbons, or a portion thereof, to a first hydrogenation reactor to produce a saturated C5 hydrocarbon stream; and

recycling the saturated C5 hydrocarbon stream to the reverse isomerization unit.

2. The method according to claim 1, wherein recycling the saturated C5 hydrocarbon stream to the reverse isomerization unit increases an ethylene and/or a propylene yield at the liquid furnace.

3. The method according to claim 1 or claim 2, wherein the NGL stream is formed from the combination of a fresh natural gas liquid feed and the saturated C5 hydrocarbon stream produced at the first hydrogenation reactor.

4. The method according to any one of claims 1-3, further comprising:

supplying the separated C4 hydrocarbons, or a portion thereof, to a second hydrogenation reactor to produce a saturated C4 hydrocarbon stream;

recycling the saturated C4 hydrocarbon stream to the reverse isomerization unit.

5. The method according to any one of claims 1-3, further comprising:

supplying the separated C4 hydrocarbons, or a portion thereof, to the first hydrogenation reactor to produce a combined saturated C4 hydrocarbon and saturated C5 hydrocarbon stream; and

recycling the combined saturated C4 and C5 hydrocarbon stream to the reverse isomerization unit.

6. The method according to claim 5, wherein the NGL stream is formed from the combination of a fresh natural gas liquid feed and the combined saturated C4 and C5 hydrocarbon stream produced at the first hydrogenation reactor.

7. The method according to claim 4, wherein the NGL stream is formed from the combination of a fresh natural gas liquid feed, the saturated C5 hydrocarbon stream produced at the first hydrogenation reactor, and the saturated C4 hydrocarbon stream produced at the second hydrogenation reactor.

8. The method according to any one of claims 1-7, further comprising:

supplying the C4 hydrocarbons separated from the pyrolyzed product stream to a butadiene and but-1-ene processing unit to produce a butadiene stream, a butene-1 stream, and a C4 raffinate stream;

supplying the C4 raffinate stream to the first hydrogenation reactor or the second hydrogenation reactor to produce a saturated C4 hydrocarbon stream; and

supplying the saturated C4 hydrocarbon stream to the reverse isomerization unit.

9. The method according to claim 8, further comprising:

separating, at a debutanizer unit, C4 hydrocarbons from the pyrolyzed product stream, or a portion thereof, to produce a separated C4 hydrocarbon stream; and

supplying the separated C4 hydrocarbon stream to the butadiene and but-1-ene processing unit.

10. The method according to any one of claims 1-9, further comprising:

supplying the pyrolyzed product stream to a product recovery section of the

separation train operable to separate propylene and ethylene from the pyrolyzed product stream to produce a C4+ hydrocarbon stream;

supplying the C4+ hydrocarbon stream to a debutanizer to produce a separated C4 hydrocarbon stream and a C5+ hydrocarbon stream;

supplying the C5+ hydrocarbon stream to a depentanizer to produce a separated C5 hydrocarbon stream and a C6+ hydrocarbon stream; and

supplying the separated C5 hydrocarbon stream to the first hydrogenation reactor.

11. The method according to any one of claims 1-10, further comprising:

supplying the C5+ hydrocarbon stream or the separated C5 hydrocarbon stream to a gas hydro treatment reactor prior to supplying the C5 hydrocarbon stream to the first hydrogenation reactor.

12. A system for producing light olefins from a natural gas liquid stream, the system comprising:

a reverse isomerization unit operable to receive a natural gas liquid (NGL) stream, the reverse isomerization unit further operable to isomerize the NGL stream to produce a n-pentane enriched NGL stream;

a liquid furnace operable to receive the n-pentane enriched NGL stream, the liquid furnace further operable to pyrolyze the n-pentane enriched NGL stream to produce a pyrolyzed product stream, the pyrolyzed product stream comprising C2 hydrocarbons, C3 hydrocarbons, C4 hydrocarbons, C5 hydrocarbons, and C6+ hydrocarbons;

a separation train operable to separate the C2 hydrocarbons, the C3 hydrocarbons, the C4 hydrocarbons, the C5 hydrocarbons, and the C6+ hydrocarbons in the pyrolyzed product stream; and

a first hydrogenation reactor operable to receive the separated C5 hydrocarbons, or a portion thereof, the first hydrogenation reactor further operable to hydrogenate the separated C5 hydrocarbons, or a portion thereof, to produce a saturated C5 hydrocarbon stream;

the reverse isomerization unit further operable to receive the saturated C5 hydrocarbon stream.

