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

**(19) World Intellectual Property Organization**
International Bureau

**(43) International Publication Date**
**18 October 2012 (18.10.2012)**

WIPO | PCT

**(10) International Publication Number**
**WO 2012/142580 A1**

**(51) International Patent Classification:**
*C10G 7/00* (2006.01)

**(21) International Application Number:**
PCT/US2012/033781

**(22) International Filing Date:**
16 April 2012 (16.04.2012)

**(25) Filing Language:** English

**(26) Publication Language:** English

**(30) Priority Data:**
61/475,519 14 April 2011 (14.04.2011) US

**(71) Applicant** *(for all designated States except US)*: **BECHTEL HYDROCARBON TECHNOLOGY SOLUTIONS, INC.** [US/US]; 3000 Post Oak Blvd., Houston, TX 77056-6503 (US).

**(72) Inventors; and**
**(75) Inventors/Applicants** *(for US only)*: **KLEIN, Benjamin** [US/US]; 14 West Broad Oaks Drive, Houston, TX 77056 (US). **ENG, Odette** [US/US]; 4906 Glen Hollow, Sugar Land, TX 77479 (US).

**(74) Agent**: **JENSEN, William, P.**; Crain, Caton & James, P.C., 1401 Mckinney Street, Suite 1700, Houston, TX 77010 (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, 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, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, 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, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, 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, ML, MR, NE, SN, TD, TG).

**Published**:

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

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

**(54) Title**: SYSTEMS AND METHODS FOR REFINING CORROSIVE CRUDES

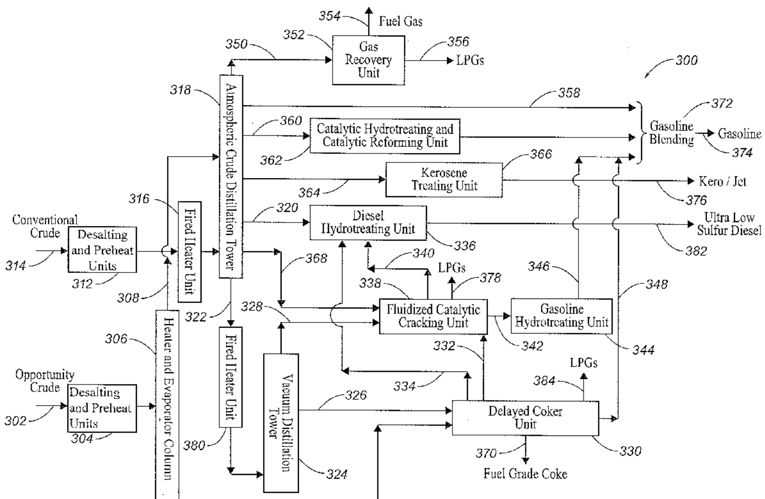


FIG. 3

**(57) Abstract**: Systems and methods for refining conventional crude and heavy, corrosive, contaminant- laden carbonaceous crude (Opportunity Crude) in partially or totally separated streams or trains.

WO 2012/142580 A1

# SYSTEMS AND METHODS FOR REFINING CORROSIVE CRUDES

## CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from U.S. Provisional Patent Application No. 61/475,519, filed on April 14, 2011, which is incorporated herein by reference.

## STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

[0002] Not applicable.

## FIELD OF THE INVENTION

[0003] The present invention generally relates to refining of corrosive crudes. More particularly, the invention relates to systems and methods for refining conventional crude and heavy, corrosive, contaminant-laden carbonaceous crude in partially separated streams or trains.

## BACKGROUND OF THE INVENTION

[0004] For existing oil refineries, the high cost of conventional, light sweet, crude oils has led refiners to consider retrofits with partial replacement of conventional crude oils with price-discounted heavy, corrosive (organic acids), contaminant laden (organic metals, polar heteroatoms, etc.) carbonaceous material more commonly referred to as “Opportunity Crude”, such as those offered from extensive reserves in Western Canada, Latin America, China, Russia, North Sea and elsewhere.

[0005] Many refiners have performed such retrofits by co-mingling or blending Opportunity Crude with conventional crude and requiring extensive modifications to almost every refinery process unit to deal with changes in the unit feed composition (e.g., boiling range, molecular structure, etc.) and level of contaminants (e.g., metals, sulfur, nitrogen, organic acids, etc.).

[0006] Declining markets for high sulfur fuel oil and asphalt, combined with shifting to heavier feedstock materials, have resulted in the need for heavy residual oil upgrading technologies, such as delayed coking, to reduce the yield of high sulfur fuel oil / asphalt and increase the yield of products in the range of liquid transportation fuels.

[0007] The combination of extensive retrofit costs and inefficient application of heavy residual oil upgrading often leads to an extremely high project capital cost, which may not justify the investment decision to introduce the Opportunity Crude into an existing refinery. This situation is likely to continue for an extended period of time on a worldwide basis.

