(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 May 2015 (28.05.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/076972 A1

(51) International Patent Classification:
C10G 55/00 (2006.01)

(21) International Application Number:
PCT/US2014/061871

(22) International Filing Date:
23 October 2014 (23.10.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/906,073 19 November 2013 (19.11.2013) US

(71) Applicant: **UOP LLC** [US/US]; 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US).

(72) Inventors: **THAKKAR, Vasant P.**; UOP LLC, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US). **BARGER, Paul T.**; UOP LLC, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US). **BRICKER, Maureen L.**; UOP LLC, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US). **CHEN, John Q.**; UOP LLC, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US). **COUGHLIN, Peter K.**; UOP LLC, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US). **FREY, Stanley J.**; UOP LLC, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US). **JOHNSON, James A.**; UOP LLC, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US). **KOCAL, Joseph A.**; UOP LLC, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US). **LIPPMANN, Matthew**; UOP LLC, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US). **VANDEN BUSSCHE, Kurt M.**; UOP LLC, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US).

(74) Agent: **PASCHALL, James C.**; UOP LLC, 25 East Algonquin Road, P. O. Box 5017, Des Plaines, Illinois 60017-5017 (US).

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

[Continued on next page]

(54) Title: PROCESS FOR PRODUCING OLEFINS FROM A COAL FEED

(57) Abstract: A process for producing olefins from a coal feed includes providing a coal tar stream and fractionating the coal tar stream to provide a hydrocarbon stream that includes hydrocarbons having an initial boiling point of 250C or greater. The hydrocarbon stream is hydrotreated to reduce a concentration of one or more of nitrogen, sulfur, and oxygen in the hydrocarbon stream, and the hydrotreated hydrocarbon stream is cracked in a fluidized catalytic cracking zone to produce an olefin stream.

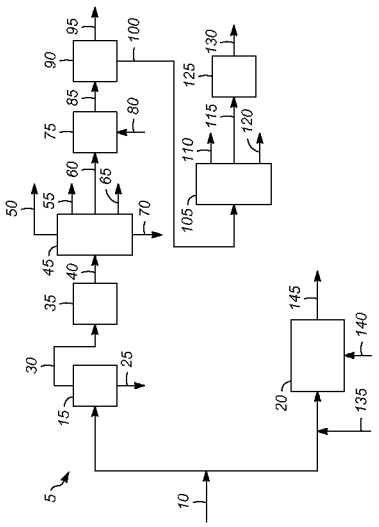

FIG. 1

WO 2015/076972 A1

SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

PROCESS FOR PRODUCING OLEFINS FROM A COAL FEED

STATEMENT OF PRIORITY

This application claims priority to U.S. Provisional Application No. 61/906,073 filed on November 19, 2013, the entirety of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Many different types of chemicals are produced from the processing of petroleum. However, petroleum is becoming more expensive because of increased demand in recent decades.

Therefore, attempts have been made to provide alternative sources for the starting materials for manufacturing chemicals. Attention is now being focused on producing liquid hydrocarbons from solid carbonaceous materials, such as coal, which is available in large quantities in countries such as the United States and China.

Pyrolysis of coal produces coke and coal tar. The coke-making or "coking" process consists of heating the material in closed vessels in the absence of oxygen to very high temperatures. Coke is a porous but hard residue that is mostly carbon and inorganic ash, which may be used in making steel.

Coal tar is the volatile material that is driven off during heating, and it comprises a mixture of a number of hydrocarbon compounds. It can be separated to yield a variety of organic compounds, such as benzene, toluene, xylene, naphthalene, anthracene, and phenanthrene. These organic compounds can be used to make numerous products, for example, dyes, drugs, explosives, flavorings, perfumes, preservatives, synthetic resins, and paints and stains. The residual pitch left from the separation is used for paving, roofing, waterproofing, and insulation.

Olefins are desirable products in the petrochemical industry. Thus, there is a need for a process for producing olefins from a coal feed.

SUMMARY OF THE INVENTION

In one aspect, a process for producing olefins from a coal feed includes providing a coal tar stream and fractionating the coal tar stream to provide a hydrocarbon stream that includes hydrocarbons having an initial boiling point of 250°C or greater. The hydrocarbon stream is hydrotreated to reduce a concentration of one or more of nitrogen, sulfur, and oxygen in the hydrocarbon stream, and the hydrotreated hydrocarbon stream is cracked in a fluidized catalytic cracking zone to produce an olefin stream.