13. The system according to claim 12, wherein the separation train comprises:

a product recovery section configured to receive the pyrolyzed product stream produced by the liquid furnace, the product recovery section further configured to separate propylene and ethylene from the pyrolyzed product stream to produce a C4+ hydrocarbon stream;

a debutanizer configured to receive the C4+ hydrocarbon stream produced by the product recovery section, the debutanizer further configured to debutanize the C4+ hydrocarbon stream to produce a separated C4 hydrocarbon stream and a C5+ hydrocarbon stream; and

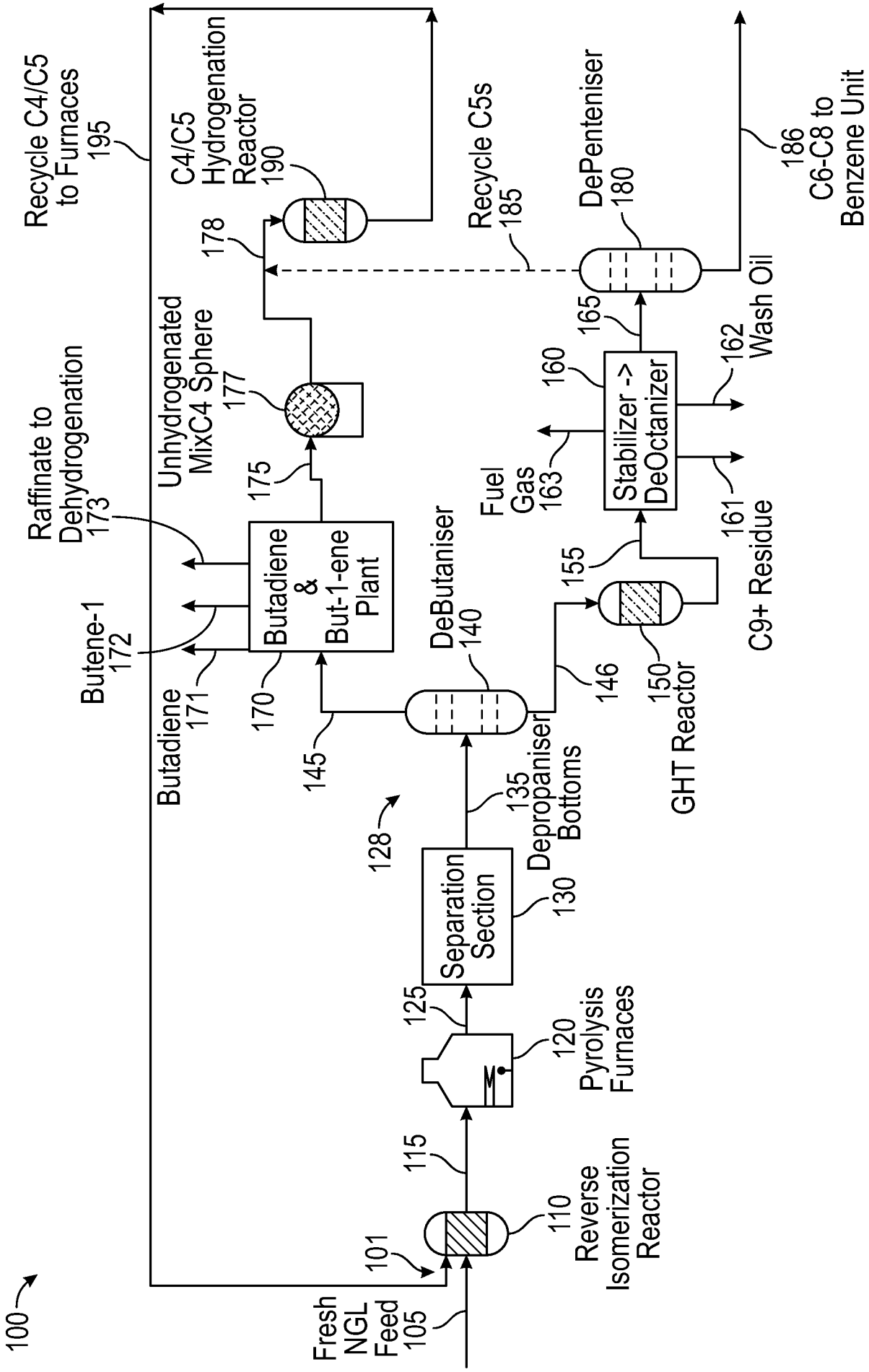
a dependanizer configured to receive the C5+ hydrocarbon stream produced by the debutanizer, the dependanizer further configured to dependenize the C5+ hydrocarbon stream to produce a separated C5 hydrocarbon stream and a C6+ hydrocarbon stream;