[0008] A typical and conventional crude (e.g., low sulfur, low metals, low naphthenic acid, high API gravity, etc.) refining system **100** is illustrated in **FIG. 1**. This conventional system may be considered as a candidate for replacement of a portion of the refinery's conventional crude with a similar volume of lower quality Opportunity Crude. Many other conventional crude configurations are possible, however, which may benefit from the present invention. Thus, **FIG. 1** is just one example of a conventional crude configuration that may benefit from the present invention. In order to realize the benefits of a low cost Opportunity Crude, the capital cost of equipment modifications and additions must represent an acceptable return on investment and the yield and quality of refined products must meet market demand goals and product quality specifications. Unfortunately, prior art systems have been insufficient to do so or have required extensive modifications.

[0009] In operation of a typical and conventional crude refining system, conventional crude is routed through Desalting and Preheat Units **102**, a Fired Heater Unit **103** (which may be an atmospheric crude fired heater), an Atmospheric Crude Distillation Tower **104**, a Fired Heater Unit **105** and a Vacuum Distillation Tower **106** to produce a number of product fractions. As all are of equal importance in the process, no single product or product fraction is generally considered the principal product, rendering the others "by-products;" however, to the extent any one product is considered the principal product, such as gasoline, the others may be considered "by-products" of the process of gasoline production and thus, the terms "product" and "by-product" may be used synonymously herein. The Atmospheric Crude Distillation Tower **104,** the Fired Heater Unit **105** and a Vacuum Distillation Tower **106** separate the conventional crude into fractions by boiling range, such that each fraction becomes a suitable feed stock for downstream conversion and treating process units.

[0010] Products separated by the Atmospheric Crude Distillation Tower **104** include light gases, light naphtha (typically $C_5$–180° F boiling range as gasoline blend stock), and heavy naphtha (typically 180°-400° F boiling range), which may be provided as a feed stock to the downstream Catalytic Hydrotreating and Catalytic Reforming Unit **110.** Light gases are separated from naphtha in the Gas Recovery Unit **108.** Products of the Gas Recovery Unit **108** include $C_3$-$C_4$ Liquefied Petroleum Gas (LPG) and refinery fuel gas, which may be burned in refinery furnaces.

[0011] Heavy naphtha undergoes contaminant sulfur/nitrogen removal and molecular rearrangement to increase gasoline octane in the Catalytic Hydrotreating and Catalytic Reforming Unit **110**. Reformed heavy naphtha becomes a gasoline blend stock.

[0012] Another product of the Atmospheric Crude Distillation Tower **104** is kerosene. Kerosene (typically 380°-550° F boiling range) is drawn from the Atmospheric Crude Distillation Tower **104** and routed to Kerosene Treating Unit **112**. Treated kerosene (e.g., low mercaptan sulfur, high smoke point, etc.) may be sold as commercial kerosene or, with suitable freeze point, aromatics concentration, gum, and flash point, as jet engine fuel.

[0013] Another product of the Atmospheric Crude Distillation Tower **104** is diesel. Diesel (typically 500°-680° F boiling range) is drawn from the Atmospheric Crude Distillation Tower **104** and routed to the Diesel Hydrotreating Unit **114**. Catalytic hydrotreating reduces sulfur content to meet ultra low sulfur diesel specifications for on-road transportation fuel service.

[0014] Heavy atmospheric gas oil (typically 650°-750° F boiling range) is drawn from the Atmospheric Crude Distillation Tower **104** and routed to the Fluidized Catalytic Cracking Unit **116**.

[0015] High boiling (typically, 650° F and higher) atmospheric residue from the bottom of the Atmospheric Crude Distillation Tower **104** flows through the Fired Heater Unit **105** and the Vacuum Distillation Tower **106**.

[0016] Products of the Vacuum Distillation Tower **106** are vacuum gas oils (typically 625°-1,000° F boiling range), which are provided as a feed stock to the Fluidized Catalytic Cracking Unit **116**, and vacuum residue (typically 1000°+ F), which may be used as high sulfur fuel oil or asphalt.

[0017] Vacuum gas oils are routed to the Fluidized Catalytic Cracking Unit **116**, which may or may not include a catalytic hydrotreating pre-treatment step. In the fluidized catalytic cracking process, higher boiling vacuum gas oils are cracked into more valuable diesel and gasoline boiling range products. Byproduct LPG and fuel gas are recovered and separated within the Fluidized Catalytic Cracking Unit **116**. The diesel product becomes a feed stock to the Diesel Hydrotreating Unit **114**, while the gasoline product is routed to the Gasoline Hydrotreating Unit **118** for sulfur removal to meet specifications for low sulfur gasoline.

[0018] The most common prior art configuration and technical basis for replacing a portion of the refinery's conventional crude with a similar volume of lower quality Opportunity Crude is illustrated in **FIG. 2**, an exemplary prior art process **200**, particularly for purposes of comparison.

