ENERGY CONSERVATION IN HEAVY-HYDROCARBON DISTILLATION

STATEMENT OF PRIORITY

[0001] This application claims priority to U.S. Application No. 12/868,286 filed on August 25, 2010.

FIELD OF THE INVENTION

[0002] This invention relates to an improved process for energy savings in the distillation of hydrocarbons. More specifically, the present invention concerns energy conservation within an aromatics-processing complex producing xylene isomers.

BACKGROUND OF THE INVENTION

[0003] The xylene isomers are produced in large volumes from petroleum as feedstocks for a variety of important industrial chemicals. The most important of the xylene isomers is para-xylene, the principal feedstock for polyester, which continues to enjoy a high growth rate from large base demand. Ortho-xylene is used to produce phthalic anhydride, which supplies high-volume but relatively mature markets. Meta-xylene is used in lesser but growing volumes for such products as plasticizers, azo dyes and wood preservers. Ethylbenzene generally is present in xylene mixtures and is occasionally recovered for styrene production, but is usually considered a less-desirable component of C_8 aromatics.

[0004] Among the aromatic hydrocarbons, the overall importance of xylenes rivals that of benzene as a feedstock for industrial chemicals. Xylenes and benzene are produced from petroleum by reforming naphtha but not in sufficient volume to meet demand, thus conversion of other hydrocarbons is necessary to increase the yield of xylenes and benzene. Often toluene is de-alkylated to produce benzene or selectively disproportionated to yield benzene and C_8 aromatics from which the individual xylene isomers are recovered.

[0005] An aromatics complex flow scheme has been disclosed by Meyers in the Handbook of Petroleum Refining Processes, 2d. Edition in 1997 by McGraw-Hill, and is incorporated herein by reference.

[0006] Aromatics complexes producing xylenes are substantial consumers of energy, notably in distillation operations to prepare feedstocks and separate products from conversion processes. The separation of xylenes from heavy aromatics in particular offers substantial potential for energy savings. Energy conservation in such processes would not only reduce processing costs but also would address current concerns about carbon emissions.

SUMMARY OF THE INVENTION

[0007] A broad embodiment of the present invention is a process for producing para-xylene from feed streams containing C_8 aromatics and C_9-and-heavier aromatics. The process comprises: (a) A distillation process comprising two xylene columns separating C_8 aromatics from C_9-and-heavier aromatics contained in at least one lower-boiling feed stream and at least one higher-boiling feed stream. The at least one higher-boiling feed stream has a higher content of C_9-and-heavier aromatics than the at least one lower-boiling feed stream. The distillation process comprises distilling the at least one higher-boiling feed stream in a first xylene column at a first pressure to separate a first C_8-aromatics stream from a first C_9-and-heavier aromatics stream, and distilling the at least one lower-boiling feed stream in a second xylene column at a second pressure to separate a second C_8-aromatics stream from a second C_9-and-heavier aromatics stream. The second pressure is higher than the first pressure, and an overhead stream from the second xylene column exchanges heat with a reboiler of the first xylene column. (b) A para-xylene separation process to recover para-xylene from one or both of the first and second C_8-aromatics streams by injecting the one or both C_8-aromatics streams and a desorbent stream into an adsorption process to obtain a first mixture comprising para-xylene and desorbent and a second mixture comprising a raffinate and desorbent. (c) A desorbent-recovery process to separate the second mixture of step (b) by distilling the second mixture in a prefractionator followed by a pressurized raffinate column to produce a raffinate stream and a desorbent stream, and returning the desorbent stream to the para-xylene separation process. An overhead stream of the first xylene column of step (a) provides heat to a reboiler of the pressurized raffinate column.

[0008] Additional objects, embodiments and details of this invention can be obtained and inferred from the following detailed description of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 schematically illustrates an aromatics complex in which energy-savings concepts could be applied.

[0010] FIG. 2 illustrates an aromatics complex in which energy conservation is applied.

[0011] FIG. 2A illustrates an alternative embodiment relating to the xylene and raffinate columns.

[0012] FIG. 2B illustrates an alternative embodiment relating to the raffinate column.

[0013] FIG. 3 shows the application of energy conservation in the distillation of C_8 aromatics from heavy aromatics.

[0014] FIG. 4 illustrates examples of specific units within an aromatics complex in which direct heat exchange could achieve energy savings.

[0015] FIG. 5 illustrates an aromatics complex in which some of the energy-savings concepts described herein are applied as a supplement or substitute for other energy savings.

[0016] FIG. 6 illustrates the generation of steam from specific units within an aromatics complex.