wherein the first hydrogenation reactor is operable to receive the separated C5 hydrocarbon stream produced by the dependanizer.

14. The system according to claim 12 or claim 13, further comprising:

a gas hydro treatment reactor configured to receive the C5+ hydrocarbon stream produced by the debutanizer or the separated C5 hydrocarbon stream produced by the dependanizer prior to supplying the C5 hydrocarbon stream to the first hydrogenation reactor.

15. The system according to claim 12 or claim 13, or claim 14, wherein the reverse isomerization unit is operated at a temperature of from about 240°C to about 440°C and at a pressure of from about 15 bar to about 30 bar.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Fresh NGL Feed 105
101
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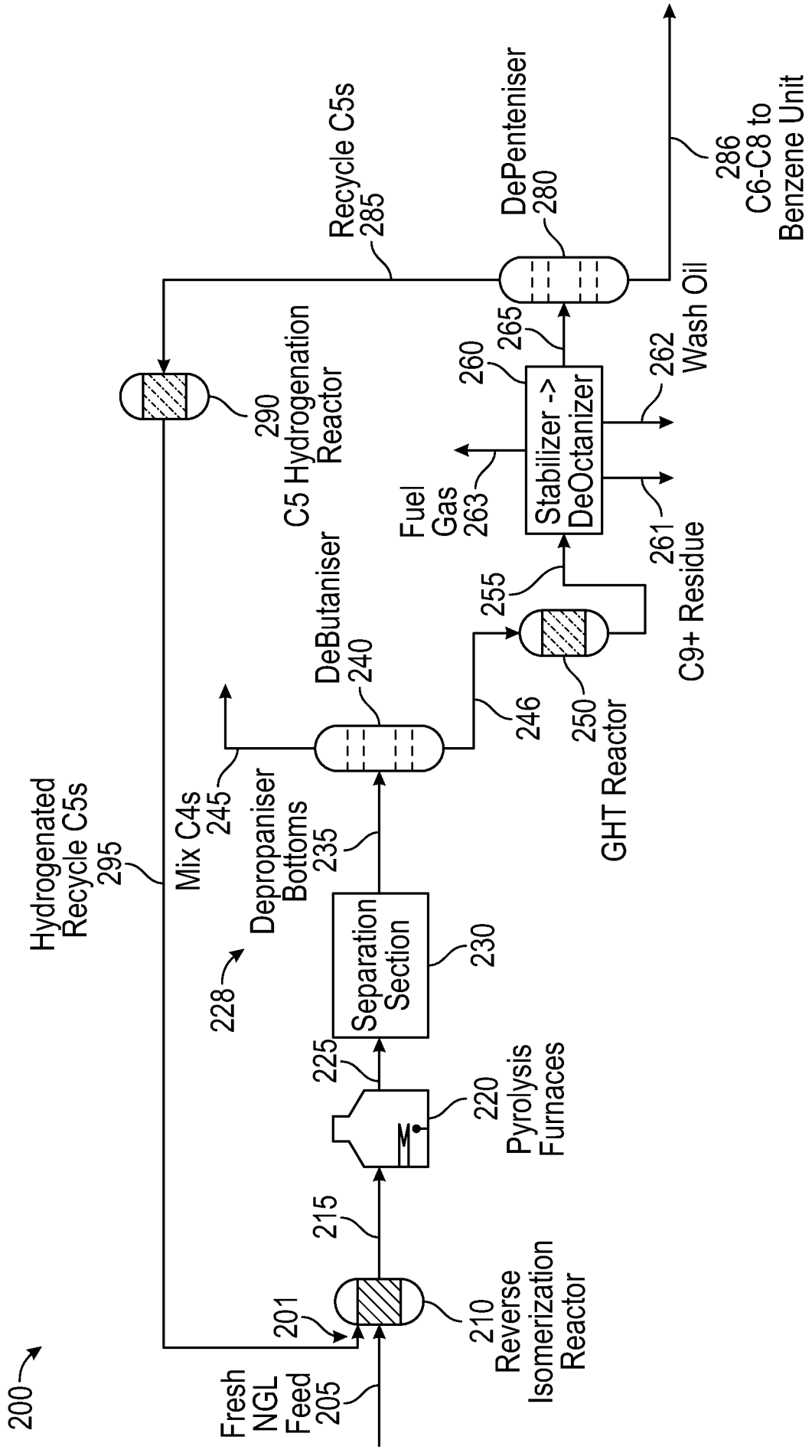
Reverse Isomerization Reactor 110
Pyrolysis Furnaces 120
125
Separation Section 130
128
Depropaniser Bottoms 135
DeButaniser 140
145
146
GHT Reactor 150
155
Stabilizer -> DeOctanizer 160
Fuel Gas 163
C9+ Residue 161
Wash Oil 162
165
DePenteniser 180
C6-C8 to Benzene Unit 186
Recycle C5s 185
C4/C5 Hydrogenation Reactor 190
178
Recycle C4/C5 to Furnaces 195
Unhydrogenated MixC4 Sphere 177
175
Butadiene & But-1-ene Plant
170
Butadiene 171
Butene-1 172
Raffinate to Dehydrogenation 173

