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(54) **PROCESS OF PRODUCING TOLUENE**

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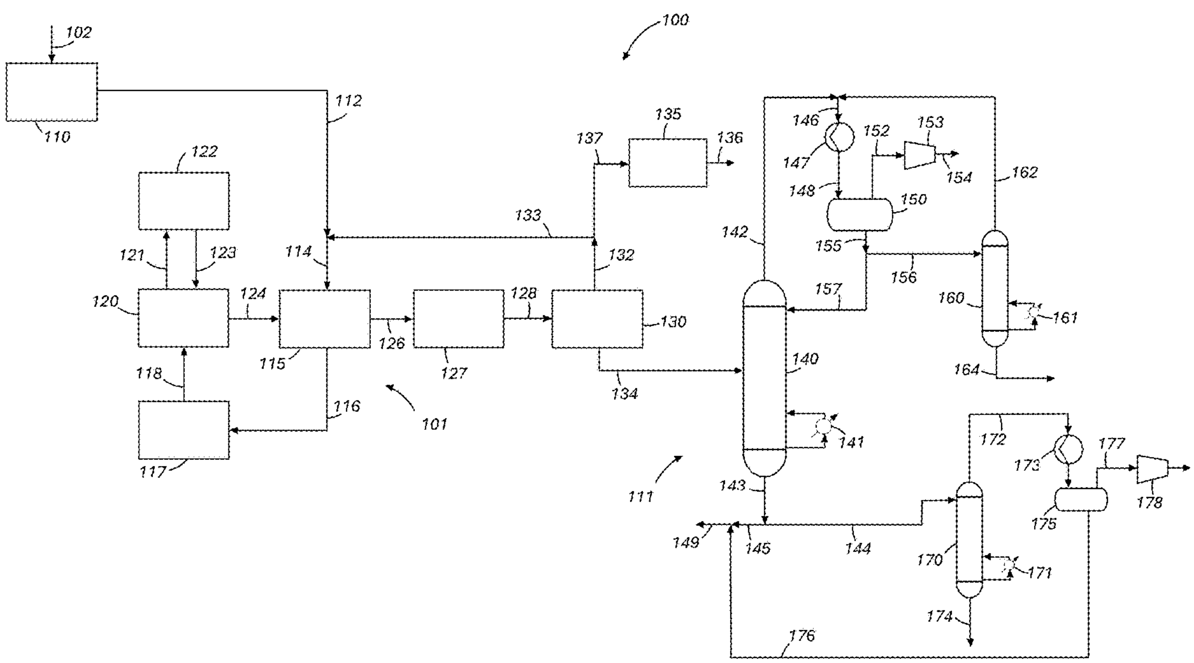
(57) **ABSTRACT**

A process of producing toluene is disclosed. The process comprises contacting a hydrocarbonaceous feed stream with a dehydrogenation catalyst to produce a dehydrogenated effluent stream. The dehydrogenated effluent stream is separated into a vapor stream comprising hydrogen and a liquid stream. The liquid stream is fractionated to provide a fractionator overhead stream comprising C7-hydrocarbons and a fractionator bottoms stream comprising toluene. The fractionator overhead stream is passed to a stabilizer column to provide an offgas stream.



