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(54) Title: HYDROCARBON PURIFICATION UTILIZING A CAUSTIC WASH

(57) Abstract: Embodiments of the present disclosure are directed towards hydrocarbon purification and specifically waste plastic purification utilizing a caustic wash.

HYDROCARBON PURIFICATION UTILIZING A CAUSTIC WASH

Field of Disclosure

[0001] Embodiments of the present disclosure are directed towards hydrocarbon purification and specifically hydrocarbon purification utilizing a caustic wash.

Background

[0002] Waste plastics have often been diverted to landfills or are incinerated, with a smaller fraction being diverted to recycling. Recycling of waste plastics can occur through a various processes in which the plastic waste is converted into solid, liquid, and/or gaseous fuels.

[0003] Hydrocarbon streams, obtained during waste plastics processing, can include a number of impurities. These impurities have the potential to poison catalysts and/or damage the other unit operations associated with waste plastic processing. As a result, it can be desirable to remove impurities from the hydrocarbon before the hydrocarbon is utilized in downstream processes.

Summary

[0004] The present disclosure provides various embodiments, including without limitation:

[0005] A method for hydrocarbon purification utilizing a caustic wash, the method including: transferring waste plastic to a depolymerization reactor; depolymerizing the waste plastic in the depolymerization reactor to provide a depolymerization reactor output; transferring the depolymerization reactor output to an extraction column having a caustic wash input; washing the depolymerization reactor output in the extraction column to provide an extraction column raffinate; transferring the extraction column raffinate to a hydroprocessing reactor; hydroprocessing the extraction column raffinate in the hydroprocessing reactor to provide a purified hydrocarbon.

Brief Description of Drawings

[0006] Figure 1 is a schematic diagram of a hydrocarbon purification system utilizing a caustic wash according to an embodiment of the present disclosure.

[0007] Figure 2 is a schematic diagram of a system utilizing a caustic wash according to an embodiment of the present disclosure.

[0008] Figure 3 is a schematic diagram of a hydrocarbon purification system utilizing a caustic wash according to an embodiment of the present disclosure.

Detailed Description

[0009] The present disclosure is directed toward methods and systems for waste plastic, e.g., hydrocarbon, purification and specifically waste plastic purification utilizing a caustic wash. One or more embodiments provide that the waste plastic, e.g., a hydrocarbon stream, is obtained during waste plastics processing. One or more embodiments provide that the waste plastic is a solid, e.g., prior to entering the depolymerization reactor.

[0010] Impurities in waste plastic, e.g., a hydrocarbon stream made from plastic waste, can be removed using a variety of techniques. One technique that has been previously utilized to remove the impurities from hydrocarbons prior to steam cracking is hydroprocessing. In hydroprocessing, hydrocarbons are catalytically processed under an atmosphere of hydrogen at elevated temperatures to help reduce the impurities.

[0011] Plastic waste including useful hydrocarbons, which may be obtained by processing the plastic waste, can also include a number of impurities, such as N, S, Cl, Br, F, Si, P, and/or I. One or more embodiments provide that the number of impurities can also comprise one or more metals. As an example, waste plastics can include impurities including heteroatoms such as chlorinated compounds, e.g., as found in polyvinyl chloride, sulfonated compounds, e.g., t-butylmethylsulfide, dimethyldisulfide, dibenzothiophene, etc, and/or nitrogen compounds, e.g., quinoline, that can be converted into acids, e.g., hydrochloric acid, sulfuric acid, and ammonia from the nitrogen compounds. Catalysts utilized for hydroprocessing can be deactivated sooner when a higher concentration of impurities is present. These impurities, as mentioned, can form undesirable compounds such as NH_3 and/or HCl, which may lead to corrosion. Additionally, HCl may react with NH_3 to form NH_4Cl, which may lead to plugging downstream lines and/or fouling of heat exchangers. To mitigate these issues, previous hydroprocessing processes have utilized large amounts of water, e.g., to reduce HBr and/or NH_3 in the hydrocarbons.

[0012] Hydroprocessing plants are designed to run at moderate pressure levels and are not designed to tolerate high amounts of catalyst impurities, e.g., poisons. Therefore, removal of poisons from waste plastic is desirable in processing plants.

[0013] Embodiments of the present disclosure provide that a caustic wash is utilized to reduce an impurity concentration in waste plastic, e.g., hydrocarbons. Embodiments provide that, advantageously, the caustic wash can replace and/or reduce water consumption from hydrocarbon purification. The caustic wash, as disclosed herein,

can reduce one or more concentrations of a number of components from a hydrocarbon stream, such as, HCl, HF, HBr, and H_2S, for instance.

[0014] Figure 1 is a schematic diagram of a hydrocarbon purification system 100 utilizing a caustic wash according to an embodiment of the present disclosure. As discussed herein, hydrocarbon purification can include depolymerization. The hydrocarbon purification system 100 can be utilized to purify a hydrocarbon material, such as waste plastic. As used herein, "waste plastic" includes raw materials defined by ISO 18604, polymers recovered from post-consumer material as defined by ISO 14021, and combinations thereof. Waste plastics may include paraffins, oxygenates, nitrogenates, chlorides, sulfur components, and combinations thereof. Waste plastics may include large amounts of dienes and olefins, as well as impurities, such as N, O, S, and Cl, for example.