[0019] In **FIG. 2**, conventional crude and Opportunity Crude compose a blended feed stock referred to as "Opportunity Crude Blend" for this system **200** rather than using only conventional crude. Conventional crude and especially Opportunity Crude contain salts, sand, clay and sediments that could foul exchangers and certain material can poison downstream catalysts. Salts are frequently present in the form of Calcium, Sodium and Magnesium Chlorides. The high temperatures that occur downstream in the system **200** could allow the formation of corrosive hydrochloric acid. Therefore, the first step is to feed the Opportunity Crude Blend through a desalter where salts, suspended solids and free water are removed at low temperatures before this feed stock is preheated in a series of heat exchangers and a fired heater. Having a higher proportion of Opportunity Crude in the Opportunity Crude Blend will raise the specific gravity, lower the API gravity, and increase the viscosity and salt content of the material passing through the Desalting and Preheat Units **202**. These factors will make desalting more difficult, resulting in the need for more desalting capacity to increase residence time and facilitate oil/water separation, along with higher operating temperature and pressure, to suppress vaporization. As the operating conditions of the Desalting and Preheat Units **202** will also become inadequate for the new function, a replacement desalter, capable of higher temperatures and with a higher mechanical design pressure must be considered.

[0020] A Fired Heater Unit **203** associated with the Atmospheric Crude Distillation Tower **204** may be used to heat up the Opportunity Crude Blend to a desired temperature (between 650°-700° F depending on the type of feed stock) before it enters an Atmospheric Crude Distillation Tower **204**. Opportunity Crude with high Total Acid Number ("TAN") (particularly high naphthenic acid content) are corrosive, particularly in the temperature range between 450°-700° F, wherein the naphthenic acids are concentrated. The preheat exchangers piping and surface areas as well as the furnace tube metallurgy operating in this temperature range therefore, must be upgraded in the Atmospheric Crude Distillation Tower **204**.

[0021] The Opportunity Crude Blend is flashed off in the Atmospheric Crude Distillation Tower **204,** which uses pumparound cooling loops to create an internal liquid reflux. Product draws are on the top, sides, and bottom. The Atmospheric Crude Distillation Tower **204** operates on a descending temperature profile from bottom up as reflux from the top of the Atmospheric Crude Distillation Tower **204** provides the cooling medium while the Fired Heater Unit **203** in the bottom of the Atmospheric Crude Distillation Tower **204** provides heat to boil up product distillates. From the top of the Atmospheric Crude Distillation Tower **204**, at any point where the temperature may exceed 450° F, column trays and their internals must be replaced with higher metallurgy material. Since the bottom portion of the Atmospheric Crude Distillation Tower **204** would be operating at higher temperatures (between 650°-700° F depending on the type of feed stock) and exposed high TAN corrosive attacks, the lower shell of the Atmospheric Crude Distillation Tower **204** may be insufficient absent some modification, to provide alloy lining or a weld overlay.

[0022] The reduced crude exiting the bottom of the Atmospheric Crude Distillation Tower **204** is heated in a Fired Heater Unit **205** before being routed to the and the Vacuum Distillation Tower **206** to recover any gas oil from the reduced crude. Product draws are on the top, sides, and bottom. The Vacuum Distillation Tower **206** operates on a descending temperature profile from bottom up as reflux from the top of the Vacuum Distillation Tower **206** provides the cooling medium while a Fired Heater Unit 205 in the bottom of the Vacuum Distillation Tower **206** provides heat to boil up product vacuum gas oils.

[0023] Light products from the top of the Atmospheric Crude Distillation Tower **204** are sent to a Gas Recovery Unit **208** to separate fuel gas from LPG.

[0024] Full range naphtha recovered from the Atmospheric Crude Distillation Tower **204** is separated into light and heavy fractions. Light naphtha is sent for gasoline blending while heavy naphtha is processed through a Catalytic Hydrotreating and Catalytic Reforming Unit **210** to become a high octane gasoline component.

[0025] A kerosene product from the Atmospheric Crude Distillation Tower **204** is sent to a Kerosene Treating Unit **212** to remove sulfur and mercaptans. To produce jet fuel, a certain level of aromatic saturation needs to take place in order to make the smoke point specifications of jet fuel material.

[0026] A diesel product from the Atmospheric Crude Distillation Tower **204** and light gas oil from the Delayed Coker Unit **220** are combined and hydrotreated in a Diesel Hydrotreating Unit **214** to remove sulfur. In this process, the operating conditions and catalyst space velocity are selected in order to ensure both sulfur removal and a high cetane index number to meet the required specifications for Ultra Low Sulfur Diesel. These units may need to be modified from a conventional design using techniques well known in the art to manage the higher feed rates as conventional diesel hydrotreating unit reactors are not of sufficient size to address the higher feed rates and higher operating temperatures.