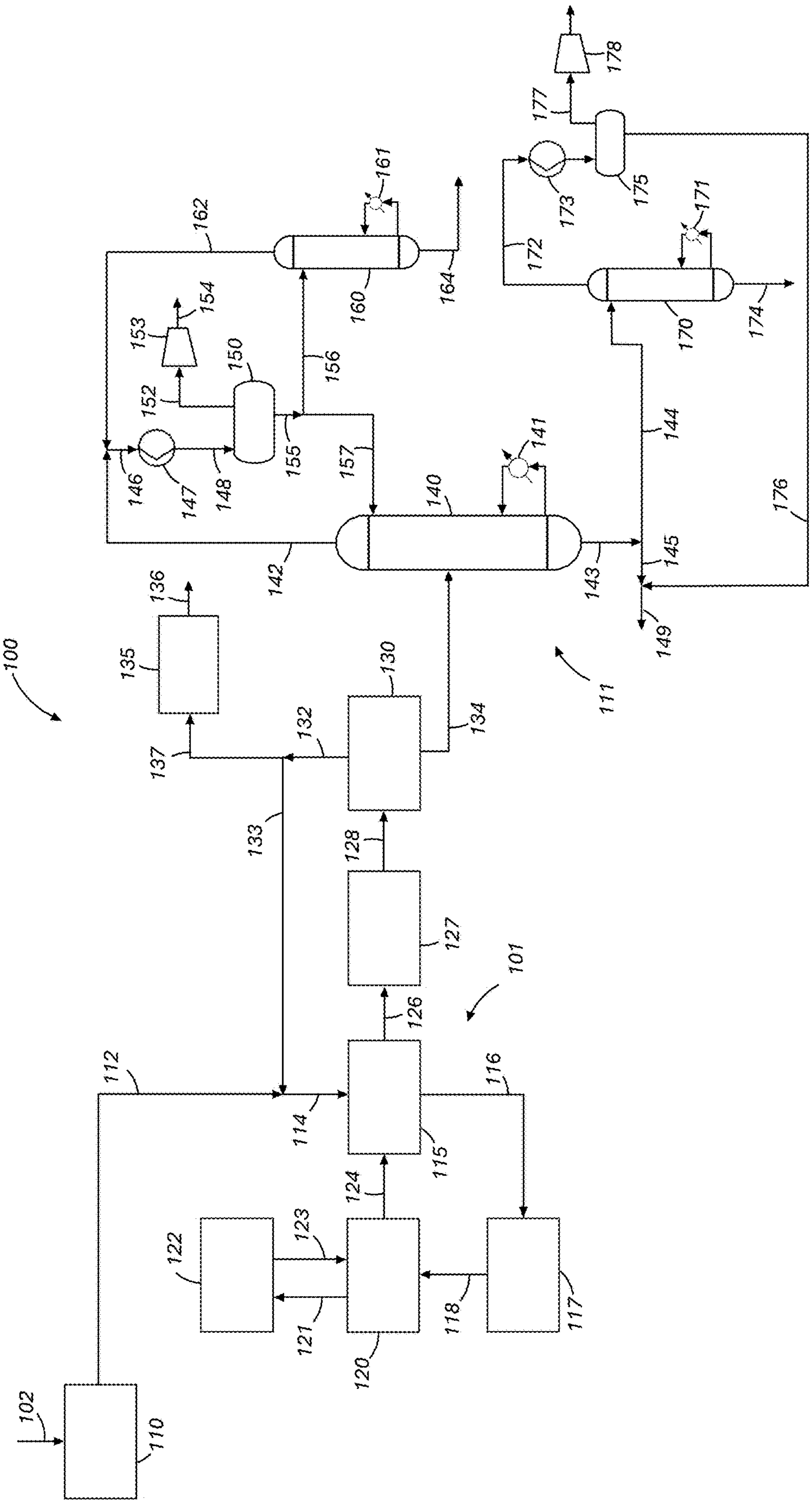

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FIGURE

PROCESS OF PRODUCING TOLUENE

FIELD

[0001] The field is the process of producing toluene. The field may particularly relate to separating hydrogen and toluene from a hydrocarbonaceous stream.

BACKGROUND

[0002] Hydrogen is expected to have significant growth potential because it is a clean-burning fuel. However, hydrogen production processes based on steam reforming, autothermal reforming, partial oxidation, or gasification of hydrocarbon or carbonaceous feedstocks are significant emitters of carbon dioxide. Government regulations and societal pressures are increasingly taxing or penalizing carbon dioxide emissions or incentivizing carbon dioxide capture. Hydrogen produced by the electrolysis of water can be powered by solar and wind without involving the production of carbon dioxide. Hydrogen produced in this manner could meet projected global energy demand in the future and play a vital role in reducing carbon dioxide emissions. The recently renewed interest in alternative energy sources and energy carriers opens up new prospects for this process to be applied as a feed system for fuel cells, power generation and many more applications.

[0003] Hydrogen is a clean, efficient energy carrier in various mobile fuel-cell applications and has no adverse effects on the environment and human health. With the increase in global demand for hydrogen, solutions need to be developed to transport hydrogen especially to locations which are renewable depleted. Hydrogen generated by renewable energy is called green hydrogen. Green hydrogen is expected to be an important element in the future carbon-neutral economy and may need to be transported to locations as far as 8000 km from the source of generation.

[0004] There exists a large regional disparity in the cost of production of hydrogen. A number of technologies have been developed for transporting hydrogen, including ammonia, liquid hydrogen, and liquid organic hydrogen carrier (LOHC) to address this disparity. Toluene-methylcyclohexane (MCH) is expected to be a significant player in LOHC considering numerous advantages, such as easy integration into the existing fuel sector supply chain and distribution network, utilization in idle refinery assets, flexibility for co-processing, and higher relative safety handling.

[0005] LOHC involves the reversible dehydrogenation reaction of methylcyclohexane (MCH) to produce toluene (TOL) and hydrogen. It has been proposed as a solution for the storage, transportation, and distribution of hydrogen produced from renewable energy sources. For power generation, the hydrogen from this process is usually compressed for a downstream power generation unit. Typically, purity requirements for power generation unit are very stringent. Due to the relatively high cost associated with green hydrogen production, it is necessary to recover almost all hydrogen.

[0006] The process of recovering toluene from MCH is highly selective but may lead to the formation of byproducts that will build up in the carrier loop. These byproducts need to be removed before they cause problems with catalyst or equipment life. Also, the energy required to remove these byproducts must be minimized in order to avoid consuming valuable hydrogen product or consuming energy from carbon-emitting sources.

[0007] Accordingly, there is a need to have more effective and efficient ways to purify and transport hydrogen and in particular hydrogen produced from a renewable resource.