In another aspect, a process for producing olefins from a coal feed includes pyrolyzing coal to produce a coke stream and a coal tar stream. The process further includes separating the coal tar stream to produce a hydrocarbon stream excluding a pitch fraction and hydrotreating the hydrocarbon stream to produce a hydrotreated hydrocarbon stream having reduced concentration of one or more of nitrogen, sulfur, and oxygen. The hydrotreated hydrocarbon stream is cracked in a fluidized catalytic cracking zone to produce an olefin stream.

In a third aspect, a process for producing olefins from a coal feed, includes pyrolyzing coal to produce a coke stream and a coal tar stream and separating the coal tar stream to produce a hydrocarbon stream excluding a pitch fraction. The hydrocarbon stream is hydrotreated to produce a hydrotreated hydrocarbon stream having reduced concentration of one or more of nitrogen, sulfur, and oxygen. The process further includes cracking the hydrotreated hydrocarbon stream in a fluidized catalytic cracking zone to produce an olefin stream comprising a plurality of olefins, and separating the olefin stream into a plurality of olefin product streams based on a carbon number of the olefins.

BRIEF DESCRIPTION OF THE DRAWING

The Figure illustrates one embodiment of the process of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The Figure shows one embodiment of an olefin producing process 5. A coal feed 10 can be sent to either a pyrolysis zone 15 or a gasification zone 20. Alternatively, the coal feed 10 can be split into two parts and sent to both.

In the pyrolysis zone 15, the coal feed 10 is heated at high temperature, e.g., up to 2,000°C (3,600°F), in the absence of oxygen to drive off the volatile components. Coking produces a coke stream 25 and coal tar stream 30. The coke from the coke stream 25 can be used in other processes, such as the manufacture of steel.

The coal tar stream 30 which comprises the volatile components from the coking process can be sent to an optional contamination removal zone 35, if desired.

The contaminant removal zone 35 for removing one or more contaminants from the coal tar stream or another process stream may be located at various positions along the process depending on the impact of the particular contaminant on the product or process and the reason for the contaminant's removal, as described further below. For example, the contaminant removal zone 35 can be positioned upstream of a separation zone 45. Some contaminants have been identified to interfere with a downstream processing step or hydrocarbon conversion process, in which case the contaminant removal zone 35 may be positioned upstream of the separation zone 45 or between the separation zone 45 and the particular downstream processing step at issue. Still other contaminants have been identified that should be removed to meet particular product specifications. Where it is desired to remove multiple contaminants from the hydrocarbon or process stream, various contaminant removal zones 35 may be positioned at different locations along the process. In still other approaches, a contaminant removal zone 35 may overlap or be integrated with another process within the system, in which case the contaminant may be removed during another portion of the process, including, but not limited to the separation zone 45 or the downstream hydrocarbon conversion zone. This may be accomplished with or without modification to these particular zones, reactors or processes. While the contaminant removal zone 35 is often positioned downstream of the hydrocarbon conversion reactor, it should be understood that the contaminant removal zone 35 in accordance herewith may be positioned upstream of the separation zone 45, between the separation zone 45 and the hydrocarbon conversion zone, or downstream of the hydrocarbon conversion zone or along other streams within the process stream, such as, for example, a carrier fluid stream, a fuel stream, an oxygen source stream, or any streams used in the systems and the processes described herein. The contaminant concentration is controlled by removing at least a portion of the contaminant from the coal tar stream 30. As used herein, the term removing may refer to actual removal, for example by

adsorption, absorption, or membrane separation, or it may refer to conversion of the contaminant to a more tolerable compound, or both.

The decontaminated coal tar feed 40 is sent to a separation zone 45 where it is separated into two or more fractions 50, 55, 60, 65, 70. Coal tar comprises a complex mixture of heterocyclic aromatic compounds and their derivatives with a wide range of boiling points. The number of fractions and the components in the various fractions can be varied as is well known in the art. A typical separation process involves separating the coal tar into four to six streams. For example, there can be a fraction comprising NH_3, CO, and light hydrocarbons, a light oil fraction with boiling points between 0°C and 180°C, a middle oil fraction with boiling points between 180°C to 230°C, a heavy oil fraction with boiling points between 230 to 270°C, an anthracene oil fraction with boiling points between 270°C to 350°C, and pitch.