[0027] Atmospheric gas oil from the Atmospheric Crude Distillation Tower **204**, vacuum gas oil from the Vacuum Distillation Tower **206** and heavy gas oil from the Delayed Coker Unit

**220** pass through a Fluidized Catalytic Cracking Unit **216** to be further converted to lighter products. These products range from LPG, naphtha, LCO and slurry oil. With the use of Opportunity Crude, feeds to the Fluidized Catalytic Cracking Unit **216** are expected to contain higher level of contaminant requiring a higher catalyst replacement rate.

[0028] A gasoline product from the Fluidized Catalytic Cracking Unit **216** is routed to the Gasoline Hydrotreating Unit **218** to remove sulfur down to 30 or 10 ppm with minimum octane loss.

[0029] A vacuum resid from the bottom of the Vacuum Distillation Tower **206** is sent to the Delayed Coking Unit **220**, which also includes gas recovery and naphtha hydrotreating units, in order to convert this resid material to lighter products, such as light gas oil and heavy gas oil while minimizing LPG production.

[0030] Various other modifications have explored replacing a portion of the refinery's conventional crude with a similar volume of lower quality Opportunity Crude such as, for example, that disclosed in U.S. Patent Application Publication No. 2010/0206773 A1, U.S. Patent Application Publication No. 2010/0206772 A1, and U.S. Patent Application Publication No. US 2004/0164001 A1. These, however, have utilized expensive conversion methods for the opportunity crude, with associated higher capital expenditure and higher operating costs, and did not explore the use of delayed coking for conversion.

[0031] The prior art therefore, is limited by processing conventional crude and opportunity crude in a combined stream or train, which exposes components to corrosive crude constituents, destroying them over time.

## SUMMARY OF THE INVENTION

[0032] The present invention therefore, meets the above needs and overcomes one or more deficiencies in the prior art by providing systems and methods for refining of corrosive crudes. Conventional crude and heavy, corrosive, contaminant-laden carbonaceous crude in partially separated streams or trains.

[0033] In one embodiment of the invention, a method is provided for processing an opportunity crude, which includes separating the opportunity crude into a light material and a heavy material and processing the heavy material using a delayed coker. In a further embodiment, a method is provided for processing an opportunity crude which includes separating the opportunity crude into a light material and a heavy material and processing only the light material and a conventional crude using an atmospheric crude distillation process. Additionally, a system is provided for processing an opportunity crude, which includes at least one of a pre-flash heater and an evaporator column for separating the opportunity crude into a light material and a heavy material and a delayed coker for processing the heavy material. An alternative embodiment of the system is also provided for processing an opportunity crude, which includes at least one of a pre-flash heater and an evaporator column for separating the opportunity crude into a light material and a heavy material and an atmospheric crude distillation tower for processing only the light material and a conventional crude.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] The present invention is described below with references to the accompanying drawings, in which like elements are referenced with like numerals, wherein:

[0035] **FIG. 1** illustrates a conventional crude oil refining system.

[0036] **FIG. 2** illustrates a prior art configuration for replacing a portion of the refinery's conventional crude with a similar volume of lower quality Opportunity Crude.

[0037] **FIG. 3** illustrates one embodiment of a system for implementing the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0038] The subject matter of the present invention is described with specificity, however, the description itself is not intended to limit the scope of the invention. The subject matter thus, might also be embodied in other ways, to include different steps or combinations of steps similar to the ones described herein, in conjunction with other present or future technologies. Moreover, although the term "step" may be used herein to describe different elements of methods employed, the term should not be interpreted as implying any particular order among or between various steps herein disclosed unless otherwise expressly limited by the description to a particular order.

[0039] The following systems and methods greatly reduce the capital and operating costs for existing petroleum refineries where the conventional crude oil feedstock will be partially replaced by a lower cost, lower quality Opportunity Crude.

[0040] Referring now to **FIG. 3**, one embodiment of a system **300** for implementing the present invention, which offers significant advantages in capital cost and construction cost, is illustrated. The system **300** achieves the cost-saving goals of replacing a portion of the refinery's conventional crude with a similar volume of lower quality Opportunity Crude and partially processing them separately by means of refinery modifications (equipment modifications and additions), which translate into both lower capital cost, lower construction cost, and a shorter construction schedule. By keeping the conventional crude in the conventional crude train as illustrated in **FIG. 2**, no metallurgy upgrade is necessary for most of the assets (equipment) in the system **300**. In other words, partially separating the processing of conventional crude and

Opportunity Crude in the system **300** eliminates the high-TAN acid crude component from some of the equipment in the system **300**.

[0041] In the system **300**, only conventional crude **314** is fed through the Desalting and Preheat Units **312**. The volume of conventional crude **314** to be processed therefore, may be reduced and replaced by at least the same volume of Opportunity Crude **302**. The optimum amount of each can vary and will be determined by refinery economics. Conventional crude **314** contains less salts, foulants and sediments than those found in Opportunity Crude **302**. Therefore, by keeping the conventional crude **314** separate from the Opportunity Crude **302**, existing system (i.e. equipment) may be utilized with nominal changes.