[0015] The hydrocarbon purification system 100 can include a depolymerization section 101. The depolymerization section 101 can reduce the size of polymers, e.g., depolymerize, polymers therein. Embodiments provide that the depolymerization section 101 may include one or more known elements, e.g., a pump, or other known processing elements, not shown in Figure 1. The depolymerization section 101 can include a depolymerization reactor. The depolymerization reactor may also be referred to as a hydro-depolymerization reactor and/or a catalytic depolymerization reactor, among other terms. The depolymerization reactor can be a fixed bed reactor. The depolymerization reactor can include a depolymerization catalyst.

[0016] The depolymerization catalyst can be supported catalyst comprising a group VIII metal chosen from the group formed by Ni, Pd, Pt, Co, Rh, Fe, Mo, W, Ti, Cr, V, Zr, and/or Ru, optionally a group VIB metal chosen from the group Mo and/or W, on an amorphous mineral support chosen from the group formed by alumina, silica, silica-aluminas, magnesia, clays and combinations thereof. The depolymerization catalyst can include a supported zeolite, such as SiO_2, Al_2O_3, $AlPO_4$ and combinations thereof, for example.

[0017] The depolymerization reactor can operate at a temperature from 50 to 250 °C. All individual values and subranges from 50 to 250 °C are included; for example, the depolymerization reactor can operate at a temperature from a lower limit of 50, 60, or 70 to an upper limit of 250, 240, or 230 °C.

[0018] The depolymerization reactor can operate at a pressure from 15 to 200 bar absolute (bara). All individual values and subranges from 15 to 200 bara are

included; for example, the depolymerization reactor can operate at a pressure from a lower limit of 15, 20, or 25 to an upper limit of 200, 190, or 180 bara. The combination of pressure and reactor outlet temperature can provide that a portion of the contents of the depolymerization reactor are in a liquid state. .

[0019] The depolymerization section 101 can have a first input 111. The first input can comprise waste plastic, e.g., non-purified hydrocarbons including one more impurities as discussed herein. The first input can comprise waste plastic in a solid state, e.g., pelletized or shredded waste plastic. In other words, embodiments provided that the first input 111 is not a liquid.

[0020] The first input 111, e.g., waste plastic, can have various compositions. The first input 111 can include, for example, waste plastic obtained from bottle caps and closures, milk, water or orange juice containers, detergent bottles, office automation equipment (printers, computers, copiers, etc.), white goods (refrigerators, washing machines, etc.), consumer electronics (televisions, video cassette recorders, stereos, etc.), automotive shredder residue (the mixed materials remaining after most of the metals have been sorted from shredded automobiles and other metal-rich products "shredded" by metal recyclers), packaging waste, household waste, rotomolded parts (kayaks/coolers), building waste and industrial molding and extrusion scrap, among others.

[0021] Examples of the waste plastic include polyolefins, such as polyethylene and polypropylene, polyesters, such as poly(ethylene terephthalate), vinyl polymers, such as poly(vinyl chloride), acrylonitrile, butadiene and styrene homopolymer and interpolymers, polyesters, such as poly(ethylene terephthalate) and poly(bisphenol-A carbonate), polyamides, such as Nylon 66, polycarbonates, such as poly(bisphenol-A carbonate), acrylics, such as poly(methyl methacrylate), fluorocarbon polymer, polyethers, polysaccharides, silicones, such as poly(dimethylsiloxane), thermoplastic elastomers, such as ethylene-propylene rubber, and combinations thereof, among others.

[0022] In one or more embodiments, the waste plastic may have a density from 0.900 to 0.990 g/cm^3. All individual values and subranges of from 0.900 to 0.9990 g/cm^3 are disclosed and incorporated herein; for example the waste plastic may have a density from a lower limit of 0.900, 0.905, or 0.910 to an upper limit of 0.990, 0.980, or 0.970 g/cm^3. Density can be determined by according to ASTM D792.

[0023] In one or more embodiments, the waste plastic may have a melt index (I_2) from 0.30 dg/min to 6.00 dg/min. All individual values and subranges of from 0.30 dg/min to 6.00 dg/min are disclosed and incorporated herein; for example the waste plastic may have a melt index (I_2) from a lower limit 0.30, 0.80, 1.00, 1.25, 1.50, or 1.80 dg/min to an upper limit of 6.00, 5.00, 4.00, 3.50, 3.00, or 2.80 dg/min. I_2 can be determined according to ASTM D1238 (190 °C, 2.16 kg).

[0024] The depolymerization section 101 can have a second input 116. The second input can comprise hydrogen. The hydrogen from the second input can react, in the presence of the depolymerization catalyst, with one or more impurities of the non-purified hydrocarbons from the first input 111.

[0025] The hydrogen in the depolymerization reactor can have a partial pressure, in the vapor phase, from 10 to 140 bar. All individual values and subranges from 10 to 140 bar are included; for example, the hydrogen can have a partial pressure from a lower limit of 10, 12, or 14 to an upper limit of 140, 135, or 130 bar.