The light oil fraction contains compounds such as benzenes, toluenes, xylenes, naphtha, coumarone-indene, dicyclopentadiene, pyridine, and picolines. The middle oil fraction contains compounds such as phenols, cresols and cresylic acids, xylenols, naphthalene, high boiling tar acids, and high boiling tar bases. The heavy oil fraction contains benzene absorbing oil and creosotes. The anthracene oil fraction contains anthracene. Pitch is the residue of the coal tar distillation containing primarily aromatic hydrocarbons and heterocyclic compounds.

As illustrated, the coal tar feed 40 is separated into a gas fraction 50 containing gases such as NH_3 and CO as well as light hydrocarbons, such as ethane, hydrocarbon fractions 55, 60, and 65 having different boiling point ranges, and a pitch fraction 70.

Suitable separation processes include, but are not limited to fractionation, such as a distillation, solvent extraction, and adsorption.

One or more of the fractions 50, 55, 60, 65, 70 can be further processed, as desired. As illustrated in the Figure, fraction 60 can be sent to a hydrotreating zone 75. The fraction 60 preferably includes relatively heavy hydrocarbons having initial boiling points greater than 250°C, preferably in the range of 300°C to 400°C, although other suitable fractions may be selected as is known in the art. Hydrotreating is a process in which hydrogen gas 80 is contacted with a hydrocarbon stream in the presence of suitable catalysts

which are primarily active for the removal of heteroatoms, such as sulfur, nitrogen, oxygen, and metals from the hydrocarbon feedstock. In this context, removal includes actual removal of at least a portion of the heteroatoms. For example, the hydrotreating process preferably reduces a concentration of sulfur to 50 parts per million or less. Similarly, the hydrotreating preferably reduces a concentration of nitrogen to 20 parts per million or less. In hydrotreating, hydrocarbons with double and triple bonds may be saturated. Aromatics may also be saturated. Typical hydrotreating reaction conditions include a temperature of 290°C (550°F) to 455°C (850°F), a pressure of 3.4 MPa (500 psig) to 27.6 MPa (4,000 psig), a liquid hourly space velocity of 0.1.hr^{-1} to 5 hr^{-1}, and a hydrogen rate of 168 to 1,685 Nm^3/m^3 oil (1,000 to 10,000 scf/bbl). Typical hydrotreating catalysts include at least one Group VIII metal, preferably iron, cobalt and nickel, and at least one Group VI metal, preferably molybdenum and tungsten, on a high surface area support material, preferably alumina. Other typical hydrotreating catalysts include zeolitic catalysts, as well as noble metal catalysts where the noble metal is selected from palladium and platinum. The hydrotreated hydrocarbon stream 85 is then routed to a cracking zone 90.

Cracking is a process in which a bond between carbon atoms in a hydrocarbon is broken or "cracked" to form lower molecular weight hydrocarbon compounds. The cracking zone 90 can take multiple forms, including, for example, a hydrocracking zone or a fluid catalytic cracking zone.

Hydrocracking is a process in which hydrocarbons crack in the presence of hydrogen to lower molecular weight hydrocarbons. Typical hydrocracking conditions may include a temperature of 290°C (550°F) to 468°C (875°F), a pressure of 3.5 MPa (500 psig) to 20.7 MPa (3,000 psig), a liquid hourly space velocity (LHSV) of 0.5 to less than 5 hr^{-1}, and a hydrogen rate of 421 to 2,527 Nm^3/m^3 oil (2,500 to 15,000 scf/bbl). Typical hydrocracking catalysts include amorphous silica-alumina bases or low-level zeolite bases combined with one or more Group VIII or Group VIB metal hydrogenating components, or a crystalline zeolite cracking base upon which is deposited a Group VIII metal hydrogenating component. Additional hydrogenating components may be selected from Group VIB for incorporation with the zeolite base.

Fluid catalytic cracking (FCC) is a catalytic hydrocarbon conversion process accomplished by contacting heavier hydrocarbons in a fluidized reaction zone with a catalytic