DETAILED DESCRIPTION OF THE INVENTION

[0017] The feedstream to the present process generally comprises alkylaromatic hydrocarbons of the general formula $C_6H_{(6-n)}R_n$, where n is an integer from 0 to 5 and each R may be CH_3, C_2H_5, C_3H_7, or C_4H_9, in any combination. The aromatics-rich feed stream to the process of the invention may be derived from a variety of sources, including without limitation catalytic reforming, steam pyrolysis of naphtha, distillates or other hydrocarbons to yield light olefins and heavier aromatics-rich byproducts (including gasoline-range material often referred to as "pygas"), and

catalytic or thermal cracking of distillates and heavy oils to yield products in the gasoline range. Products from pyrolysis or other cracking operations generally will be hydrotreated according to processes well known in the industry before being charged to the complex in order to remove sulfur, olefins and other compounds which would affect product quality and/or damage catalysts or adsorbents employed therein. Light cycle oil from catalytic cracking also may be beneficially hydrotreated and/or hydrocracked according to known technology to yield products in the gasoline range; the hydrotreating preferably also includes catalytic reforming to yield the aromatics-rich feed stream. If the feed stream is catalytic reformate, the reformer preferably is operated at high severity to achieve high aromatics yield with a low concentration of nonaromatics in the product.

[0018] FIG. 1 is a simplified flow diagram of a typical aromatics-processing complex of the known art directed to the production of at least one xylene isomer. The complex may process an aromatics-rich feed which has been derived, for example, from catalytic reforming. Usually such a stream will have been treated to remove olefinic compounds and light ends, e.g., butanes and lighter hydrocarbons and preferably pentanes; such removal, however, is not essential to the practice of the broad aspects of this invention. The aromatics-containing feed stream contains benzene, toluene and C_8 aromatics and typically contains higher aromatics and aliphatic hydrocarbons including naphthenes.

[0019] The feed stream is passed via conduit 10 via a heat exchanger 12 to reformate splitter 14 and distilled to separate a stream comprising C_8 and heavier aromatics, withdrawn as a bottoms stream in conduit 16, from toluene and lighter hydrocarbons recovered overhead via conduit 18. The toluene and lighter hydrocarbons are sent to extractive distillation process unit 20 which separates a largely aliphatic raffinate in conduit 21 from a benzene-toluene aromatics stream in conduit 22. The aromatics stream in conduit 22 is separated, along with stripped transalkylation product in conduit 45 and overhead from para-xylene finishing column in conduit 57, in benzene column 23 into a benzene stream in conduit 24 and a toluene-and-heavier aromatics stream in conduit 25 which is sent to a toluene column 26. Toluene is recovered overhead from this column in conduit 27 and may

be sent partially or totally to a transalkylation unit 40 as shown and discussed hereinafter.

[0020] A bottoms stream from the toluene column 26 is passed via conduit 28, along with bottoms from the reformate splitter in conduit 16, after treating via clay treater 17, and recycle C_8 aromatics in conduit 65, to fractionator 30. The fractionator 30 separates concentrated C_8 aromatics as overhead in conduit 31 from a high-boiling stream comprising C_9, C_{10} and heavier aromatics as a bottoms stream in conduit 32. This bottoms stream is passed in conduit 32 to heavies column 70. The heavy-aromatics column provides an overhead stream in conduit 71 containing C_9 and at least some of the C_{10} aromatics, with higher boiling compounds, primarily C_{11} and higher alkylaromatics, being withdrawn as a bottoms stream via conduit 72.

[0021] The C_9+ aromatics from heavies column in conduit 71 is combined with the toluene-containing overhead contained in conduit 27 as feed to transalkylation reactor 40, which contains a transalkylation catalyst as known in the art to produce a transalkylation product comprising benzene through C_{11}+ aromatics with xylenes as the focus. The transalkylation product in conduit 41 is stripped in stripper 42 to remove gases in conduit 43 and C_6 and lighter hydrocarbons which are returned via conduit 44 to extractive distillation 20 for recovery of light aromatics and purification of benzene. Bottoms from the stripper are sent in conduit 45 to benzene column 23 to recover benzene product and unconverted toluene.