[0026] The hydrocarbon purification system 100 can include an extraction section 105. The extraction section 105 can include an extraction column. Embodiments provide that the extraction section 105 may include one or more known elements, e.g., a pump, or other known processing elements, not shown in Figure 1. Depolymerized contents from the depolymerization section 101 can be input to the extraction section 105 by depolymerization output 112. In other words, a depolymerization reactor output can be transferred to the extraction column. As used herein, two components are in "fluid communication" with one another when fluid is transferred from a first of the components to a second of the components.

[0027] The hydrocarbon purification system 100, e.g., the extraction column, can include a caustic wash input 110 to extraction section 105. As used herein, "caustic wash" refers to a liquid phase composition having a pH from 8 to 14. All individual values and subranges from 8 to 14 are included; for example, the caustic wash can have a pH from a lower limit of 8, 8.5, or 9 to an upper limit of 14, 13, 12, 11, or 10. The pH of the caustic wash can be determined by a known method, e.g., ASTM D1067. The caustic wash can be utilized for extraction, e.g., washing the depolymerization reactor output in the extraction column.

[0028] One or more embodiments provide that the caustic wash is a solution. One or more embodiments provide that the caustic wash is an aqueous solution. One or more embodiments provide that the caustic wash can be prepared with a base, e.g., an

alkali. One or more embodiments provide that the caustic wash can be prepared with sodium hydroxide (NaOH), potassium hydroxide (KOH), calcium hydroxide ($Ca(OH)_2$), or combinations thereof. One or more embodiments provide that the caustic wash is prepared with NaOH. The caustic wash input 110 can partially extract hydrocarbons bonded to heteroatoms, e.g., chlorine and/or silicon, as well as produced inorganics such as H_2S, HCl, HF and HBr.

[0029] The caustic wash input 110 can be from 20 to 150 weight percent (wt %), of a total weight of depolymerized contents from the depolymerization section that are input to the extraction section, e.g., the depolymerization reactor output (depolymerized contents from the depolymerization reactor) that is transferred to the extraction column. All individual values and subranges from 20 to 150 are included; for example, the caustic wash can be from a lower limit of 20, 25, or 30 wt% to an upper limit of 150, 130, or 110 wt% of the total weight of depolymerized contents from the depolymerization section that are input to the extraction section.

[0030] One or more embodiments provide that internal recycle streams may be utilized to control the caustic wash flow rate into the extraction column.

[0031] The extraction column can operate at a temperature from 150 to 300 °C. All individual values and subranges from 150 to 300 °C are included; for example, the extraction column can operate at a temperature from a lower limit of 150, 160, or 170 to an upper limit of 300, 280, or 260 °C.

[0032] The extraction column can operate at a pressure from 15 to 200 bara. All individual values and subranges from 15 to 200 bara are included; for example, the extraction column can operate at a pressure from a lower limit of 15, 20, or 25 to an upper limit of 200, 195, or 190 bara.

[0033] The hydrocarbon purification system 100 can include a first extraction section output 119. Recovered material from the extraction column of exaction section 105 can be sent via the first extraction section output 119 to the depolymerization section 101 and/or a heat transfer section 103.

[0034] The hydrocarbon purification system 100 can include a first split line 113. A portion of recovered material, e.g., liquid, from the first extraction section output 119 can be sent to the depolymerization section 101 via the first split line 113. Different portions of recovered material from the first extraction section output 119 can be sent to the depolymerization section 101 for various applications. One or more embodiments provide that from 5 weight percent (wt%) to 75 wt% of recovered material from the first

extraction section output 119 can be sent to the depolymerization section based upon a total wt% of recovered material in the first extraction section output 119. All individual values and subranges from 5 to 75 wt% are included; for example, from a lower limit of 5, 10, or 20 wt% to an upper limit of 75, 65, or 50 wt% of recovered material from the first extraction section output 119 can be sent to the depolymerization section based upon the total wt% of recovered material in the first extraction section output 119.

[0035] The hydrocarbon purification system 100 can include a second split line 114. A portion of recovered material from the first extraction section output 119 can be sent to a heat transfer section 103 via the second split line 114. Different portions of recovered material from the first extraction section output 119 can be sent to the heat transfer section 103 for various applications. One or more embodiments provide that from 25 wt% to 95 wt% of recovered material from the first extraction section output 119 can be sent to the heat transfer section 103 based upon a total wt% of recovered material in the from the first extraction section output 119. All individual values and subranges from 25 to 95 wt% are included; for example, from a lower limit of 25, 35, or 50 wt% to an upper limit of 95, 90, or 80 wt% of recovered material from the first extraction section output 119 can be sent to the heat transfer section 103 based upon the total wt% of recovered material from the first extraction section output.

[0036] The hydrocarbon purification system 100 can include a second extraction section output 102. Recovered material from the extraction column of exaction section 105 can be sent via the second extraction section output 102 to the heat transfer section 103. The second extraction section output 102 may be utilized in place of and/or in conjunction with a second split line 114. In other words, the total wt% of recovered material transferred from the extraction section 105 to the heat transfer section 103 can be transferred via the second split line 114, the second extraction section output 102, or a combination thereof.

[0037] The hydrocarbon purification system 100 can include a third extraction section output 120. The third extraction section output 120 can be a hydrocarbon-rich output 120. For example, a separator, e.g., as shown in Figure 2, can be utilized to separate hydrocarbons and water from an extraction column output to provide the hydrocarbon-rich output 120. The third extraction section output 120 can be removed from the hydrocarbon purification system 100.