BRIEF SUMMARY

[0008] A process for producing toluene is provided. The process comprises contacting a hydrocarbonaceous feed stream with a dehydrogenation catalyst to produce a dehydrogenated effluent stream. The dehydrogenated effluent stream is separated into a vapor stream comprising hydrogen and a liquid stream. The liquid stream is fractionated to provide a fractionator overhead stream comprising C7-hydrocarbons and a fractionator bottoms stream comprising toluene. The fractionator overhead stream is passed to a stabilizer column to provide an offgas stream.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The FIGURE is a schematic drawing of an exemplary embodiment of a process and apparatus of the present disclosure.

DEFINITIONS

[0010] The term "communication" means that fluid flow is operatively permitted between enumerated components, which may be characterized as "fluid communication".

[0011] The term "downstream communication" means that at least a portion of fluid flowing to the subject in downstream communication may operatively flow from the object with which it fluidly communicates.

[0012] The term "upstream communication" means that at least a portion of the fluid flowing from the subject in upstream communication may operatively flow to the object with which it fluidly communicates.

[0013] The term "direct communication" or "directly" means that fluid flow from the upstream component enters the downstream component without passing through any other intervening vessel.

[0014] The term "indirect communication" means that fluid flow from the upstream component enters the downstream component after passing through an intervening vessel.

[0015] The term "column" means a distillation column or columns for separating one or more components of different volatilities. Unless otherwise indicated, each column includes a condenser on an overhead of the column to condense and reflux a portion of an overhead stream back to the top of the column and a reboiler at a bottom of the column to vaporize and send a portion of a bottoms stream back to the bottom of the column. Feeds to the columns may be preheated. The top pressure is the pressure of the overhead vapor at the vapor outlet of the column. The bottom temperature is the liquid bottom outlet temperature. Overhead lines and bottoms lines refer to the net lines from the column downstream of any reflux or reboil to the column. Stripper columns may omit a reboiler at a bottom of the column and instead provide heating requirements and separation impetus from a fluidized inert media such as steam. Stripping columns typically feed a top tray and take main product from the bottom.

[0016] As used herein, the term "a component-rich stream" means that the rich stream coming out of a vessel has a greater concentration of the component than the feed to the vessel.

[0017] As used herein, the term "a component-lean stream" means that the lean stream coming out of a vessel has a smaller concentration of the component than the feed to the vessel.

[0018] As used herein, the term "separator" means a vessel which has an inlet and at least an overhead vapor outlet and a bottoms liquid outlet and may also have an aqueous stream outlet from a boot. A flash drum is a type of separator which may be in downstream communication with a separator that may be operated at higher pressure.

[0019] The term "Cx" is to be understood to refer to molecules having the number of carbon atoms represented the subscript "x". Similarly, the term "Cx−" refers to molecules that contain less than or equal to x and preferably x and less carbon atoms. The term "Cx+" refers to molecules with more than or equal to x and preferably x and more carbon atoms.

DETAILED DESCRIPTION

[0020] The liquid organic hydrogen carrier (LOHC) process involves hydrogenating toluene to methylcyclohexane (MCH) at a first location, transferring the MCH to a second location, and dehydrogenating the MCH to toluene and hydrogen at the second location. To ensure minimal loss of hydrogen, the dehydrogenation process must be performed with no by-products or efficiently removing the by-products. MCH acts as a liquid organic hydrogen carrier, and it can be transferred in storage vessels and/or pipelines for several thousands of miles to the final destination with very minimal to no degradation. The LOHC process helps address the supply and demand gap of blue and green hydrogen as well as the huge differential cost of production between regions.

[0021] The present disclosure provides a process and apparatus to optimize the purification loop/system for separating hydrogen from MCH to minimize the energy consumption, maximize the hydrogen and toluene yield and the sustainability of the process.

[0022] A hydrocarbon stream comprising methylcyclohexane may be produced at a location and transferred to a second location. The methylcyclohexane feed stream from the storage tanks which may not be completely dry or nitrogen-blanketed may be treated in an oxygen stripper before being routed to the dehydrogenation reactor section. The methylcyclohexane feed may be mixed with a recycle methylcyclohexane stream for example which may be taken from a purification section. The methylcyclohexane feed may be mixed with the hydrogen and preheated for example by exchange with a reactor effluent stream. The temperature of the methylcyclohexane feed may be raised to the reaction temperature in the convection section of a charge heater and passed to the dehydrogenation reactor section. The dehydrogenation reactor section may comprise one or more dehydrogenation reactor(s). The methylcyclohexane feed is charged to the dehydrogenation reactor(s). The dehydrogenation reactor(s) may be radial flow reactors. Interheaters may be used to raise the reactor effluent back to the desired reactor inlet temperature for the next dehydrogenation reactor. The effluent from the last dehydrogenation reactor is cooled in a combined feed exchanger and the product condenser before passing to the separator.

[0023] In the separator, the reactor effluent is separated into vapor and liquid streams. The separator vapor may be separated into net gas and recycle gas. The recycle gas may be sent back to be mixed with the feed. The net gas is the hydrogen gas product stream which may be passed to the hydrogen gas compression section. Toluene-rich liquid from the separator is pumped to the purification section.