[0022] The C_8-aromatics overhead provided by fractionator 30 contains para-xylene, meta-xylene, ortho-xylene and ethylbenzene and passes via conduit 31 to para-xylene separation process 50. The separation process operates, preferably via adsorption employing a desorbent, to provide a mixture of para-xylene and desorbent via conduit 51 to extract column 52, which separates para-xylene via conduit 53 from returned desorbent in conduit 54; the para-xylene is purified in finishing column 55, yielding a para-xylene product via conduit 56 and light material which is returned to benzene column 23 via conduit 57. A non-equilibrium mixture of C_8-aromatics raffinate and desorbent from separation process 50 is sent via conduit 58 to raffinate column 59, which separates a raffinate for isomerization in conduit 60 from returned desorbent in conduit 61.

[0023] The raffinate, comprising a non-equilibrium mixture of xylene isomers and ethylbenzene, is sent via conduit 60 to isomerization reactor 62. The raffinate is isomerized in reactor 62, which contains an isomerization catalyst to provide a product approaching equilibrium concentrations of C_8-aromatic isomers. The product is passed via conduit 63 to deheptanizer 64, which removes C_7 and lighter hydrocarbons with bottoms passing via conduit 65 to xylene column 30 to separate C_9 and heavier materials from the isomerized C_8-aromatics. Overhead liquid from deheptanizer 64 is sent to stripper 66, which removes light materials overhead in conduit 67 from C_6 and C_7 materials which are sent via conduit 68 to the extractive distillation unit 20 for recovery of benzene and toluene values.

[0024] There are many possible variations of this scheme within the known art, as the skilled routineer will recognize. For example, the entire C_6-C_8 reformate or only the benzene-containing portion may be subjected to extraction. Para-xylene may be recovered from a C_8-aromatic mixture by crystallization rather than adsorption. Meta-xylene as well as para-xylene may be recovered from a C_8-aromatic mixture by adsorption, and ortho-xylene may be recovered by fractionation. Alternatively, the C_9-and heavier stream or the heavy-aromatics stream is processed using solvent extraction or solvent distillation with a polar solvent or stripping with steam or other media to separate highly condensed aromatics as a residual stream from C_9+ recycle to transalkylation. In some cases, the entire heavy-aromatic stream may be processed directly in the transalkylation unit. The present invention is useful in these and other variants of an aromatics-processing scheme, aspects of which are described in US 6,740,788 which is incorporated herein by reference.

[0025] The separation of C_8 aromatics from heavy aromatics in fractionator 30 is a situation in which the distillation process of the invention generally is effective. A distillation process of the present invention is represented by two or more xylene columns each effecting substantially the same separation between C_8 and C_9+ aromatics contained in two or more internal or external-feed streams of the aromatics complex designated respectively as a first and a second feed streams. Preferably the two streams comprise a first feed stream which is higher-boiling and a second feed stream which is lower-boiling, wherein the higher-boiling first feed

stream has a higher content of C_9+ hydrocarbons than the second feed stream. The invention comprises distilling the first feed stream in at least one first fractionation column at a low pressure to separate a first C_8-aromatics stream from a first C_9-and-heavier aromatics stream, distilling the second feed stream in a second fractionation column at an elevated pressure to separate a second C_8-aromatics stream from a second C_9-and-heavier aromatics stream, and circulating an overhead stream from the second column to provide heat to a reboiler of the first column. The low pressure typically is between 100 and 800 kPa and the elevated pressure is chosen to enable heat transfer from the second column to the first and typically is at least 400 kPa above the low pressure. This concept of different pressures in parallel columns is particularly valuable when the heavy components present in the higher-boiling feed stream are subject to degradation at reboiler temperatures needed to separate the light and heavy components.

[0026] The second fractionation column processes a second feed stream with a lower concentration of heavy materials subject to decomposition than the feed to the first column, and the pressure thus may be raised higher in order to effect energy savings through heat exchange between the first and second columns without loss of product yield or risk of equipment fouling. This feed preferably comprises most or all of the isomerized C_8 aromatics from the isomerization reactor following deheptanization, but may also comprise other C_8-aromatic streams with low concentrations of heavy aromatics. This stream to the second column typically contains less than 10 weight-% C_9+ aromatics, more often less than 5 weight-% C_9+ aromatics, and frequently less than 2 weight-% C_9+ aromatics. Effectively, the process comprises operating the second column at a pressure that would enable the overhead to provide heat to a reboiler of the first column and, preferably, a reboiler of at least one other column and/or steam generator in an associated processing complex.

[0027] In another embodiment, the process comprises operating the second fractionation column at a pressure that would enable the overhead to provide heat to generate steam useful in an associated processing complex. Further, the C_8-aromatics fractionator may comprise three or more columns comprising additional

heat exchange between overheads and reboilers in an analogous manner to the above description.