particulate material. The reaction in catalytic cracking is carried out in the absence of substantial added hydrogen or the consumption of hydrogen. The process typically employs a powdered catalyst having the particles suspended in a rising flow of feed hydrocarbons to form a fluidized bed. In representative processes, cracking takes place in a riser, which is a vertical or upward sloped pipe. Typically, a pre-heated feed is sprayed into the base of the riser via feed nozzles where it contacts hot fluidized catalyst and is vaporized on contact with the catalyst, and the cracking occurs converting the high molecular weight oil into lighter components including liquefied petroleum gas (LPG), gasoline, and a distillate. The catalyst-feed mixture flows upward through the riser for a short period (a few seconds), and then the mixture is separated in cyclones. The hydrocarbons are directed to a fractionator for separation into LPG, gasoline, diesel, kerosene, jet fuel, and other possible fractions. While going through the riser, the cracking catalyst is deactivated because the process is accompanied by formation of coke which deposits on the catalyst particles. Contaminated catalyst is separated from the cracked hydrocarbon vapors and is further treated with steam to remove hydrocarbon remaining in the pores of the catalyst. The catalyst is then directed into a regenerator where the coke is burned off the surface of the catalyst particles, thus restoring the catalyst's activity and providing the necessary heat for the next reaction cycle. The process of cracking is endothermic. The regenerated catalyst is then used in the new cycle. Typical FCC conditions include a temperature of 400°C to 800°C, a pressure of 0 to 688 kPag (0 to 100 psig), and contact times of 0.1 seconds to 1 hour. The conditions are determined based on the hydrocarbon feedstock being cracked, and the cracked products desired. Zeolite-based catalysts are commonly used in FCC reactors, as are composite catalysts which contain zeolites, silica-aluminas, aluminas, and other binders. For example, the cracking catalyst may include one or more of an active amorphous clay type catalyst, a high activity crystalline molecular sieve, and an MFI zeolite.

The cracking produces an olefin stream 100 which may be routed from the cracking zone 90 to an olefin separation zone 105 to separate the olefin stream 100 into two or more product streams. The olefin separation zone 105 can include one or more of a distillation zone, a solvent extraction zone, or a fractionation zone. The olefin stream 100 is separated into multiple product streams 110, 115, 120 based on the number of carbon atoms in the olefins. As shown in the Figure, the stream 105 is separated into three product streams 110, 115, 120, although it will be appreciated that the stream 105 can be divided into more or fewer streams without departing from the scope of the invention. The olefin product streams 110, 115, 120

may be collected as end products, or may be subject to additional downstream processing, as is known in the art. As an example, the Figure shows a product stream 115 that includes C_2 olefins is subject to additional processing. The stream 115 is routed to a polymerization zone 125. The stream 115 is polymerized to produce higher molecular weight hydrocarbons having a higher carbon number.

In addition, the hydrocarbon streams 55, 65 of the separation zone 45 and the olefin streams 110, 120 of the olefin separation zone 105 may be also subject to additional processing including, but not limited to, transalkylation, alkylation, oxidation, hydrogenation processing.

Transalkylation is a chemical reaction resulting in transfer of an alkyl group from one organic compound to another. Catalysts, particularly zeolite catalysts, are often used to effect the reaction. If desired, the transalkylation catalyst may be metal stabilized using a noble metal or base metal, and may contain suitable binder or matrix material such as inorganic oxides and other suitable materials. In a transalkylation process, a polyalkylaromatic hydrocarbon feed and an aromatic hydrocarbon feed are provided to a transalkylation reaction zone. The feed is usually heated to reaction temperature and then passed through a reaction zone, which may comprise one or more individual reactors. Passage of the combined feed through the reaction zone produces an effluent stream comprising unconverted feed and product monoalkylated hydrocarbons. This effluent is normally cooled and passed to a stripping column in which substantially all C_5 and lighter hydrocarbons present in the effluent are concentrated into an overhead stream and removed from the process. An aromatics-rich stream is recovered as net stripper bottoms, which is referred to as the transalkylation effluent.

The transalkylation reaction can be effected in contact with a catalytic composite in any conventional or otherwise convenient manner and may comprise a batch or continuous type of operation, with a continuous operation being preferred. The transalkylation catalyst is usefully disposed as a fixed bed in a reaction zone of a vertical tubular reactor, with the alkylaromatic feed stock charged through the bed in an upflow or downflow manner. The transalkylation zone normally operates at conditions including a temperature in the range of 130°C to 540°C. The transalkylation zone is typically operated at moderately elevated pressures broadly ranging from 100 kPa to 10 MPa absolute. The

transalkylation reaction can be effected over a wide range of space velocities. That is, volume of charge per volume of catalyst per hour; weight hourly space velocity (WHSV) generally is in the range of from 0.1 to 30 hr^{-1}. The catalyst is typically selected to have relatively high stability at a high activity level.