[0024] The hydrogen gas compression section may comprise one or more hydrogen gas compressor(s) which provide sufficient pressure to meet hydrogen purity requirements. The hydrogen purity increases through each stage of compression.

[0025] The purification section may comprise a deheptanizer column and a stabilizer column. The present disclosure provides passing the toluene-rich liquid from the separator first to the deheptanizer column. Applicants found that placing the deheptanizer column upstream of the stabilizer significantly reduces the reflux stream to both the deheptanizer column and the stabilizer column. Also, the disclosed process reduces the number of stages required in the deheptanizer column for the separation of toluene. Also, the deheptanizer column is operated at a pressure as low as possible order to minimize reboiler duty and the column temperature. Moreover, the purification section of the present disclosure comprises a rerun column to remove heavy contaminants. A vent compressor is required to recover the small vapor stream from the deheptanizer column and deliver it to the fuel gas system. The rerun column may also be operated at a pressure as low as possible to be able to recover as much toluene as possible.

[0026] In the deheptanizer column, toluene is separated in the toluene-rich liquid bottoms stream. The overhead stream comprising C7-hydrocarbons and light gases is condensed and passed to the stabilizer column. A reflux stream is taken from the condensed liquid stream. The stabilizer column separates offgas comprising hydrogen, methane and traces of C5-6 hydrocarbons from a liquid stream comprising C6-7 hydrocarbons, dimethylcyclopentane (DMCP), and ethylcyclopentane (ECP). The offgas stream can be sent to the refinery or used as fuel gas, for example.

[0027] The toluene-rich liquid bottoms stream may be passed to the rerun column to separate a heavy stream comprising C8-16 hydrocarbons and provide a toluene product stream.

[0028] FIGURE illustrates an exemplary embodiment of the process of producing toluene **100**. The process **100** comprises a dehydrogenation reaction section **101** and a purification section **111**. A hydrocarbonaceous stream is taken from a storage tank in line **102** and passed to the dehydrogenation reaction section **101**. In an aspect, the hydrocarbonaceous stream in line **102** may be taken from a saturation unit. The feed stream to the saturation unit may comprise an aromatic hydrocarbons stream and a hydrogen stream produced from renewable sources for example "green hydrogen" or "blue hydrogen". In an exemplary embodiment, the hydrocarbonaceous stream in line **102** comprises MCH. In another exemplary embodiment, the hydrocarbonaceous stream in line **102** comprises one or both of MCH and toluene. In an aspect, the dehydrogenation reaction section **101** may comprise an oxygen stripper **110**, a combined feed exchanger **115**, a charge heater **117**, and a dehydrogenation reactor **120**.

[0029] The hydrocarbonaceous stream in line **102** is passed to the oxygen stripper **110** to remove oxygen and provide a stripped hydrocarbonaceous stream in line **112**. The stripped hydrocarbonaceous stream in line **112** may be combined with a recycle hydrogen stream in line **133** forming a combined feed stream in line **114**. The combined feed stream in line **114** may be passed to a combined feed exchanger **115** to preheat the combined feed stream in line **114** by heat exchange with a dehydrogenation reactor effluent stream in line **124**. In an embodiment, the oxygen stripper **110** is optional and the hydrocarbonaceous stream in line **102** may be combined with the recycle hydrogen stream to provide the combined feed stream in line **114**. A preheated combined feed stream is taken in line **116** from the combined feed exchanger **115**. The preheated combined feed stream in line **116** may be further heated in a charge heater **117** to the reactor temperature. A heated combined feed stream is taken in line **118** from the charge heater **117** and passed to the dehydrogenation reactor **120**. The dehydrogenation reactor **120** may comprise one or more dehydrogenation catalyst bed(s). In an aspect, the dehydrogenation reactor **120** may comprise one or more dehydrogenation reactor vessels to dehydrogenate the heated combined feed stream. In another aspect, the dehydrogenation reaction section **101** may comprise one or more interheater(s) **122** to heat an intermediate reactor effluent stream in line **121** to the desired reactor inlet temperature between dehydrogenation reactors. A heated intermediate reactor effluent stream may be taken in line **123** from the interheater **122** and sent back to the dehydrogenation reactor **120**.

[0030] The hydrocarbonaceous feed **102** typically comprises methylcyclohexane (MCH). This stream may be produced from a number of different processes. In the exemplary embodiment, it is envisioned that the MCH may be produced in a toluene saturation unit that will chemically bind green or blue hydrogen to a toluene stream. It is further envisioned that this toluene stream may be chemically similar to a toluene product stream of the process as described later in detail or be the toluene product stream of the process itself.

[0031] Any suitable dehydrogenation catalyst that can achieve a selectivity in the dehydrogenation of methylcyclohexane to toluene and hydrogen in excess of 99.8% can be used in the dehydrogenation reactor **120**. Suitable dehydrogenation catalysts may include, but are not limited to, alumina, a noble metal, and an alkali or alkaline earth metal. Suitable noble metals include, but are not limited to, platinum, palladium, rhodium, ruthenium, rhenium, iridium, gold, osmium, silver, or combinations thereof. Suitable alkali or alkaline earth metals include, but are not limited to, sodium, cesium, potassium, rubidium, francium, lithium, beryllium, strontium, barium, calcium, magnesium, radium, or combinations thereof.