[0028] FIG. 2 is an energy-efficient aromatics complex employing a number of concepts of the invention. For ease of reference, a parallel numbering system is employed to those of Figures 1 and 2. The feed stream is passed via conduit 110 via heat exchangers 112 and 113, which raise the temperature of the feed stream, to reformate splitter 114. The heat exchange is supplied via conduits 213 and 214 respectively from the net para-xylene product and the recovered para-xylene separation process recovered desorbent as discussed later in this section.

[0029] As in FIG. 1, C_8 and heavier aromatics are withdrawn as a bottoms stream in conduit 116 while toluene and lighter hydrocarbons recovered overhead via conduit 118 are sent to extractive distillation process unit 120 which separates a largely aliphatic raffinate in conduit 121 from a benzene-toluene aromatics stream in conduit 122. The aromatics stream in conduit 122 is separated, along with stripped transalkylation product in conduit 144 and overhead from para-xylene finishing column in conduit 157, in fractionator 123 into a benzene stream in conduit 124 and a toluene-and-heavier aromatics stream in conduit 125 which is sent to a toluene column 126. Toluene is recovered overhead from this column in conduit 127 and may be sent partially or totally to a transalkylation unit 140 as shown and discussed hereinafter.

[0030] A bottoms stream from the toluene column 126 is passed via conduit 128, along with bottoms from the reformate splitter in conduit 116, after treating via clay treater 117, and recycle C_8 aromatics in conduit 148, to low-pressure xylene column 130. Other C8-aromatics streams having significant contents of C9 and heavier aromatics, including streams obtained from sources outside the complex, also may be processed in this column; a portion of deheptanizer bottoms in stream 165 also may be included depending on overall energy balances. The low-pressure xylene column separates concentrated C_8 aromatics as overhead in conduit 131 from a high-boiling stream comprising C_9, C_{10} and heavier aromatics as a bottoms stream in conduit 132.

[0031] Simultaneously, an isomerized C_8-aromatics stream is passed via conduit 165 to a high-pressure second xylene column 133. This is characterized as a lower-boiling feed stream which contains a lower concentration of heavy materials subject to decomposition than the feed to column 130, and the column pressure thus can be increased in order to effect energy savings. Other C_8-aromatics-containing streams having similarly low contents of C_9-and-heavier aromatics, including streams obtained from sources outside the complex, also may be contained in the feed stream to this column. The second xylene column separates a second C_8-aromatics stream as overhead in conduit 134 from a second C_9-and-heavier stream in conduit 132. At least a portion of overhead vapor from the high-pressure xylene column in conduit 134 preferably is employed to reboil low-pressure xylene column 130 in reboiler 135, leaving as a condensed liquid to the xylene-separation process 150 in conduit 136 as well as reflux (not shown) to column 133. In addition, the overhead in conduit 134 preferably is used to provide energy to the reboiler of extract column 152 as well as other such services which are described later or will be apparent to the skilled routineer.

[0032] The C_9+ bottoms stream passing to reboiler 137 may provide energy via one or both of the stream before the reboiler in conduit 270 and the heated stream from the reboiler in conduit 259 for reboiling respectively one or both of heavy-aromatics column 170 and raffinate column 159; the bottoms stream after heat exchange would be sent to the heavy-aromatics column 170. Other similar heat-exchange services will be apparent to the skilled routineer. The net bottoms stream in conduit 138 usually is passed through column 130 or may be in conduit 139 combined directly with the stream in conduit 132 to heavies column 170. The heavies column provides an overhead a stream in conduit 171 containing C_9 and at least some of the C_{10} aromatics, with higher boiling compounds, primarily C_{11} and higher alkylaromatics, being withdrawn as a bottoms stream via conduit 172. This column may be reboiled by xylene column bottoms in conduit 270, as discussed above. Overhead vapor from columns 130 and 170 also may generate steam respectively via conduits 230 and 271 as indicated, with condensed liquids either serving as reflux to each column or as net overhead respectively in streams 131 or 171.

[0033] The C_9+ aromatics from heavies column in conduit 171 is combined with the toluene-containing overhead contained in conduit 127 as feed to transalkylation reactor 140 to produce a transalkylation product containing xylenes. The transalkylation product in conduit 141 is stripped in stripper 142 to remove gases in conduit 143 and C_7 and lighter liquids which are returned via conduit 144 to extractive distillation 120 for recovery of light aromatics following stabilization in isomerate stripper 166. Bottoms from the stripper are sent in conduit 145 to benzene column 123 to recover benzene product and unconverted toluene.