[0042] The conventional crude **314** enters Desalting and Preheat Units **312** where salts and suspended solids are removed at low temperature. This feed is preheated in a series of heat exchangers and a Fired Heater Unit **316**. The Fired Heater Unit **316** is used to heat up the conventional crude **314** to a desired temperature (between 650°-700° F depending on the type of feed) before this material is fed to an Atmospheric Crude Distillation Tower **318**.

[0043] Exiting the Fired Heater Unit **316**, the conventional crude **314** is flashed off in the Atmospheric Crude Distillation Tower **318**, which uses pumparound cooling loops to create internal liquid reflux. Product draws are on the top, sides, and bottom of the Atmospheric Crude Distillation Tower **318**. The Atmospheric Crude Distillation Tower **318** operates on a descending temperature profile from the bottom up as reflux from the top of the Atmospheric Crude Distillation Tower **318** provides the cooling medium while a fired heater in the bottom of the Atmospheric Crude Distillation Tower **318** provides heat to boil up product distillates. Light products **350** from the top of the Atmospheric Crude Distillation Tower **318** are sent to a Gas Recovery Unit **352** to separate fuel gas **354** from LPG **356**.

[0044] Full range naphtha from the Atmospheric Crude Distillation Tower **318** is separated into a light fraction **358** and a heavy fraction **360**. The light naphtha fraction **358** is sent for use in gasoline blending **372** to produce gasoline **374** while the heavy naphtha fraction **360** is sent to a Catalytic Hydrotreating and Catalytic Reforming Unit **362** to produce a high octane gasoline for use in gasoline blending **372** to produce gasoline **374**.

[0045] A kerosene product **364** from the Atmospheric Crude Distillation Tower **318** is sent to a Kerosene Treating Unit **366** to remove sulfur and mercaptans and produce jet fuel **376**. To produce jet fuel **376**, a certain level of aromatic saturation must take place in order to make the smoke point specifications of jet fuel.

[0046] A diesel product **320** from the Atmospheric Crude Distillation Tower **318,** light gas oil **334** from the Delayed Coker Unit **330** and a product for diesel fuel **340** from the Fluidized Catalytic Cracking unit (FCCU) **338** are sent to a Diesel Hydrotreating Unit **336** to remove sulfur and produce a diesel component **382** for Ultra Low Sulfur Diesel. The operating conditions and catalyst space velocity are therefore, selected in order to ensure both sulfur removal and a high cetane index number to meet the required specifications for the diesel component **382**, which may be used for Ultra Low Sulfur Diesel. Due to the higher feed rates, the Atmospheric Crude Distillation Tower **318** may need to be modified from a conventional design using techniques well known in the art to manage the higher feed rates.

[0047] Atmospheric gas oil **368** from the Atmospheric Crude Distillation Tower **318,** vacuum gas oil **328** from the Vacuum Distillation Tower **324** and heavy gas oil **332** from the Delayed Coker Unit **330** are sent to the FCCU **338** to be converted into lighter products. These products range from LPG **378**, naphtha **342**, to light cycle oil and slurry oil. Due to the higher feed rates, the FCCU **338** may need to be modified from a conventional design using techniques well known in the art to manage the higher feed rates. With the use of Opportunity Crude **302**, heavy gas oil **332** from the Delayed Coker Unit **330** is expected to contain a higher level of contaminants requiring higher catalyst replacement.

[0048] Naphtha **342** from the FCCU **338** is sent through a Gasoline Hydrotreating Unit **344** to reduce the sulfur concentration to 10-30 ppm with minimum octane loss thus, producing a product for use in gasoline blending **372** to produce gasoline **374**.

[0049] The reduced crude **322** from the bottom of the Atmospheric Crude Distillation Tower **318** is heated in a Fired Heater Unit **380** before being fed to the Vacuum Distillation Tower **324** to recover any gas oil from the reduced crude **322**.

[0050] The Opportunity Crude **302** enters a Desalting and Preheat Units **304** where salts and suspended solids are removed from the oil at low temperatures and the oil is preheated in one or a series of heat exchangers. The product of the Desalting and Preheating Units **304** is then heated in the heater of the Heater and Evaporator Column **306**. Due to the high acidity of this product, upgraded metallurgy may be used in areas where its temperature is greater than 450° F with higher operating conditions anticipated for high temperature/pressure desalting. The heat exchangers of the Desalting and Preheat Units **304** and the heater of the Heater and Evaporator Column **306** may be designed for high viscosity material and may require upgraded metallurgy, which may be accessed based on specific feedstock characteristics.