[0038] The heat transfer section 103 can include a heat exchanger. Embodiments provide that the heat transfer section 103 may include one or more known

elements, e.g., a pump, or other known processing elements, not shown in Figure 1. The heat exchanger can operate at, e.g., materials sent to the heat exchanger can be brought to a desired temperature, a temperature from 250 to 350 °C. All individual values and subranges from 250 to 350 °C are included; for example, the heat exchanger can operate at an inlet temperature from a lower limit of 30, 35, or 40 to an upper limit of 100, 90, or 80 °C.

[0039] The heat exchanger can operate at a pressure from 15 to 200 bara. All individual values and subranges from 15 to 200 bara are included; for example, the heat exchanger can operate at a pressure from a lower limit of 15, 20, or 30 to an upper limit of 200, 190, or 180 bara.

[0040] The heat transfer section 103 can include a hydrogen input 107. The hydrogen from input 107 can have a partial pressure from 15 to 200 bara. All individual values and subranges from 15 to 200 bara are included; for example, the hydrogen from input 107 can have a partial pressure from a lower limit of 15, 20, or 25 to an upper limit of 200, 190, or 180 bara, wherein the hydrogen from input 107 has a pressure greater than the heat exchanger of heat transfer section 103.

[0041] The heat transfer section 103 can include an output 106. The contents of heat transfer section 103 can be transferred to a hydroprocessing section 104 via the output 106.

[0042] Embodiments provide that the hydroprocessing section 104 may include one or more known elements, e.g., a pump, or other known processing elements, not shown in Figure 1. The hydroprocessing section 104 can include a hydroprocessing reactor. The hydroprocessing reactor can be a fixed bed reactor. The hydroprocessing reactor can include a hydroprocessing catalyst.

[0043] The hydroprocessing catalyst can be supported catalyst comprising a group VIII metal chosen from the group formed by Ni, Pd, Pt, Co, Rh and/or Ru, optionally a group VIB metal chosen from the group Mo and/or W, on an amorphous mineral support chosen from the group formed by alumina, silica, silica-aluminas, magnesia, clays and mixtures thereof.

[0044] The hydroprocessing reactor can operate at a temperature from 250 to 350 °C. All individual values and subranges from 250 to 350 °C are included; for example, the hydroprocessing reactor can operate at a temperature from a lower limit of 250, 260, or 270 to an upper limit of 350, 340, or 330 °C. One or more embodiments

provide that the hydroprocessing reactor operates at a temperature that is greater than a temperature that the depolymerization reactor operates at.

[0045] The hydroprocessing reactor can operate at a pressure from 15 to 200 bara. All individual values and subranges from 15 to 200 bara are included; for example, the hydroprocessing reactor can operate at a pressure from a lower limit of 15, 20, or 25 to an upper limit of 200, 190, or 180 bara.

[0046] The hydrogen in the hydroprocessing reactor can have a partial pressure, in the vapor phase, from 10 to 140 bar. All individual values and subranges from 10 to 140 bar are included; for example, the hydrogen can have a partial pressure from a lower limit of 10, 15, or 20 to an upper limit of 140, 130, or 120 bar. One or more embodiments provide that the hydrogen in the hydroprocessing reactor can have a partial pressure that is less than the hydrogen partial pressure in the depolymerization reactor.

[0047] The hydroprocessing section 104 can include an output 108. Hydroprocessed, e.g., hydrotreated, contents of the hydroprocessing section 104 can be transferred out of the hydroprocessing section 104, e.g., to a downstream process such as a stream cracker, via the output 108. The output 108 can be a purified hydrocarbon stream. One or more embodiments provide that the purified hydrocarbon stream comprises saturated hydrocarbons, e.g., paraffins. As an example, the purified hydrocarbon stream can comprise C_2 to C_{25} saturated hydrocarbons.

[0048] Figure 2 is a schematic diagram of an extraction section utilizing a caustic wash according to an embodiment of the present disclosure. Figure 2 provides a more detailed view of extraction section 105, shown in Figure 1.

[0049] As discussed with Figure 1 depolymerized contents from the depolymerization section 101 can be input to the extraction section 105 by output 112. As shown in Figure 2, output 112 can be transferred to a heat transfer unit 250. The heat transfer unit 250 can provide that the contents of the output 112 are at a temperature from 150 to 300 °C to enter extraction column 252. All individual values and subranges from 150 to 300 °C are included; for example, the heat transfer unit 250 can provide that the contents of the output 112 are at a temperature from a lower limit of 150, 160, or 170 to an upper limit of 300, 280, or 260 °C to enter extraction column 252.

[0050] One or more embodiments provide that the heat transfer unit 250 can be optional, e.g., the contents of the output 112 can be at a temperature from 150 to 400 °C from an upstream process not shown in Figure 2.

[0051] The contents of the output 112, which can be heated by heat transfer unit 250, can be transferred to extraction column 252. One or more embodiments provide that the contents of the output 112 can be transferred to a lower section of the extraction column 252. The extraction column 252 can be utilized for a liquid-liquid extraction. The extraction column 252 can include different known configurations for various applications. The extraction may be referred to as a "reactive extraction", as the caustic wash can react with one or more impurities in the extraction column.