[0032] A dehydrogenated reactor effluent stream is taken in line **124** from the dehydrogenation reactor **120** and passed to the combined feed exchanger **115**. A heat exchanged perhaps cooled dehydrogenated reactor effluent stream is taken in line **126** from the combined feed exchanger **115**. The heat exchanged dehydrogenated reactor effluent stream in line **126** may be passed to a cooler **127** to provide a further cooled dehydrogenated reactor effluent stream in line **128**. The reactions taking place in the dehydrogenation reactor **120** may include a main reaction of dehydrogenation of the MCH to toluene releasing hydrogen and may include one or more side reactions. One side reaction includes cracking of toluene to benzene and methane. Another side reaction includes isomerization of methylcyclohexane to dimethylcyclopentane (DMCP), and ethylcyclopentane (ECP). A third side reaction includes the dimerization of methylcyclohexanes to heavier molecules, such as dimethyl diphenyl compounds. These side reactions affect the overall yield and the purity of the products streams of the process **100**. The purification section **111** separates byproducts from the products streams to promote the purity of the product streams while consuming a minimum energy in the separation.

[0033] The dehydrogenation reaction section **101** further comprises a separator **130** to separate the reactor effluent into vapor and liquid streams. The cooled dehydrogenated reactor effluent stream in line **126** is passed to the separator **130** where it is separated into a separator vapor stream comprising hydrogen in line **132** and a separator liquid stream comprising toluene in line **134**. The recycle hydrogen stream is taken in line **133** from the separator vapor stream in line **132**. The remaining portion of the separator vapor stream is taken in line **137** and passed to a hydrogen compressor **135** where it is compressed to provide a hydrogen product stream which is taken in line **136**.

[0034] The separator liquid stream in line **134** is a toluene rich liquid stream, and toluene is separated from this stream. The separator liquid stream in line **134** is passed to the purification section **111**.

[0035] In an embodiment, the purification section **111** comprises a fractionation column **140**, a stabilizer column **160**, and a rerun column **170**.

[0036] In an embodiment, separator liquid stream in line **134** is fractionated in the fractionation column **140** to provide a fractionator overhead stream in line **142** and a fractionator bottoms stream in line **143**. In an exemplary embodiment, the fractionation column **140** is a deheptanizer column. The fractionator overhead stream in line **142** may comprise C7-hydrocarbons. In an embodiment, the fractionator overhead stream in line **142** may comprise benzene and C7-saturated hydrocarbons including hexanes, methylcyclopentane, cyclohexane, heptane, dimethylcyclopentane, methylcyclohexane, and ethylcyclopentane. In another embodiment, the fractionator overhead stream in line **142** may comprise light hydrocarbons, for example C3-hydrocarbons, and/or C2-hydrocarbons. Some toluene may slip to the fractionator overhead stream in line **142**. The fractionator overhead stream in line **142** may also comprise trace amounts of hydrogen and methane.

[0037] In an exemplary embodiment, the fractionation column **140** may be operated at an overhead pressure of about 34 kPa (g) (5 psig) to about 207 kPa (g) (30 psig) and a bottoms temperature of about 93° C. (200° F.) to about 177° C. (350° F.). In an aspect, the heat to the fractionation column **140** may be supplied from a reboiler **141** using steam. Alternatively, a hot oil system or any suitable hot fluid medium may be used for the reboiler **141**. Operating the fractionation column **140** at a lower pressure minimizes the duty of the reboiler **141**.

[0038] The fractionator overhead stream in line **142** may be passed to the stabilizer column. In an aspect, the fractionator overhead stream in line **142** may be combined with a stabilizer column overhead stream in line **162** to provide a combined overhead stream in line **146**. The combined overhead stream in line **146** may be cooled in an overhead heat exchanger **147** and a cooled overhead stream in line **148** is passed to an overhead receiver **150**. The cooled overhead stream in line **148** may be totally or partially condensed in the overhead receiver **150** to provide a condensed overhead liquid stream in line **155** and an offgas stream in line **152**. A reflux stream is taken in line **157** from the condensed overhead liquid stream in line **155**. In an embodiment, the reflux stream in line **157** may be passed to the fractionation column **140** at a reflux to feed ratio of about 0.02 to 0.5. In another embodiment, the reflux stream in line **157** may be passed to the fractionation column **140** at a reflux to feed ratio of about 0.03 to 0.4. In another embodiment, the reflux stream in line **157** may be passed to the fractionation column **140** at a reflux to feed ratio of about 0.04 to 0.3 or about 0.05 to 0.2. In yet another embodiment, the reflux stream in line **157** may be passed to the fractionation column **140** at a reflux to feed ratio of about 0.1 to about 0.1.