Alkylation is typically used to combine light olefins, for example mixtures of alkenes such as propylene and butylene, with isobutane to produce a relatively high-octane branched-chain paraffinic hydrocarbon fuel, including isoheptane and isooctane. Similarly, an alkylation reaction can be performed using an aromatic compound such as benzene in place of the isobutane. When using benzene, the product resulting from the alkylation reaction is an alkylbenzene (e.g. toluene, xylenes, ethylbenzene, etc.). For isobutane alkylation, typically, the reactants are mixed in the presence of a strong acid catalyst, such as sulfuric acid or hydrofluoric acid. The alkylation reaction is carried out at mild temperatures, and is typically a two-phase reaction. Because the reaction is exothermic, cooling is needed. Depending on the catalyst used, normal refinery cooling water provides sufficient cooling. Alternatively, a chilled cooling medium can be provided to cool the reaction. The catalyst protonates the alkenes to produce reactive carbocations which alkylate the isobutane reactant, thus forming branched chain paraffins from isobutane. Aromatic alkylation is generally now conducted with solid acid catalysts including zeolites or amorphous silica-aluminas.

The alkylation reaction zone is maintained at a pressure sufficient to maintain the reactants in liquid phase. For a hydrofluoric acid catalyst, a general range of operating pressures is from 200 to 7,100 kPa absolute. The temperature range covered by this set of conditions is from -20°C to 200°C. For at least alkylation of aromatic compounds, the temperature range is from 100°C to 200°C at the pressure range of 200 to 7,100 kPa.

Oxidation involves the oxidation of hydrocarbons to oxygen-containing compounds, such as aldehydes. The hydrocarbons include alkanes, alkenes, typically with carbon numbers from 2 to 15, and alkyl aromatics, linear, branched, and cyclic alkanes and alkenes can be used. Oxygenates that are not fully oxidized to ketones or carboxylic acids can also be subjected to oxidation processes, as well as sulfur compounds that contain -S-H moieties, thiophene rings, and sulfone groups. The process is carried out by placing an oxidation catalyst in a reaction zone and contacting the feed stream which contains the desired hydrocarbons with the catalyst in the presence of oxygen. The type of reactor which

can be used is any type well known in the art such as fixed-bed, moving-bed, multi-tube, CSTR, fluidized bed, etc. The feed stream can be flowed over the catalyst bed either up-flow or down-flow in the liquid, vapor, or mixed phase. In the case of a fluidized-bed, the feed stream can be flowed co-current or counter-current. In a CSTR the feed stream can be continuously added or added batch-wise. The feed stream contains the desired oxidizable species along with oxygen. Oxygen can be introduced either as pure oxygen or as air, or as liquid phase oxidants including hydrogen peroxide, organic peroxides, or peroxy-acids. The molar ratio of oxygen (O_2) to alkane can range from 5:1 to 1:10. In addition to oxygen and alkane or alkene, the feed stream can also contain a diluent gas selected form nitrogen, neon, argon, helium, carbon dioxide, steam or mixtures thereof. As stated, the oxygen can be added as air which could also provide a diluent. The molar ratio of diluent gas to oxygen ranges from greater than zero to 10:1. The catalyst and feed stream are reacted at oxidation conditions which include a temperature of 300°C to 600°C, a pressure of 101 kPa to 5,066 kPa and a space velocity of 100 to 100,000 hr^{-1}.

Hydrogenation involves the addition of hydrogen to hydrogenatable hydrocarbon compounds. Alternatively hydrogen can be provided in a hydrogen-containing compound with ready available hydrogen, such as tetralin, alcohols, hydrogenated naphthalenes, and others via a transfer hydrogenation process with or without a catalyst. The hydrogenatable hydrocarbon compounds are introduced into a hydrogenation zone and contacted with a hydrogen-rich gaseous phase and a hydrogenation catalyst in order to hydrogenate at least a portion of the hydrogenatable hydrocarbon compounds. The catalytic hydrogenation zone may contain a fixed, ebulated or fluidized catalyst bed. This reaction zone is typically at a pressure from 689kPag (100 psig) to 13,790 kPa gauge (2,000 psig) with a maximum catalyst bed temperature in the range of 177°C (350°F) to 454°C (850°F). The liquid hourly space velocity is typically in the range from 0.2 hr^{-1} to 10 hr^{-1} and hydrogen circulation rates from 200 standard cubic feet per barrel (SCFB) (35.6 m^3/m^3) to 10,000 SCFB (1778 m^3/m^3).

In some processes, all or a portion of the coal feed 10 is mixed with oxygen 135 and steam 140 and reacted under heat and pressure in the gasification zone 20 to form syngas 145, which is a mixture of carbon monoxide and hydrogen. The syngas 145 can be further processed using the Fischer-Tropsch reaction to produce gasoline or using the water-gas shift reaction to produce more hydrogen.