[0034] The first and second C_8-aromatics streams provided by xylene columns 130 and 133, containing para-xylene, meta-xylene, ortho-xylene and ethylbenzene, pass via conduit 131 and 136 to xylene-isomer separation process 150. The description herein may be applicable to the recovery of one or more xylene isomers other than para-xylene; however, the description is presented for para-xylene for ease of understanding. The xylene-isomer separation is effected via an adsorption process to extract a desired isomer which is recovered using a desorbent. An adsorbent may be employed in the form of a fixed bed which is alternately contacted with the feed stream and desorbent or in multiple beds with appropriate piping/valves to allow continual passage of the feed stream through one or more adsorbent beds while the desorbent stream is passed through other beds in the set. In a countercurrent moving-bed mode of operation, a stationary concentration profile of the feed mixture components can be achieved to effect continuous operation with fixed points of feed stream and desorbent stream introduction along with extract and raffinate withdrawal. In a simulated moving-bed process, the progressive movement of fluids through multiple access points along an adsorbent chamber simulates the movement of adsorbent contained in one or more chambers. The operating principles and step sequence of a simulated moving-bed flow system are described in US 2,985,589, US 3,310,486, and US 4,385,993, which are incorporated herein by reference in their entirety.

[0035] The adsorption process provides a first mixture of para-xylene and desorbent via conduit 151 to extract column 152, which separates para-xylene via conduit 153 from returned desorbent in conduit 154. Extract column 152 preferably

is operated at an elevated pressure, at least 300 kPa and more preferably 500 kPa or higher, such that the overhead from the column is at sufficient temperature to reboil finishing column 155 via conduit 256 or deheptanizer 164 via conduit 265. Heat supplied for reboiling duty via conduits 256 and 265 results in the condensation of the extract in these streams which is either or both refluxed to column 152 (not shown) or sent as a net stream in conduit 153 to finishing column 155. The para-xylene is purified in finishing column 155, yielding a para-xylene product via conduit 156 and light material which is returned to benzene column 123 via conduit 157.

[0036] A second mixture of raffinate, as a non-equilibrium blend of C_8 aromatics, and desorbent from separation process 150 is sent via conduit 158 to raffinate column 159, which separates a raffinate to isomerization in conduit 160 from returned desorbent in conduit 161. The raffinate column may be operated at higher pressure to generate steam via conduit 260 or to exchange heat in other areas of the complex; condensed liquids from such heat exchange either serve as reflux to the raffinate column or as net overhead in conduit 160. Recovered desorbent in conduits 154 and 161 and net finishing column bottoms may heat the incoming feed stream in conduit 110 via conduits 213 and 212, respectively. Energy savings are attainable through tailoring the equipment and operations around the raffinate column 159, as illustrated in FIGS. 2A and 2B. These drawings illustrate modifications to selective portions of FIG. 2.

[0037] FIG. 2A illustrates energy savings through pressurization of the raffinate column with provisions to avoid decomposition of the desorbent in the reboiler of the column. A pressurized raffinate column operating usually at more than 400 kPa, and preferably 500 kPa or higher, permits an overhead stream from the column to generate steam and/or exchange useful energy with other streams in an aromatics complex; however, such pressurizations results in a temperature in the bottom of the column which could result in significant decomposition of the desorbent. FIG. 2A shows the section of the complex of FIG. 2 pertaining to the lower section of high-pressure xylene column 133 and to the raffinate column 159. Here, at least a portion of the effluent from reboiler 237 is directed to a drum 240 which separates a vapor in conduit 242 from a liquid in conduit 241 which is returned

to column 133 along with any remaining portion of the reboiler effluent in conduit 238. The vapor in conduit 242 provides heat to reboiler 243, maintaining peak film temperature below decomposition limits preferably using exchangers having enhanced nucleate boiling surface as discussed below. The overhead condenser preferably operates at a temperature to produce medium-pressure steam, yielding net non-equilibrium mixed xylenes In conduit 160.

[0038] FIG. 2B illustrates an alternative energy-saving method, focusing on the area of the raffinate column 159 of FIG. 2. The feed mixture of raffinate and desorbent in conduit 158 passes to a prefractionator 258, which recovers overhead via condenser 261 a portion of the net mixed xylene stream via conduit 262. The remaining xylenes plus desorbent pass via conduit 264 to a pressurized raffinate column 159. Overhead is at least partially condensed via conduit 265 in prefractionator reboiler 263, returning via conduit 266 to the top of the raffinate column with the remainder of the mixed xylenes being recovered via conduit 160. As in FIG. 2, the column is reboiled with overhead from the high-pressure xylene column in conduit 259 with net desorbent being returned to adsorption via conduit 161 as before.