[0039] For complete conversion of the methylcyclohexane to toluene and hydrogen in the dehydrogenation reactor **120**, the separator liquid stream in line **134** may not comprise a significant amount of methylcyclohexane. The present process does not require a recycle stream of methylcyclohexane from the fractionation column **140** to the dehydrogenation reactor **120** for complete conversion in the dehydrogenation reactor **120**. With no recycle stream from the fractionation column **140**, the fractionation column of the current process may be run at a much lower reflux to feed ratio. Also, the fractionation column **140** of the current process requires a much smaller number of stages even as low as 50% of the number of stages when compared with a fractionation column with a recycle stream. For the situation with limited methylcyclohexane conversion in the dehydrogenation reactor such as revamps, some methylcyclohexane may be present in the separator liquid stream in line **134**. Under limited conversion conditions, a recycle stream may be taken from the fractionation column and passed to the dehydrogenation reactor **120**.

[0040] A fractionator overhead liquid stream is taken in line **156** from the condensed overhead liquid stream in line **155**. The fractionator overhead liquid stream in line **156** is a net liquid stream from the overhead receiver **150**. The net liquid stream in line **156** is passed to the stabilizer column **160**. The stabilizer column removes the byproducts and/or impurities from the process in a bottoms stream in line **164**. In an aspect, the stabilizer column bottoms stream in line **164** may comprise benzene and C7-saturated hydrocarbons such as hexane, methylcyclopentane, cyclohexane, heptane, dimethylcyclopentane, methylcyclohexane, and ethylcyclopentane. The stabilizer column overhead stream in line **162** may comprise hydrogen and methane. The stabilizer column overhead stream in line **162** may be recycled. The stabilizer column overhead stream in line **162** may be combined with the fractionator overhead stream in line **142** to provide the combined overhead stream in line **146** and passed to the overhead receiver **150**. The offgas stream may be taken in line **152** from the overhead receiver **150**, compressed in an overhead compressor **153** to provide a compressed offgas stream in line **154**. The compressed offgas stream in line **154** may comprise hydrogen and methane. The compressed offgas stream in line **154** may be used in the process, for example, burned to provide heat to the reactor or the column or it may be sent to an off-site utility. In an aspect, at least a portion of the compressed offgas stream in line **154** may be recycled to the hydrogen compressor **135**. The compressed offgas stream in line **154** may be recycled to the hydrogen compressor **135** with the separator vapor stream in line **137** to recover hydrogen into the hydrogen product stream **136**. In an embodiment, about 50 vol % to about 70 vol % of the compressed offgas stream in line **154** may be recycled to the hydrogen compressor **135**.

[0041] In an embodiment, the stabilizer column **160** may be operated at an overhead pressure of about 34 kPa (g) (5 psig) to about 207 kPa (g) (30 psig) and a bottoms temperature of about 65° C. (150° F.) to about 122° C. (250° F.). In an aspect, the heat to the stabilizer column **160** may be supplied from a reboiler **161** using steam. Alternatively, a hot oil system or any suitable hot fluid medium may be used for the reboiler **161**.

[0042] Referring back to the fractionation column **140**, the fractionator bottoms stream in line **143** may be separated to provide a first liquid stream in line **144** and a second liquid stream in line **145**. The fractionator bottoms stream in line **143** may comprise aromatic hydrocarbons. Preferably, the fractionator bottoms stream in line **143** may comprise toluene. The first liquid stream in line **144** may be further processed to separate the toluene. In an embodiment, the first liquid stream in line **144** may be passed to the rerun column **170** to separate heavies from the toluene. In an embodiment, the rerun column **170** may be operated at an overhead pressure of below atmospheric pressure or vacuum pressure. In an exemplary embodiment, the rerun column **170** may be operated at an overhead pressure of about −69 kPa (g) (−10 psig) to about 95 kPa(a) (13.8 psia) or about −6 kPa (g) (−1 psig) to about 32 kPa(a) (4.7 psia). In another exemplary embodiment, the rerun column **170** may be operated at atmospheric pressure. In an embodiment, the rerun column **170** may be operated at a bottom temperature of about 65° C. (150° F.) to about 149° C. (300° F.). In an aspect, the heat to the rerun column **170** may be supplied from a reboiler **171** using steam. Alternatively, a hot oil system or any suitable hot fluid medium may be used for the reboiler **171**. A heavy stream is separated in the rerun column **170** bottoms and taken in line **174**. In an embodiment, the heavy stream in line **174** may comprise C8-C16 aromatics and multi-ring aromatics but may also include some toluene.

[0043] A rerun overhead stream comprising toluene is taken in line **172** from the rerun column **170**. The rerun overhead stream comprising toluene in line **172** may be cooled in a heat exchanger **173** and a cooled rerun overhead stream is passed to a rerun overhead receiver **175**. The rerun overhead stream **172** is further cooled in the rerun overhead receiver **175** to provide a toluene stream in line **176**. A vacuum pump **178** is provided at the overhead of the rerun column **170** on the stream **177** from the overhead receiver **175** to operate the rerun column **170** at a pressure as low as possible. The recovered toluene stream in line **176** may be combined with the second liquid stream in line **145** to provide a toluene product stream in line **149**.