[0052] As shown in Figure 2, the caustic wash input 110 can be transferred to extraction column 252. One or more embodiments provide that the contents of the caustic wash input 110 can be transferred to an upper section of the extraction column 252. A number of processing components can be utilized to transfer heat associated with the caustic wash input 110. The number of processing components can be utilized to provide that the caustic wash input 110 is at a temperature from 150 to 300 °C when entering the extraction column 252. All individual values and subranges from 150 to 300 °C are included; for example, the heater 250 can provide that the caustic wash input 110 is a at temperature from a lower limit of 150, 160, or 170 to an upper limit of 300, 280, or 260 °C when entering the extraction column 252.

[0053] As shown in Figure 2, heat transfer unit 254 can be utilized to transfer heat to the caustic wash input 110. A water-rich extraction column output 256 can be utilized to transfer heat, e.g., within the heat transfer unit 254, to the caustic wash input 110. The water-rich extraction column output 256 can be discharged by gravity, for example, at a bottom portion of the extraction column 252.

[0054] As shown in Figure 2, after exiting the heat transfer unit 254, the water-rich extraction column output 256 can be transferred to heat transfer unit 258. The water-rich extraction column output 256 exiting the heat transfer unit 254 can be at a temperature from 30 to 85 °C. All individual values and subranges from 30 to 85 °C are included; for example, the water-rich extraction column output exiting the heat transfer unit can be at a temperature from a lower limit of 30, 35, or 40 to an upper limit of 85, 75, or 65 °C.

[0055] The heat transfer unit 258 can provide that the water-rich extraction column output 256 can be at a temperature from 15 to 65 °C. All individual values and subranges from 15 to 65 °C are included; for example, the heat transfer unit 258 can provide that the water-rich extraction column output is at a temperature from a lower limit of 15, 20, or 25 to an upper limit of 65, 55, or 45 °C.

[0056] From the heat transfer unit 258, the water-rich extraction column output 256 can be sent to a separator 260. The separator 260 can be utilized to separate hydrocarbons and water from the water-rich extraction column output 256. The separator 260 can include different known configurations for various applications.

[0057] The separator 260 can provide a hydrocarbon-rich separator output 120 and a water-rich separator output 262. The hydrocarbon-rich separator output 120 can be removed from extraction section 105.

[0058] The water-rich separator output 262 can be transferred to pump 264. As shown in Figure 2, the caustic wash input 110 can comprise a first portion of the water-rich separator output 262, while second portion of the water-rich separator output 262 can be removed, e.g., to avoid over accumulation of undesirable components, from the extraction section 105 by output 266. One or more embodiments provide that pump 264 can be utilized to help diminish the intake of make-up caustic solution via recirculation of the water-rich separator output 262. One or more embodiments provide that the recirculation of the first portion of the water-rich separator output 262 can provide that a recycled water to hydrocarbon mass ratio can be maintained at approximately 1:1.

[0059] As shown in Figure 2, the extraction section 105 can include an extraction column raffinate 268. The extraction column raffinate 268 can be hydrogen rich. The extraction column raffinate 268 can be produced by washing the depolymerization reactor output in the extraction column. As discussed further herein, the extraction column raffinate 268 can be transferred to a hydroprocessing reactor for hydroprocessing to provide a purified hydrocarbon stream.

[0060] The extraction column raffinate 268 can comprise hydrocarbons. The extraction column raffinate 268 can be from 60 wt% to 100 wt% hydrocarbons based upon a total weight of hydrocarbons and water in the extraction column raffinate 268. All individual values and subranges from 60 wt% to 100 wt% are included; for example, the extraction column raffinate can be from a lower limit of 60, 65, or 70 wt% to an upper limit of 100, 95, or 90 wt% hydrocarbons based upon a total weight of hydrocarbons and water in the extraction column raffinate. Water, in the extraction column raffinate 268, may be harmful to one or more downstream catalysts.

[0061] The extraction column raffinate 268 can have a temperature from 100 to 185 °C. All individual values and subranges from 150 to 300 °C are included; for example, the extraction column raffinate 268 can have a temperature from a lower limit of 150, 160, or 170 to an upper limit of 300, 280, or 260 °C.

[0062] The extraction column raffinate 268 can be transferred to heat transfer unit 270. One or more embodiments provide that extraction column raffinate 268 entering the heat transfer unit 270 has a temperature greater than the caustic wash input 110 entering the heat transfer unit 270. In other words, heat can be transferred from the extraction column raffinate 268 to the caustic wash input 110.

[0063] From the heat transfer unit 270, the extraction column raffinate 268 can be transferred heat transfer unit 272. Heat transfer unit 272 can be utilized to precisely control a temperature of the extraction column raffinate 268 entering a three-phase separator 274. The extraction column raffinate 268 entering a three-phase separator 274 can have different temperatures for various applications.

[0064] The three-phase separator 274 can have a temperature from 25 to 100 °C. All individual values and subranges from 25 to 100 °C are included; for example, the three-phase separator can have a temperature from a lower limit of 25, 30, or 35 to an upper limit of 100, 90, or 80 °C. The three-phase separator 274 can have a pressure that maintains 60 wt% or more of water in the three-phase separator in a liquid state.

[0065] The three-phase separator 274 can be utilized to separate the extraction column raffinate 268 into a hydrogen stream 276, an aqueous stream 278, and a hydrocarbon stream 280. The aqueous stream 278 can include spent caustic.