FIG. 1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201
210 Reverse Isomerization Reactor
215
220 Pyrolysis Furnaces
225
Separation Section 230
228
Depropaniser Bottoms 235
Hydrogenated Recycle C5s 295
Mix C4s 245
DeButaniser 240
246
255
GHT Reactor 250
290 C5 Hydrogenation Reactor
Recycle C5s 285
DePenteniser 280
286 C6-C8 to Benzene Unit
260
265
Stabilizer -> DeOctanizer
262 Wash Oil
Fuel Gas 263
261 C9+ Residue

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2023/061239

A. CLASSIFICATION OF SUBJECT MATTER
INV. F25J3/00 C07C4/04 C07C5/03 C07C5/27 C10G11/00
C10G69/00 C07C11/04 C07C11/06 C07C11/08 C07C11/167
C07C9/14 C07C9/15

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 F25J C10G

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/171704 A1 (ERISKEN SELMAN ZIYA [US] ET AL) 19 June 2014 (2014-06-19) paragraph [0015] - paragraph [0017] paragraph [0022] - paragraph [0026] paragraph [0028] - paragraph [0029] figure * claims	1-15
X	US 2019/337869 A1 (ERISKEN SELMAN ZIYA [US] ET AL) 7 November 2019 (2019-11-07)	12-14
A	paragraph [0026] - paragraph [0033]; figure 1	1-11
A	US 2019/062655 A1 (HOUSMANS THOMAS HUBERTUS MARIA [NL] ET AL) 28 February 2019 (2019-02-28) paragraph [0091] - paragraph [0114] figure 1	1-15

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 January 2024	08/02/2024

Name and mailing address of the ISA/	Authorized officer
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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2023/061239

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 10 260 011 B2 (SAUDI BASIC IND CORP [SA]; SABIC GLOBAL TECHNOLOGIES BV [NL]) 16 April 2019 (2019-04-16) column 9, line 45 - column 11, line 37; figure 5 column 14, line 4 - column 17, line 27 example 3 -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2023/061239

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014171704 A1	19-06-2014	US 2014171704 A1	19-06-2014
		WO 2014093016 A1	19-06-2014
US 2019337869 A1	07-11-2019	CN 109790475 A	21-05-2019
		KR 20190020775 A	04-03-2019
		US 2019337869 A1	07-11-2019
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