[0051] The Heater and Evaporator Column **306** is used to separate condensate and remove any light material **308** with a boiling point below 650° F (referred to as 650° F- or low boiling Opportunity Crude), which is fed to Atmospheric Crude Distillation Tower **318**. A heavy material **310** with a boiling point above 650° F (referred to as 650° F+ or high boiling Opportunity Crude) at the bottom of the Heater and Evaporator Column **306** is sent directly to the Delayed Coker Unit **330** to save the cost of a new alloy-lined vacuum unit. Another embodiment, however, may include a vacuum unit upstream of the Delayed Coker Unit **330**. This separation point, of about 650° F may be adjusted depending on the characteristics of the opportunity crude, including down to 600° F or up to 750° F. However, while a higher temperature is better, as it results in the need for smaller vacuum-related components, the effects of higher temperature on the opportunity crude may be problematic, including cracking of the opportunity crude, particularly within the piping.

[0052] Vacuum resid **326** from the Vacuum Distillation Tower **324** together with the heavy material **310** are sent to the Delayed Coker Unit **330** in order to convert the vacuum resid **326** to lighter products, such as light gas oil **334**, heavy gas oil **332,** LPG **384,** and fuel grade coke **370** while minimizing gasoline production. A dual function crude atmospheric fractionator incorporated into the Delayed Coker Unit **330** will also serve as a fractionator for coker products thus, eliminating the need for a vacuum distillation unit upstream of Delayed Coker Unit **330** as explained previously. Process operating costs can be further reduced when utilizing heat from coke drum vapor at or about 800° F to preheat coker feed thereby, eliminating or greatly reducing the size of a separate fired heater for the dual function crude atmospheric fractionator. Thus, the atmospheric pressure flash unit operation and delayed coker product fractionation are incorporated into a single fractionation tower of the Delayed Coker Unit **330**. The Delayed Coker Unit **330** may include a dual function crude atmospheric fractionator. Thus, this configuration eliminates or reduces the need for a conventional delayed coker fired heater and thus reduces the capital cost of the coker unit.

[0053] Delayed Coker Unit **330** may also include conventional gas recovery unit and naphtha hydrotreating components to produce a treated product **348** for gasoline blending, which is sent for use in gasoline blending **372** to produce gasoline **374**. Distillate products (naphtha, diesel, gas oil) from the Delayed Coker **330** can be integrated with refinery hydroprocessing (hydrotreating, hydrocracking, hydro-isomerization). The Delayed Coker Unit **330** offers a shift toward higher value products such as middle distillates over gasoline. Due to special design features for Delayed Coker Unit **330**, the system **300** may also focus on maximizing middle distillate production.

[0054] The system **300** may be implemented in most, if not all, existing refineries with a crude oil production capacity in the range of 50,000 – 200,000 barrels per stream/day although an existing refinery implementing the system **300** may, or may not, have existing resid bottoms upgrading (i.e. coking, solvent deasphalting, thermal cracking, visbreaking). By separating the Opportunity Crude **302** from the conventional crude **314** and directing the heavy material **310** and the vacuum resid **326** from the Vacuum Distillation Tower **324** to the Delayed Coker Unit **330**, the system **300** avoids the need for significant equipment modifications and metallurgy upgrades in an existing refinery. The selection of Opportunity Crude type and feed rate are key evaluation factors for implementation of the system **300** to both optimize the capital cost of new equipment and minimize impacts to the existing refinery equipment (hydroprocessing, catalytic cracking, etc.). The system **300** thus, offers a low capital expenditure solution while minimizing field construction labor and downtime for the modification of existing refinery equipment. The system **300** can be implemented and applied to a modification of existing refinery assets (or equipment) with or without expansion of the refinery crude processing capacity.

[0055] The advantages of the system **300** thus, include:

- combining the atmospheric pressure flash unit operation and delayed coker product fractionation functions in a single fractionation tower.

- separating low quality corrosive Opportunity Crude from existing front-end processing to avoid equipment/piping modifications and metallurgy upgrades;
- minimizing shutdown time and construction inefficiencies related to work in existing process units, whereby new process units can be constructed separately (green field) and tied into the existing refinery;
- maximizing a middle distillates-to-gasoline ratio from bottoms upgrading to help increase refinery margins and take advantage of higher diesel and/or jet fuel demand and pricing;
- integrating Opportunity Crude pre-flash and coker product fractionation to save equipment cost;
- eliminating vacuum distillation required for Opportunity Crude;
- using existing fuels refinery processes to manufacture finished products; and
- integrating the delayed coker and the separated Opportunity Crude to reduce operating costs, which i) provides significant fraction of bitumen pre-flash heat requirement (minimize pre-flash heat duty) for a superheated coke drum vapor (800° F); and ii) refrigerates lean oil absorption to reduce coker gas recovery costs.

[0056] In the foregoing specification, the invention has been described with reference to specific embodiments thereof, and has been demonstrated as effective in providing systems and methods for lowering the processing cost of Opportunity Crude. However, it will be evident to those skilled in the art that various modifications and changes can be made thereto without departing from the broader spirit or scope of the invention. Accordingly, the specification is to be regarded in an illustrative rather than a restrictive sense. For example, it is anticipated that by routing certain streams differently or by adjusting operating parameters, different optimizations and efficiencies may be obtained, which would nevertheless not cause the system to fall outside of the scope of the present invention. It is therefore, contemplated that various alternative embodiments and modifications may be made to the disclosed embodiments without departing from the spirit and scope of the invention defined by the appended claims and equivalents thereof.