SPECIFIC EMBODIMENTS

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.

A first embodiment of the invention is a process for producing olefins from a coal feed, comprising providing a coal tar stream; fractionating the coal tar stream to provide a hydrocarbon stream comprising hydrocarbons having an initial boiling point of 250°C or greater; hydrotreating the hydrocarbon stream to reduce a concentration of one or more of nitrogen, sulfur, and oxygen in the hydrocarbon stream; and cracking the hydrotreated hydrocarbon stream in a fluidized catalytic cracking zone to produce an olefin stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein hydrotreating the hydrocarbon stream comprises contacting the hydrocarbon stream with a hydrotreating catalyst including a metal function comprising one or more of nickel, molybdenum, cobalt, and tungsten. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the hydrocarbon stream comprises hydrocarbons having the initial boiling point between 300°C and 400°C. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein the olefin stream comprises a plurality of olefins, the process further comprising separating the olefin stream into a plurality of olefin product streams based on a carbon number of the olefins. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein separating the olefin stream comprises distilling the olefin stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein separating the olefin stream comprises performing a solvent extraction on the olefin stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein separating the olefin stream produces at least a first olefin product stream including C_2 olefins, and further comprising polymerizing the first olefin product stream to produce hydrocarbons of a higher carbon number. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first

embodiment in this paragraph, wherein cracking the hydrotreated hydrocarbon stream comprises contacting the hydrotreated hydrocarbon stream with a cracking catalyst, the cracking catalyst comprising one or more of an active amorphous clay type catalyst, a high activity crystalline molecular sieve, and an MFI zeolite. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein hydrotreating the hydrocarbon stream reduces the concentration of sulfur to less than 50 parts per million, or reduces the concentration of nitrogen to less than 20 parts per million, or both.

A second embodiment of the invention is a process for producing olefins from a coal feed, comprising pyrolyzing coal to produce a coke stream and a coal tar stream; separating the coal tar stream to produce a hydrocarbon stream comprising hydrocarbons having an initial boiling point in a range of 250°C to 400°C; hydrotreating the hydrocarbon stream to produce a hydrotreated hydrocarbon stream having reduced concentration of one or more of nitrogen, sulfur, and oxygen; and cracking the hydrotreated hydrocarbon stream in a fluidized catalytic cracking zone to produce an olefin stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, wherein hydrotreating the hydrocarbon stream comprises contacting the hydrocarbon stream with a hydrotreating catalyst including a metal function comprising one or more of nickel, molybdenum, cobalt, and tungsten. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, wherein the hydrocarbon stream comprises hydrocarbons having an initial boiling point between 300°C and 400°C. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, wherein the olefin stream comprises a plurality of olefins, the process further comprising separating the olefin stream into a plurality of olefin product streams based on a carbon number of the olefins. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, wherein separating the olefin stream comprises distilling the olefin stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, wherein separating the olefin stream comprises performing a solvent extraction on the olefin stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph,

wherein separating the olefin stream produces at least a first olefin product stream comprising C_1 and C_2 hydrocarbons, and further comprising polymerizing the first olefin product stream to produce hydrocarbons of a higher carbon number. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, wherein cracking the hydrotreated hydrocarbon stream comprises contacting the hydrotreated hydrocarbon stream with a cracking catalyst, the cracking catalyst comprising one or more of an active amorphous clay type catalyst, a high activity crystalline molecular sieve, and an MFI zeolite. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, wherein hydrotreating the hydrocarbon stream reduces the concentration of sulfur to less than 50 parts per million, or reduces the concentration of nitrogen to less than 20 parts per million, or both.

A third embodiment of the invention is a process for producing olefins from a coal feed, comprising pyrolyzing coal to produce a coke stream and a coal tar stream; separating the coal tar stream to produce a hydrocarbon stream comprising hydrocarbons having an initial boiling point in a range of 250°C to 400°C; hydrotreating the hydrocarbon stream to produce a hydrotreated hydrocarbon stream having reduced concentration of one or more of nitrogen, sulfur, and oxygen; and cracking the hydrotreated hydrocarbon stream in a fluidized catalytic cracking zone to produce an olefin stream comprising a plurality of olefins; separating the olefin stream into a plurality of olefin product streams based on a carbon number of the olefins. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph, wherein separating the olefin stream produces at least a first olefin product stream comprising C_1 and C_2 hydrocarbons, and further comprising polymerizing the first olefin product stream to produce hydrocarbons of a higher carbon number.