[0039] The raffinate, comprising a non-equilibrium blend of xylene isomers and ethylbenzene, is sent via conduit 160 to isomerization reactor 162. In the isomerization reactor 162, raffinate is isomerized to provide a product approaching equilibrium concentrations of C_8-aromatic isomers. The product is passed via conduit 163 to deheptanizer 164, which removes C_7 and lighter hydrocarbons and preferably is reboiled using overhead in conduit 265 from extract column 152. Bottoms from the deheptanizer passes via conduit 165 to xylene column 133 to separate C_9 and heavier materials from the isomerized C_8-aromatics. Overhead liquid from deheptanizer 164 is sent to stripper 166, which separates light materials overhead in conduit 167 from C_6 and C_7 materials which are sent via conduit 168 to the extractive distillation unit 120 for recovery and purification of benzene and toluene values. Pressures of deheptanizer 164 and stripper 166 are selected to exchange heat or generate steam in a manner analogous to the xylene columns discussed elsewhere in this specification.

[0040] FIG. 3 shows in more detail the heat exchange of the invention between parallel xylene distillation columns 130 and 133. Feed to the low-pressure xylene column 130 comprises bottoms from the toluene column via conduit 128, clay-treated bottoms from the reformate splitter in conduit 116, and purge C_8 aromatics in conduit 138 and may comprise other C_8-aromatics-containing streams not suitable for processing in the high-pressure xylene column as well as a portion of the deheptanized stream 165 if appropriate for energy balances. The combined feeds of heavy reformate and toluene-column bottoms may contain heavy aromatics which are susceptible to degradation at high temperatures, and operating at a pressure lower than 800 kPa permits temperatures to be maintained in the bottom of the column and reboiler which avoid such decomposition. The low-pressure xylene column separates concentrated C_8 aromatics as overhead in conduit 131 from a high-boiling stream comprising C_9, C_{10} and heavier aromatics as a bottoms stream in conduit 132. The overhead stream from column 130 may be used at least partially via conduit 230 of FIG. 2 to generate steam or reboil other columns as discussed previously and thus be condensed to provide reflux to the column as well as the net overhead to xylene separation in conduit 131.

[0041] Simultaneously, an isomerized C_8-aromatics stream is passed via conduit 165 to high-pressure xylene column 133; this stream contains a lower concentration of heavy materials subject to decomposition than the feed to column 130; the column pressure is elevated with respect to that of the low-pressure xylene column according to the invention, as discussed previously, in order to effect energy savings through concomitantly higher temperatures which may be employed to exchange heat at useful levels. The temperature of the overhead vapor from the high-pressure xylene column 133 therefore is sufficient to provide useful energy to other services in an aromatics complex. As shown, the temperature of the overhead vapor is sufficient to reboil the low-pressure xylene column 130 in reboiler 135, providing reflux to column 133 and a net stream in conduit 136. A small net bottoms stream in conduit 138 preferably is sent to low-pressure column 130 for recovery of remaining C_8 aromatics.

[0042] Alternatively or in addition, the temperature of overhead vapor from high-pressure xylene column 133 is sufficient to generate steam useful for heating services or to reboil columns in other processing units. Such steam is generated usually at a pressure of in excess of 300 kPa, preferably at least 500 kPa, and most preferably 1000 kPa or higher. The overhead stream may be indirectly heat exchanged with a water circuit which feeds a steam drum. Most usually, boiler feed water is heated in heat exchangers decoupled from the steam drum. Multiple water circuits serving different exchangers are arranged in parallel with each other and feed a single steam drum to provide a steam product of a desired pressure for which only one set of instrumentation is needed. Such steam systems are well known, and details can be added through such teachings as found in US 7,730,854 which is incorporated herein by reference in its entirety.

[0043] Energy recovery according to the present invention, often involving close temperature approaches between process fluids, is improved through the use of exchangers having enhanced nucleate boiling surface. Such enhanced boiling surface can be effected in a variety of ways as described, for example, in US 3,384,154; US 3,821,018; US 4,064,914; US 4,060,125; US 3,906,604; US 4,216,826; US 3,454,081; US 4,769,511 and US 5,091,075; all of which are incorporated herein by reference in their entirety. Such high-flux tubing is particularly suitable for the exchange of heat between the overhead of the second high-pressure xylene column and the reboiler of the first low-pressure xylene column or for the generation of steam from the xylene-column overhead.