Claims

We claim:

1. A method for processing an opportunity crude, comprising:

separating the opportunity crude into a light material and a heavy material; and

processing the heavy material using a delayed coker.

2. The method of claim 1 wherein the light material comprises a carbonaceous material with a boiling point below about 650° F and the heavy material comprises a heavy, corrosive, carbonaceous material with a boiling point above about 650° F.

3. The method of claim 1 wherein the light material comprises a low boiling opportunity crude and the heavy material comprises a high boiling opportunity crude.

4. The method of claim 1 wherein the opportunity crude is separated into the light material and the heavy material using only at least one of a pre-flash heater and an evaporator column.

5. The method of claim 1 wherein the heavy material is processed with a vacuum resid using the delayed coker to convert the vacuum resid into one of a light gas oil, and a fuel grade coke product.

6. The method of claim 1 wherein the heavy material is processed without vacuum distillation.

7. The method of claim 1 further comprising:

processing only at least one of the light material and a reduced crude using a vacuum distillation process to recover a vacuum gas oil from the reduced crude and to produce a vacuum resid for the delayed coker.

8. The method of claim 7 further comprising:

processing the vacuum resid using the delayed coker to produce a treated product for gasoline blending.

9. A method for processing an opportunity crude, comprising:

separating the opportunity crude into a light material and a heavy material;

processing only the light material and a conventional crude using an atmospheric crude distillation process.

10. The method of claim 9 wherein the light material and the conventional crude are processed to produce at least one of a reduced crude, a diesel product, atmospheric gas oil, a kerosene product, a light naphtha fraction, and a heavy naphtha fraction.

11. The method of claim 9 wherein the light material comprises a carbonaceous material with a boiling point below about 650° F and the heavy material comprises a heavy, corrosive, carbonaceous material with a boiling point above about 650° F.

12. The method of claim 9 wherein the light material comprises a low boiling opportunity crude and the heavy material comprises a high boiling opportunity crude.

13. The method of claim 9 wherein the opportunity crude is separated into the light material and the heavy material using only at least one of a pre-flash heater and an evaporator column.

14. The method of claim 9 further comprising:

processing the heavy material with a vacuum resid using a delayed coker to convert the vacuum resid into one of a light gas oil and a fuel grade coke product.

15. The method of claim 14 wherein the heavy material is processed without vacuum distillation.

16. The method of claim 15 further comprising:

processing only at least one of the light material and a reduced crude using a vacuum distillation process to recover a vacuum gas oil from the reduced crude and to produce a vacuum resid for the delayed coker.

17. The method of claim 16 further comprising:

processing the vacuum resid using the delayed coker to produce a treated product for gasoline blending.

18. A system for processing an opportunity crude, comprising:

at least one of a pre-flash heater and an evaporator column for separating the opportunity crude into a light material and a heavy material; and

a delayed coker for processing the heavy material.

19. The system of claim 18 wherein the heavy material is processed with a vacuum resid using the delayed coker to convert the vacuum resid into one of a light gas oil and a fuel grade coke products.

20. The system of claim 18 wherein the light material comprises a carbonaceous material with a boiling point below about 650° F and the heavy material comprises a heavy, corrosive, carbonaceous material with a boiling point above about 650° F.

21. The system of claim 18 wherein the light material comprises a low boiling opportunity crude and the heavy material comprises a high boiling opportunity crude.

22. The system of claim 18 wherein the heavy material is processed without vacuum distillation.

23. The system of claim 18 further comprising:

a vacuum distillation tower for processing only at least one of the light material and a reduced crude to recover a vacuum gas oil from the reduced crude and produce a vacuum resid for the delayed coker.

24. The system of claim 23 wherein the vacuum resid is further processed using the delayed coker to produce a treated product for gasoline blending.

25. A system for processing an opportunity crude, comprising:

at least one of a pre-flash heater and an evaporator column for separating the opportunity crude into a light material and a heavy material; and

an atmospheric crude distillation tower for processing only the light material and a conventional crude.

26. The system of claim 25 wherein the light material and the conventional crude are processed to produce at least one of a reduced crude, a diesel product, atmospheric gas oil, a kerosene product, a light naphtha fraction, and a heavy naphtha fraction.

27. The system of claim 25 wherein the light material comprises a carbonaceous material with a boiling point below about 650° F and the heavy material comprises a heavy, corrosive, carbonaceous material with a boiling point above about 650° F.

28. The method of claim 25 wherein the light material comprises a low boiling opportunity crude and the heavy material comprises a high boiling opportunity crude.