While at least one exemplary embodiment has been presented in the foregoing detailed description of the invention, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the invention. It being understood that various changes may be made in the

function and arrangement of elements described in an exemplary embodiment without departing from the scope of the invention as set forth in the appended claims.

CLAIMS

1. A process for producing olefins from a coal feed, comprising:

providing a coal tar stream (30);

fractionating the coal tar stream to provide a hydrocarbon stream (60) comprising hydrocarbons having an initial boiling point of 250°C or greater;

hydrotreating the hydrocarbon stream (60) to reduce a concentration of one or more of nitrogen, sulfur, and oxygen in the hydrocarbon stream (60) to provide a hydrotreated hydrocarbon stream (85); and

cracking the hydrotreated hydrocarbon stream (85) in a fluidized catalytic cracking zone to produce an olefin stream (100).

2. The process of claim 1, wherein hydrotreating the hydrocarbon stream (60) comprises contacting the hydrocarbon stream (60) with a hydrotreating catalyst (80) including a metal function comprising one or more of nickel, molybdenum, cobalt, and tungsten.

3. The process of claim 1, wherein the hydrocarbon stream (60) comprises hydrocarbons having the initial boiling point between 300°C and 400°C.

4. The process of any one of claims 1 to 4, wherein the olefin stream (100) comprises a plurality of olefins, the process further comprising:

separating the olefin stream (100) into a plurality of olefin product streams (110, 115, 120) based on a carbon number of the olefins.

5. The process of claim 4, wherein separating the olefin stream (100) comprises distilling the olefin stream (100).

6. The process of claim 4, wherein separating the olefin stream (100) comprises performing a solvent extraction on the olefin stream (100).

7. The process of claim 4, wherein separating the olefin stream (100) produces at least a first olefin product stream (115) including C_2 olefins, and further comprising polymerizing said first olefin product stream (115) to produce hydrocarbons of a higher carbon number (130).

8. The process of any one of claims 1 to 4, wherein cracking the hydrotreated hydrocarbon stream (85) comprises contacting the hydrotreated hydrocarbon stream (85) with a cracking catalyst, the cracking catalyst comprising one or more of an active amorphous clay type catalyst, a high activity crystalline molecular sieve, and an MFI zeolite.

9. The process of any one of claims 1 to 4, wherein hydrotreating the hydrocarbon stream (80) reduces the concentration of sulfur to less than 50 parts per million, or reduces the concentration of nitrogen to less than 20 parts per million, or both.

10. The process of any one of claims 1 to 4, wherein separating the olefin stream (100) produces at least a first olefin product (115) stream comprising C_1 and C_2 hydrocarbons, and further comprising polymerizing said first olefin product stream (115) to produce hydrocarbons of a higher carbon number (130).