[0066] Desirably, the hydrocarbon stream 280 may provide reduced poisoning to catalysts, as compared to hydrocarbon streams prepared by other processes. As such, the hydrocarbon stream 280 can be advantageously utilized for further downstream processing.

[0067] Figure 3 is a schematic diagram of a hydrocarbon purification system 300 utilizing a caustic wash according to an embodiment of the present disclosure. Figure 3 provides a more detailed view of hydrocarbon purification system 100, shown in Figure 1.

[0068] As discussed with Figure 1, the first input 111 comprising waste plastic, e.g., non-purified hydrocarbons, can be utilized. The first input can comprise waste plastic, which may be in a solid phase.

[0069] The first input 111 can be transferred to heat transfer unit 330. Heat transfer unit 330 can provide that the first input 111 is at a temperature from 150 to 400 °C. All individual values and subranges from 150 to 400 °C are included; for example, the heat transfer unit 330 can provide that the first input 111 is at a temperature from a lower limit of 150, 160, or 170 to an upper limit of 400, 380, or 360 °C.

[0070] From the heat transfer unit 330, the first input 111 can be transferred to a depolymerization reactor 332, e.g., non-purified hydrocarbons can be transferred to a depolymerization reactor 332. In other words, the depolymerization reactor 332 can be fluid communication with an upstream process, e.g., a conveyor, that provides a waste plastic stream to the depolymerization reactor 332.The depolymerization reactor 332 can be as discussed with Figure 1, e.g., part of the depolymerization section 101. Embodiments provide that within the depolymerization reactor 332 waste plastic of the first input 111 is depolymerized, e.g., the waste plastic is made into relatively smaller polymer segments.

[0071] From the depolymerization reactor 332, output can be transferred to the extraction section 105, as discussed herein. Embodiments of the present disclosure provide that the caustic wash, as previously mentioned, is utilized to reduce an impurity concentration in hydrocarbons, such as the output from the depolymerization reactor 332. The caustic wash, as disclosed herein, can reduce one or more concentrations of a number of components from a hydrocarbon stream, such as, HCl, HF, HBr, and H_2S, for instance.

[0072] As shown in Figure 2, a number of streams, including hydrogen stream 276, aqueous stream 278, and hydrocarbon stream 280, can be output from the extraction section 105.

[0073] As shown in Figure 3, the aqueous stream 278 can be removed from the hydrocarbon purification system 300. The hydrogen stream 276 can be recirculated in the hydrocarbon purification system 300. The hydrocarbon stream 280, which comprises hydrocarbons that have been purified utilizing the caustic wash of the extraction section 105, can be used for further downstream hydroprocessing that utilizes catalysts, which are deactivated sooner when a relatively higher concentration of impurities is present. Because the hydrocarbon stream 280 comprises hydrocarbons that have been purified, i.e. hydrocarbon stream 280 comprises a relatively lower concentration of impurities as compared to hydrocarbon streams provided by other processes, advantageously, downstream hydroprocessing catalysts remain active longer than hydroprocessing catalysts that are exposed to hydrocarbon streams having relatively higher concentrations of impurities. One or more embodiments provide that the purified hydrocarbon stream 280 comprises saturated hydrocarbons, e.g., paraffins. Various saturated hydrocarbons may be obtained for different applications.

[0074] As shown in Figure 3, the hydrocarbon stream 280 can be transferred, via pump 342, to a number of heat transfer units, e.g., heat transfer unit 334, heat transfer unit 336, heat transfer unit 338 enroute to a hydroprocessing reactor 340 of the hydroprocessing section 104 discussed with Figure 1. While three heat transfer units 334, 336, 338 are shown the enroute to the hydroprocessing reactor 340, embodiments are not so limited. For instance, various embodiments provide there may be fewer than three or more than three heat transfer units enroute to the hydroprocessing reactor 340.

[0075] Hydrocarbons, which have been hydroprocessed in the hydroprocessing reactor 340 can be transferred to a flash unit 344, e.g., a flash drum. As shown in Figure 3, hydrocarbons, which have been hydroprocessed in the hydroprocessing reactor 340 enroute to the flash unit 344 may pass through a number of heat transfer units, e.g., heat transfer unit 336 and heat transfer unit 342. While two heat transfer units 336, 342 are shown the enroute to the flash unit 344, embodiments are not so limited. For instance, various embodiments provide there may be fewer than two or more than two heat transfer units enroute to the flash unit 344.

[0076] The flash unit 344 can be utilized to provide a gas-phase stream 346 and a liquid-phase stream 348. The liquid-phase stream 348 may be referred to as an end product of the hydrocarbon purification system 300. The liquid-phase stream 348 may comprise hydrocarbons, e.g., aromatics, and/or paraffins ranging from C_5 to C_{12}.

[0077] The gas-phase stream 346 may comprise hydrogen, relatively lighter hydrocarbons (as compared to the liquid-phase stream 348), and/or inorganic byproducts of the hydroprocessing, such as H_2S, NH_3, and HCl.