[0044] Typically, these enhanced nucleate boiling surfaces are incorporated on the tubes of a shell-and-tube type heat exchanger. These enhanced tubes are made in a variety of different ways which are well known to those skilled in the art. For example, such tubes may comprise annular or spiral cavities extending along the tube surface made by mechanical working of the tube. Alternately, fins may be provided on the surface. In addition the tubes may be scored to provide ribs, grooves, a porous layer and the like.

[0045] Generally, the more efficient enhanced tubes are those having a porous layer on the boiling side of the tube. The porous layer can be provided in a

number of different ways well known to those skilled in the art. The most efficient of these porous surfaces have what are termed reentrant cavities that trap vapors in cavities of the layer through restricted cavity openings. In one such method, as described in US 4,064,914, the porous boiling layer is bonded to one side of a thermically conductive wall. An essential characteristic of the porous surface layer is the interconnected pores of capillary size, some of which communicate with the outer surface. Liquid to be boiled enters the subsurface cavities through the outer pores and subsurface interconnecting pores, and is heated by the metal forming the walls of the cavities. At least part of the liquid is vaporized within the cavity and resulting bubbles grow against the cavity walls. A part thereof eventually emerges from the cavity through the outer pores and then rises through the liquid film over the porous layer for disengagement into the gas space over the liquid film. Additional liquid flows into the cavity from the interconnecting pores and the mechanism is continuously repeated. Such an enhanced tube containing a porous boiling layer is commercially available under the trade name High Flux Tubing made by UOP, Des Plaines, IL.

[0046] FIG. 4 illustrates examples of specific units within an aromatics complex in which direct heat exchange of overhead from one or more higher-temperature columns to reboilers of one or more lower-temperature columns could achieve energy savings, using numerical designations of processes from Figure 2. Overhead in conduit 134 from the high-pressure xylene column 133 has a temperature sufficient to provide energy to reboil extract column 152 via reboiler 235, condensing the xylene overhead in conduit 236 for return to 133 as reflux or net overhead. The extract column may be pressurized such that overhead in conduit 256 has a sufficient temperature to reboil finishing column 155, which preferably operates at vacuum pressure, via reboiler 257, condensing extract column overhead in conduit 258. As before, the product para-xylene is recovered in conduit 156.

[0047] FIG. 5 summarizes a number, not exhaustive or exclusive, of direct heat-exchange possibilities related to Figure 2. High-pressure xylene column 133 may provide heat to reboil one or more of low-pressure xylene column 130, extract column 152, and raffinate column 159. The low-pressure xylene column 130 may provide heat to reboil extractive distillation column 120. A pressurized extract

column 152 may provide heat to reboil one or more of benzene column 123 and finishing column 155. A pressurized raffinate column 159 may provide heat to reboil one or more of reformate splitter 114, toluene column 126, and deheptanizer 164.

[0048] FIG. 6 summarizes nonexhaustive examples of indirect heat-exchange possibilities through the generation of medium-pressure steam. Overhead streams 230 (FIG. 2) from the low-pressure xylene column 130 and 260 (FIG. 2) from the pressurized raffinate column 159 may generate medium-pressure steam in header 100 at 0.6 to 2 MPa, and preferably 0.7 to 1.5 MPa, which can be used to reboil one or more of reformate splitter 114, extractive distillation column 120 and toluene column 126 with the added potential of exporting steam to other units. Such generation and usage of steam can be considered as a supplement or substitute for other energy savings such as those described in Figure 5. For example, the high-pressure xylene column 133 may provide heat to reboil the low-pressure xylene column 130 and extract column 152, which in turn reboils the benzene column 123 and finishing column 155.

EXAMPLE

[0049] The combination of steam generation and direct heat exchange described above in Figure 6 was evaluated in terms of payback on investment. The base case is the facility described in Figure 1 and the case of the invention is the Figure 6 case as applied to the flow scheme in Figure 3. The relative key parameters for the production of para-xylene are as follows:

	Base Case	Invention
Fuel consumption	1.0	0.922
Net Steam consumed	1.0	0
generated	1.0	1.35

CLAIMS

The invention claimed is:

1. A process for producing para-xylene from feed streams containing C8 aromatics and C9-and-heavier aromatics, comprising:
(a) a distillation process comprising two xylene columns separating C8 aromatics from C9-and-heavier aromatics contained in at least one lower-boiling and at least one higher-boiling feed stream, wherein the at least one higher-boiling feed stream has a higher content of C9-and heavier aromatics than the at least one lower-boiling feed stream, comprising distilling the at least one higher-boiling feed stream in a first xylene column having a reboiler at a low pressure to separate a first C8-aromatics stream from a first C9-and-heavier aromatics stream, distilling the at least one lower-boiling feed stream in a second xylene column at an elevated pressure above the low pressure to separate a second C8-aromatics stream from a second C9-and-heavier aromatics stream, wherein an overhead stream from the second column exchanges heat with the reboiler of the first column;
(b) a para-xylene separation process to recover para-xylene from one or both of the first and second C8-aromatics streams by injecting the one or both C8-aromatics streams and a desorbent stream into a moving-bed adsorption process to obtain a first mixture of para-xylene and desorbent and a second mixture of a raffinate and desorbent; and,
(c) a desorbent-recovery process to separate the second mixture of step (b) by distillation in a prefractionator followed by a pressurized raffinate column into the raffinate and a desorbent stream returned to the separation process, wherein the overhead stream of the second xylene column of step (a) further provides heat to a reboiler of the raffinate column.

2. The process of claim 1 wherein the low pressure is between 100 and 800 kPa and the elevated pressure is at least about 400 kPa higher than the low pressure.

3. The process of claim 1 wherein the reboiler of the second column has an enhanced nucleate boiling surface.

4. The process of claim 1 wherein the at least one lower-boiling feed stream comprises part or all of a bottoms stream from deheptanization of a C8-aromatics isomerization product.

5. The process of claim 1 wherein overhead from the raffinate column exchanges heat with a medium-pressure steam generator to generate steam.

6. A process for producing para-xylene from feed streams containing C8 aromatics and C9-and-heavier aromatics, comprising:
(a) a distillation process comprising two xylene columns separating C8 aromatics from C9-and-heavier aromatics contained in at least one lower-boiling and at least one higher-boiling feed stream, wherein the at least one higher-boiling feed stream has a higher content of C9-and heavier aromatics than the at least one lower-boiling feed stream, comprising distilling the at least one higher-boiling feed stream in a first xylene column having a reboiler at a low pressure to separate a first C8-aromatics stream from a first C9-and-heavier aromatics stream, distilling the at least one lower-boiling feed stream in a second xylene column having a reboiler at an elevated pressure above the low pressure to separate a second C8-aromatics stream from a second C9-and heavier aromatics stream, wherein an overhead stream from the second column exchanges heat with the reboiler of the first column;
(b) a para-xylene separation process to recover para-xylene from one or both of the first and second C8-aromatics streams by injecting the one or both C8-aromatics streams and a desorbent stream into a moving-bed adsorption process to obtain a first mixture of para-xylene and desorbent and a second mixture of a raffinate and desorbent; and,
(c) a desorbent-recovery process which separates the second mixture of step (b) by distillation in a pressurized raffinate column into the raffinate and a desorbent stream returned to the separation process, wherein a reboiler effluent of the second xylene column is separated into a vapor and a liquid stream and the vapor stream provides heat to a reboiler of the raffinate column.

7. The process of claim 6 wherein the reboiler of the raffinate column of step (c) has an enhanced nucleate boiling surface.

8. The process of claim 6 wherein overhead from the raffinate column exchanges heat with a medium-pressure steam generator to generate steam.

9. A process for producing para-xylene from feed streams containing C8 aromatics and C9-and-heavier aromatics, comprising:
(a) a distillation process comprising two xylene columns separating C8 aromatics from C9-and-heavier aromatics contained in at least one lower-boiling and at least one higher-boiling feed stream, wherein the at least one higher-boiling feed stream has a higher content of C9-and heavier aromatics than the at least one lower-boiling feed stream, comprising distilling the at least one higher-boiling feed stream in a first xylene column having a reboiler at a low pressure to separate a first C8-aromatics stream from a first C9-and-heavier aromatics stream, distilling the at least one lower-boiling feed stream in a second xylene column having a reboiler at an elevated pressure above the low pressure to separate a second C8-aromatics stream from a second C9-and heavier aromatics stream, wherein an overhead stream from the second column exchanges heat with the reboiler of the first column;
(b) a para-xylene separation process to recover para-xylene from one or both of the first and second C8-aromatics streams by injecting the one or both C8-aromatics streams and a desorbent stream into a moving-bed adsorption process to obtain a first mixture of para-xylene and desorbent and a second mixture of a raffinate and desorbent; and,
(c) a desorbent-recovery process which separates the second mixture of step (b) by distillation in a prefractionator followed by a pressurized raffinate column into the raffinate and a desorbent stream returned to the separation process, wherein an overhead stream from the raffinate column provides heat to a reboiler of the prefractionator.

10. The process of claim 9 wherein the prefractionator reboiler has an enhanced nucleate boiling surface.