1/1

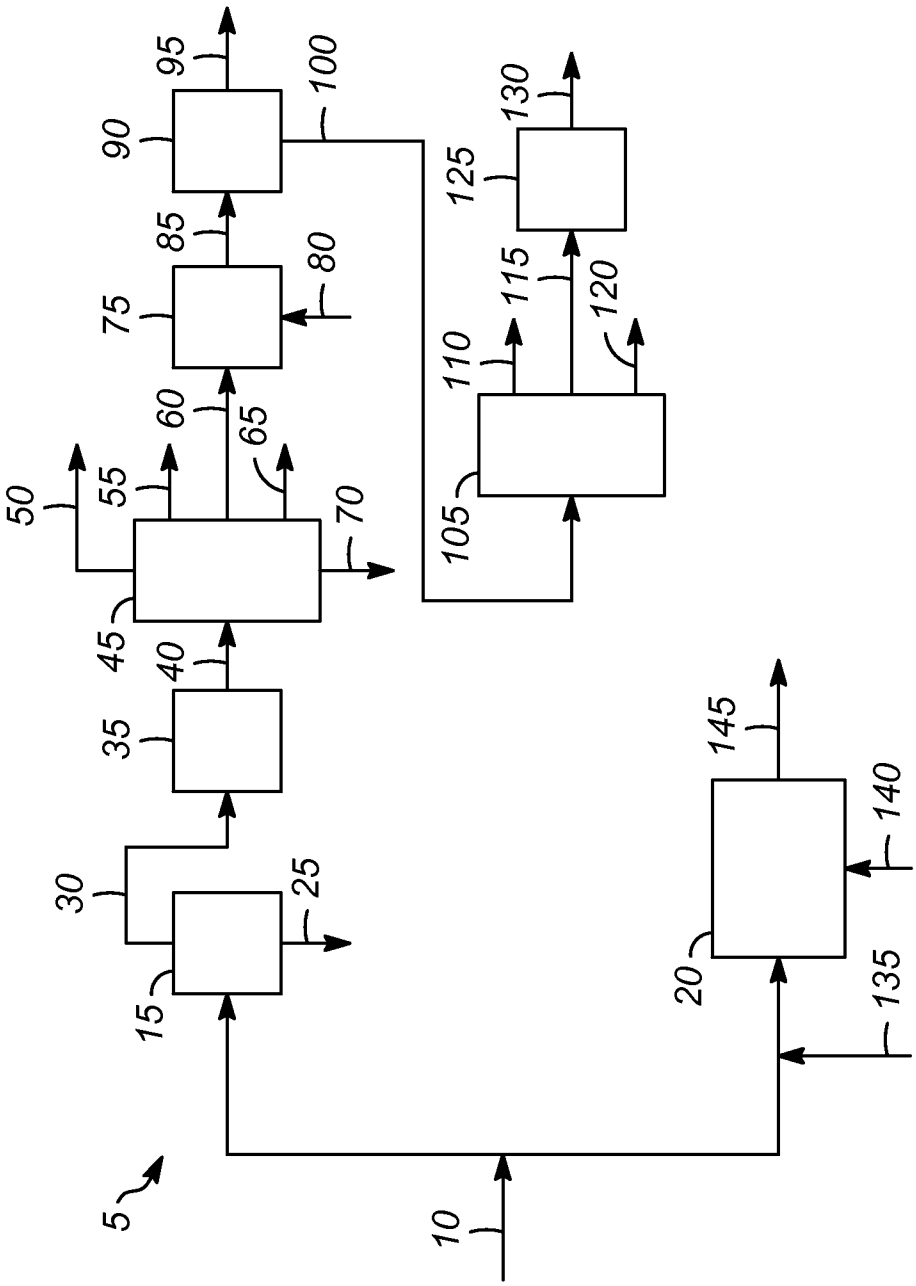
95
100
90
130
125
85
80
75
115
120
110
60
65
50
55
70
105
45
40
35
145
140
30
25
20
135
15
5
10

FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/061871

A. CLASSIFICATION OF SUBJECT MATTER

C10G 55/00(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10G 55/00; C07C 4/06; C10G 51/02; C07C 5/13

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: olefins, coal tar, fractionating, hydrotreating, cracking

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 102899088 A (WANG, XIAOYING) 30 January 2013 See abstract; paragraphs [0019], [0028]; claim 1; and figure 1.	1-10
Y	US 2013-0178673 A1 (KIM, H. C. et al.) 11 July 2013 See abstract; paragraphs [0013] - [0028], [0033], [0043], [0050] - [0057]; claims 1, 5 - 7, 9; and figure 1.	1-10
A	US 2006-0108261 A1 (STEFFENS, T. R. et al.) 25 May 2006 See abstract; paragraphs [0012] - [0019], [0032]; and claim 1.	1-10
A	US 5164071 A (HARANDI, M. N.) 17 November 1992 See abstract; column 2, lines 39 - 63, column 4, lines 7 - 13, column 6, line 60 - column 7, line 62, column 8, line 50 - column 9, line 11; claims 1, 4, 6; and figure 1.	1-10
A	CN 102851071 A (WANG, XIAOYING) 02 January 2013 See abstract; paragraphs [0013] - [0016], [0022], [0026], [0048], [0066]; claims 1, 3; and figure 1.	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"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
27 January 2015 (27.01.2015)	**27 January 2015 (27.01.2015)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea
Facsimile No. ++82 42 472 3473

Authorized officer
LEE, Dong Wook
Telephone No. +82-42-481-8163

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2014/061871

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 102899088 A	30/01/2013	None	
US 2013-0178673 A1	11/07/2013	CN 103108849 A	15/05/2013
		EP 2616415 A2	24/07/2013
		JP 2013-537223 A	30/09/2013
		KR 10-2012-0029143 A	26/03/2012
		SG 188984 A1	28/06/2013
		WO 2012-036484 A2	22/03/2012
		WO 2012-036484 A3	18/05/2012
US 2006-0108261 A1	25/05/2006	US 7374660 B2	20/05/2008
US 5164071 A	17/11/1992	US 5000837 A	19/03/1991
CN 102851071 A	02/01/2013	CN 102851071 B	13/08/2014