[0078] The gas-phase stream 346 may be transferred to a scrubber 350. The scrubber 350 may utilize an aqueous NaOH stream 352 for processing the gas-phase stream 346. Spent NaOH from the scrubber 350 can be recovered via scrubber output 350. Scrubbed gas can be recycled, via compressor 358, to the hydrocarbon purification system 300 by scrubbed gas recycle stream 356. As shown in Figure 3, the scrubbed gas recycle stream 356 can be combined with a hydrogen input stream 360, e.g., prior to the compressor 358.

[0079] A portion of scrubbed gas from scrubber 350 may purged from the hydrocarbon purification system 300 by scrubbed gas purge stream 362. Different amounts of scrubbed gas from scrubber 350 may purged for various applications.

Claims

What is claimed is:

1. A method for hydrocarbon purification utilizing a caustic wash, the method comprising:

transferring waste plastic to a depolymerization reactor;

depolymerizing the waste plastic in the depolymerization reactor to provide a depolymerization reactor output;

transferring the depolymerization reactor output to an extraction column having a caustic wash input;

washing the depolymerization reactor output with the caustic wash input in the extraction column to provide an extraction column raffinate.

2. The method of claim 1, further comprising transferring the extraction column raffinate to a hydroprocessing reactor;

hydroprocessing the extraction column raffinate in the hydroprocessing reactor to provide a purified hydrocarbon stream.

3. The method of claim 1, wherein the caustic wash is a liquid phase composition having a pH from 8 to 14.

4. The method of claim 1, wherein the caustic wash is an aqueous solution.

5. The method of claim 1, wherein the caustic wash comprises sodium hydroxide.

6. The method of claim 1, wherein the caustic wash is from 20 to 150 weight percent of a total weight of depolymerized contents from the depolymerization reactor that are input to the extraction column.

7. The method of claim 1, where the extraction column operates at a temperature from 100 to 300 °C and a pressure from 15 to 200 bar absolute.

8. A hydrocarbon purification system comprising:

a depolymerization reactor;

an extraction column in fluid communication with the depolymerization reactor, wherein the extraction column includes a caustic wash input; and

a hydroprocessing reactor in fluid communication with the extraction column.

9. The system of claim 8, wherein the depolymerization reactor is in fluid communication with an upstream process that provides a waste plastics stream to the depolymerization reactor.

10. The system of claim 8, wherein the hydroprocessing reactor hydroprocesses an extraction column raffinate to provide a purified hydrocarbon stream.

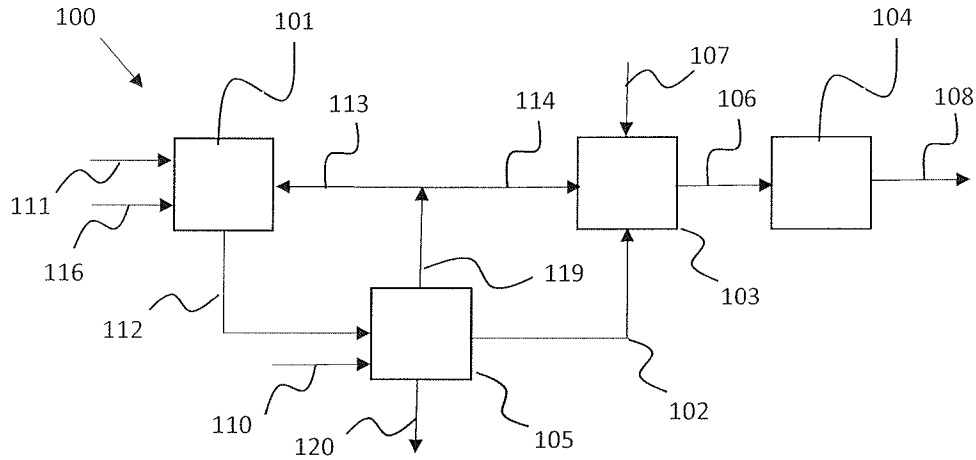
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Figure 1