[0044] While the foregoing embodiment envisages the use of methylcyclohexane (MCH) and toluene as the liquid organic hydrogen carrier (LOHC), the alternative, similar LOHC systems may benefit from the disclosed process. Examples may include cyclohexane and benzene; dimethylcyclohexanes and xylenes; and trimethylcyclohexanes and trimethylbenzenes.

[0045] The foregoing process and apparatus provide an efficient way of producing hydrogen from a hydrocarbonaceous stream.

EXAMPLE

[0046] A simulation study was performed to compare an exemplary embodiment of the process of the present disclosure with another process wherein a recycle stream was taken from the deheptanizer column **140** to the dehydrogenation reactor **120**. For this study, the feed stream to both the process had the same concentration of heavies, ethylcyclopentane, and dimethylcyclopentane. The results including the various parameters, yield, and heat duty of the column are summarized in Table 1 below:

TABLE 1

	Exemplary embodiment of the present disclosure			Process with recycle stream		
	Deheptanizer	Stabilizer	Rerun	Deheptanizer	Stabilizer	Rerun
No. of stages	32	5	10	60	5	10
Column overhead pressure, kPa(g)	104	83	−46	104	83	-46
Reflux/feed ratio	0.15	—	—	1.85	—	—
Reboiler duty, MMBTU/hr	13.3	0.05	10.5	55.7	0.05	5.9
Condenser duty, MMBTU/hr	5.2	—	15.35	52.3		5.95
Feed-bottoms exchanger duty	6.9	—	—	10.95	—	—
% Recovery from Toluene purification section						
Toluene recovery		99.9			98.2	
C7 cyclopentanes rejection		20.5			20	
Heavies rejection		49.8			19.7	

[0047] The results in Table 1 show that the current process required much lower deheptanizer column reboiler duty. Also, the current process provided a higher toluene recovery and higher (over 200%) heavies rejection from the process.

SPECIFIC EMBODIMENTS

[0048] 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.

[0049] A first embodiment of the present disclosure is a process of producing aromatic hydrocarbons, comprising contacting a hydrocarbonaceous feed stream with a dehydrogenation catalyst to produce a dehydrogenated effluent stream; separating the dehydrogenated effluent stream into a vapor stream comprising hydrogen and a liquid stream; fractionating the liquid stream to provide a fractionator overhead stream and a fractionator bottoms stream; and passing the fractionator overhead stream to a stabilizer column to provide an offgas stream. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the hydrocarbonaceous feed stream comprises methylcyclohexane. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the hydrocarbonaceous feed stream comprises aromatic hydrocarbons. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein the stabilizer column also provides a bottoms stream comprising C7 cyclopentanes. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising separating a heavy stream from the fractionator bottoms stream. 5 An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising separating the fractionator bottoms stream into a first liquid stream and a second liquid stream; fractionating the first liquid stream in a rerun column to separate heavies from a recovered aromatics; and combining the recovered aromatics with the second liquid stream to provide an aromatics product stream. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the first liquid stream is fractionated in a rerun column operating at an overhead pressure of about 32 kPa(a) (4.7 psia) to about 95 kPa(a) (13.8 psia). An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising fractionating the first liquid stream into an overhead stream comprising toluene and a bottoms stream heavy stream; condensing the overhead stream comprising toluene to provide a toluene stream and a bottoms gas stream; and combining the toluene stream with the second liquid stream to provide a toluene product stream. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising combining a fractionated overhead stream with a stabilizer column overhead stream to provide a combined overhead stream; condensing the combined overhead stream to provide a condensed overhead liquid and the offgas stream; and passing a reflux stream taken from the condensed overhead liquid to the fractionation column. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein the reflux stream is passed to the fractionation column at a reflux to feed ratio of about 0.05 to about 0.5. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, further comprising taking a net liquid stream from the condensed overhead liquid as the fractionator overhead stream. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the rerun column is operated at a vacuum pressure. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the dehydrogenation catalyst comprises Al_2O3, a noble metal, and an alkali or alkaline earth metal. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising separating the vapor stream into a recycle hydrogen stream and a product hydrogen stream for further compression and distribution. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the hydrocarbonaceous feed stream is taken from a saturation unit, and wherein a feed stream to the saturation unit comprises an aromatic hydrocarbons stream and a hydrogen stream produced from renewable sources.

[0050] A second embodiment of the present disclosure is a process of producing aromatic hydrocarbons, comprising contacting a hydrocarbonaceous feed stream with a dehydrogenation catalyst to produce a dehydrogenated effluent stream; separating the dehydrogenated effluent stream into a vapor stream comprising hydrogen and a liquid stream; fractionating the liquid stream in a fractionation column to provide a fractionator overhead stream and a fractionator bottoms stream comprising aromatics hydrocarbons; and passing the fractionator overhead stream to a stabilizer column to provide an offgas stream. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, wherein the fractionator bottoms stream comprises toluene. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, wherein the hydrocarbonaceous feed stream comprises methylcyclohexane.