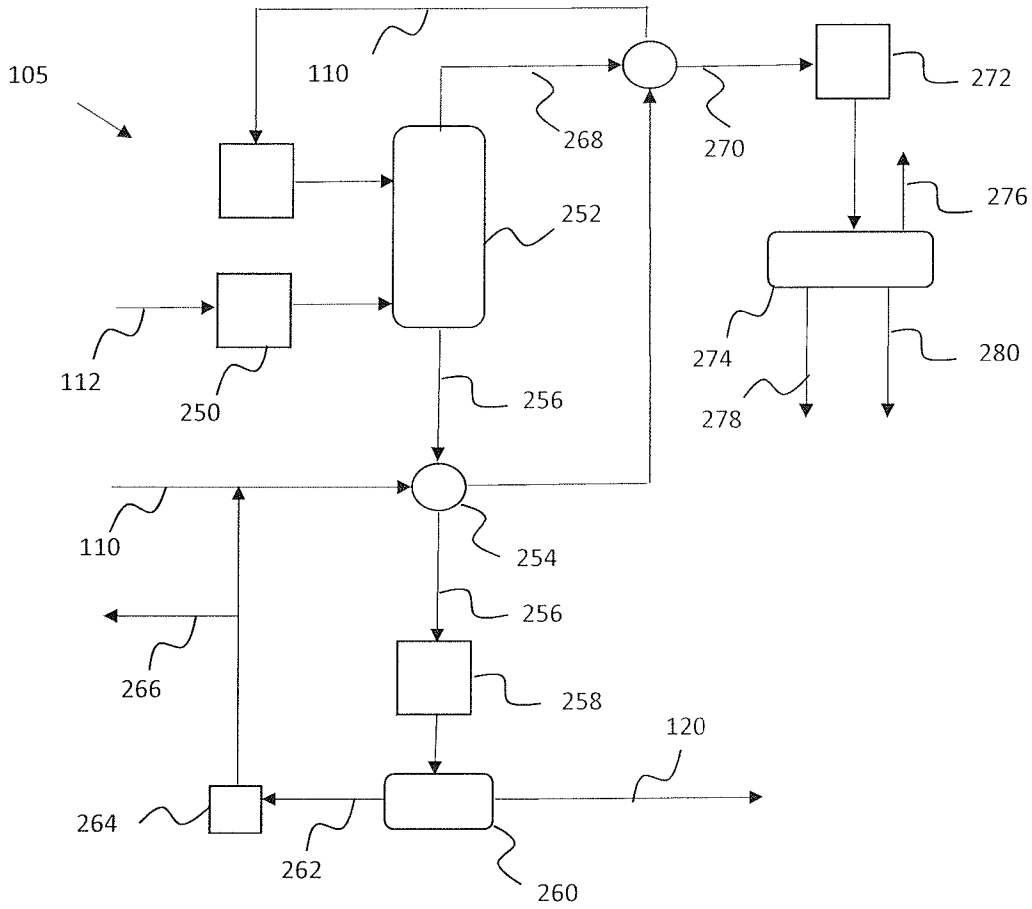
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Figure 2

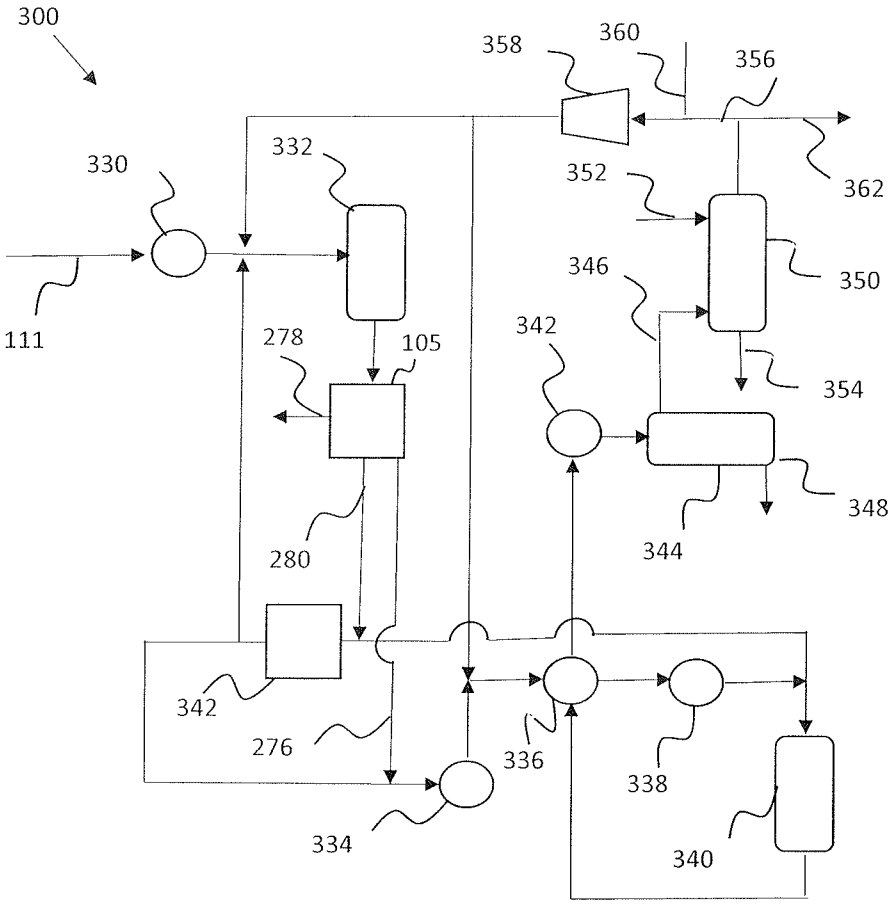
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Figure 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/GR2023/000034

A. CLASSIFICATION OF SUBJECT MATTER

INV. C10G1/00 C10G1/10 C10G19/02 C10G67/10
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10G

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	WO 2021/105326 A1 (NESTE OYJ [FI]) 3 June 2021 (2021-06-03) page 7, line 23 - line 24; claim 1 page 15, line 26 - line 35 page 25, line 27 - line 32 page 16, line 18 - line 29	1-10
X	WO 2023/100139 A1 (SABIC GLOBAL TECHNOLOGIES BV [NL]) 8 June 2023 (2023-06-08) paragraph [0034]; claims 1,5,6,12,14,15; figure 2; example 1	1-10
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[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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

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INTERNATIONAL SEARCH REPORT

International application No
PCT/GR2023/000034

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 2023/066739 A1 (SHELL INT RESEARCH [NL]; SHELL USA INC [US]) 27 April 2023 (2023-04-27) page 24, line 13 - line 25; claim 1	1-7

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