[0051] A third embodiment of the present disclosure is a process of producing aromatic hydrocarbons, comprising contacting a hydrocarbonaceous feed stream comprising methylcyclohexane with a dehydrogenation catalyst to produce a dehydrogenated effluent stream; separating the dehydrogenated effluent stream into a vapor stream comprising hydrogen and a liquid stream; fractionating the liquid stream in a fractionation column to provide a fractionator overhead stream and a fractionator bottoms stream comprising aromatics hydrocarbons; and passing the fractionator overhead stream to a stabilizer column to provide an offgas stream. An embodiment of the present disclosure is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph, wherein the fractionator bottoms stream comprises toluene.

[0052] Without further elaboration, it is believed that using the preceding description that one skilled in the art can utilize the present disclosure to its fullest extent and easily ascertain the essential characteristics of this disclosure, without departing from the spirit and scope thereof, to make various changes and modifications of the present disclosure 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 way whatsoever, and that it is intended to cover various modifications and equivalent arrangements included within the scope of the appended claims.

[0053] In the foregoing, all temperatures are set forth in degrees Celsius and, all parts and percentages are by weight, unless otherwise indicated.

1. A process of producing aromatic hydrocarbons, comprising:

contacting a hydrocarbonaceous feed stream with a dehydrogenation catalyst to produce a dehydrogenated effluent stream;

separating said dehydrogenated effluent stream into a vapor stream comprising hydrogen and a liquid stream;

fractionating said liquid stream in a fractionation column to provide a fractionator overhead stream and a fractionator bottoms stream; and

passing said fractionator overhead stream to a stabilizer column to provide an offgas stream.

2. The process of claim **1**, wherein said hydrocarbonaceous feed stream comprises methylcyclohexane.

3. The process of claim **1**, wherein said hydrocarbonaceous feed stream comprises aromatic hydrocarbons.

4. The process of claim **1** wherein the stabilizer column provides a bottoms stream comprising C7-hydrocarbons.

5. The process of claim **1** further comprising separating a heavy stream from said fractionator bottoms stream.

6. The process of claim **5** further comprising:

separating said fractionator bottoms stream into a first liquid stream and a second liquid stream;

fractionating said first liquid stream in a rerun column to separate heavies from a recovered aromatics stream; and

combining said recovered aromatics stream with said second liquid stream to provide an aromatic product stream.

7. The process of claim **6**, wherein said first liquid stream is fractionated in a rerun column operating at an overhead gauge pressure of about 32 kPa(a) (4.7 psia) to about 95 kPa(a) (13.8 psia).

8. The process of claim **6** further comprising:

fractionating said first liquid stream into an overhead stream comprising toluene and a bottoms stream heavy stream;

condensing said overhead stream comprising toluene to provide a toluene stream and a bottoms gas stream; and

combining said toluene stream with said second liquid stream to provide a toluene product stream.

9. The process of claim **1** further comprising:

combining a fractionated overhead stream with a stabilizer column overhead stream to provide a combined overhead stream;

condensing said combined overhead stream to provide a condensed overhead liquid stream and said offgas stream; and

passing a reflux stream taken from said condensed overhead liquid stream to the fractionation column.

10. The process of claim **9**, wherein the reflux stream is passed to the fractionation column at a reflux to feed ratio of about 0.05 to about 0.5.

11. The process of claim **9**, further comprising taking a net liquid stream from said condensed overhead liquid as said fractionator overhead stream.

12. The process of claim **7**, wherein the rerun column is operated at a vacuum pressure.

13. The process of claim **1**, wherein the dehydrogenation catalyst comprises alumina, a noble metal, and an alkali or alkaline earth metal.

14. The process of claim **1** further comprising separating said vapor stream into a recycle hydrogen stream and a product hydrogen stream for further compression and distribution.

15. The process of claim **1** wherein said hydrocarbonaceous feed stream is taken from a saturation unit, and wherein a feed stream to the saturation unit comprises an aromatic hydrocarbons stream and a hydrogen stream produced from renewable sources.

16. A process of producing aromatic hydrocarbons, comprising:

contacting a hydrocarbonaceous feed stream with a dehydrogenation catalyst to produce a dehydrogenated effluent stream;

separating said dehydrogenated effluent stream into a vapor stream comprising hydrogen and a liquid stream;

fractionating said liquid stream in a fractionation column to provide a fractionator overhead stream and a fractionator bottoms stream comprising aromatics hydrocarbons; and

passing said fractionator overhead stream to a stabilizer column to provide an offgas stream.

17. The process of claim **16**, wherein said fractionator bottoms stream comprises toluene.

18. The process of claim **16**, wherein said hydrocarbonaceous feed stream comprises methylcyclohexane.

19. A process of producing aromatic hydrocarbons, comprising:

contacting a hydrocarbonaceous feed stream comprising methylcyclohexane with a dehydrogenation catalyst to produce a dehydrogenated effluent stream;

separating said dehydrogenated effluent stream into a vapor stream comprising hydrogen and a liquid stream;

fractionating said liquid stream in a fractionation column to provide a fractionator overhead stream and a fractionator bottoms stream comprising aromatics hydrocarbons; and

passing said fractionator overhead stream to a stabilizer column to provide an offgas stream.

20. The process of claim **19**, wherein said fractionator bottoms stream comprises toluene.

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