29. The system of claim 25 further comprising:

a delayed coker for processing the heavy material with a vacuum resid to convert the vacuum resid into one of a light gas and a fuel grade coke product.

30. The system of claim 29 wherein the heavy material is processed without vacuum distillation.

31. The system of claim 25 further comprising:

a vacuum distillation tower for processing only at least one of the light material and a reduced crude to recover a vacuum gas oil from the reduced crude and produce a vacuum resid for the delayed coker.

32. The system of claim 31 wherein the vacuum resid is further processed using the delayed coker to produce a treated product for gasoline blending.

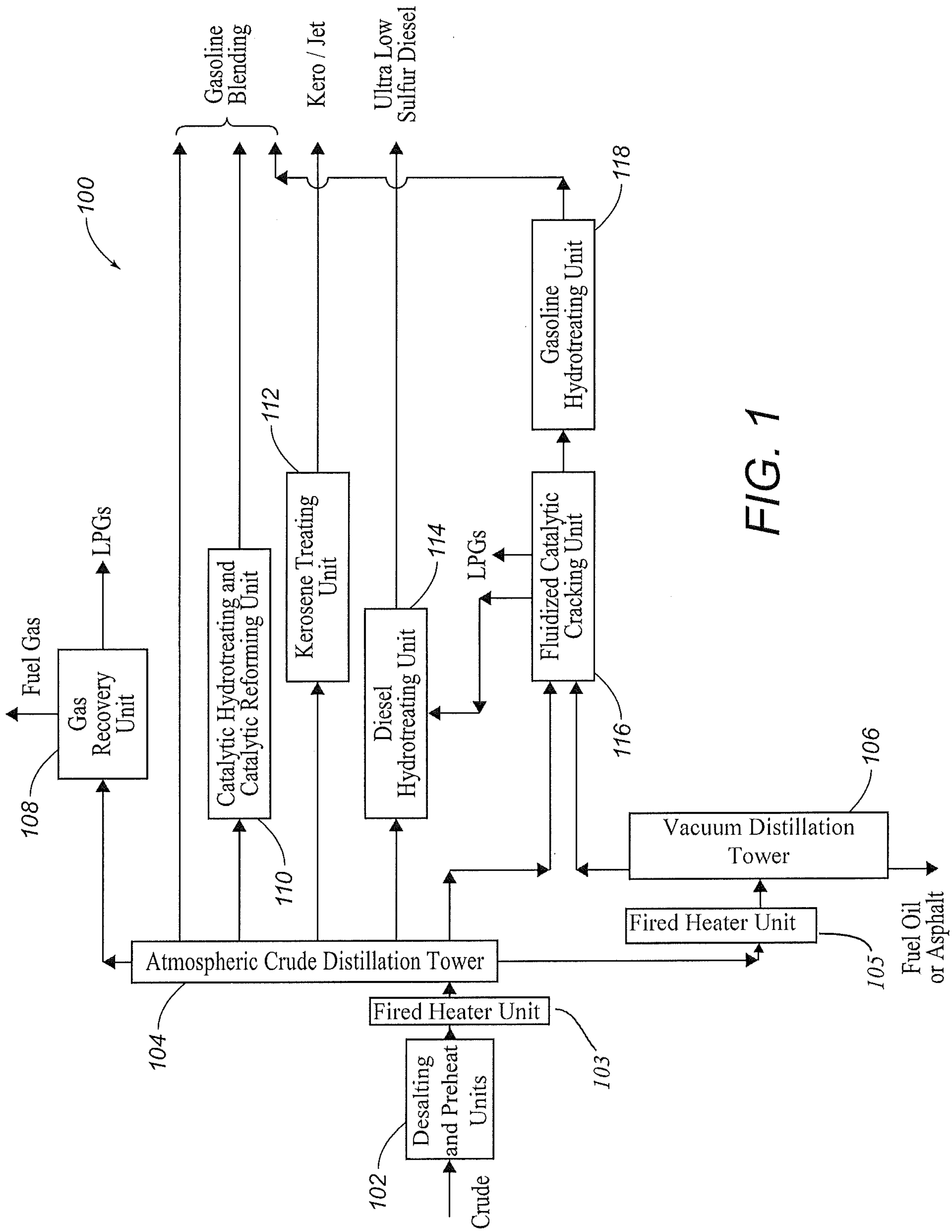
100
Fuel Gas
LPGs
Gas Recovery Unit
108
Gasoline Blending
Kero / Jet
Ultra Low Sulfur Diesel
Catalytic Hydrotreating and Catalytic Reforming Unit
110
Kerosene Treating Unit
112
Diesel Hydrotreating Unit
114
LPGs
Fluidized Catalytic Cracking Unit
116
Gasoline Hydrotreating Unit
118
Vacuum Distillation Tower
106
Fired Heater Unit
105
Fuel Oil or Asphalt
Atmospheric Crude Distillation Tower
104
Fired Heater Unit
103
Desalting and Preheat Units
102
Crude

FIG. 1

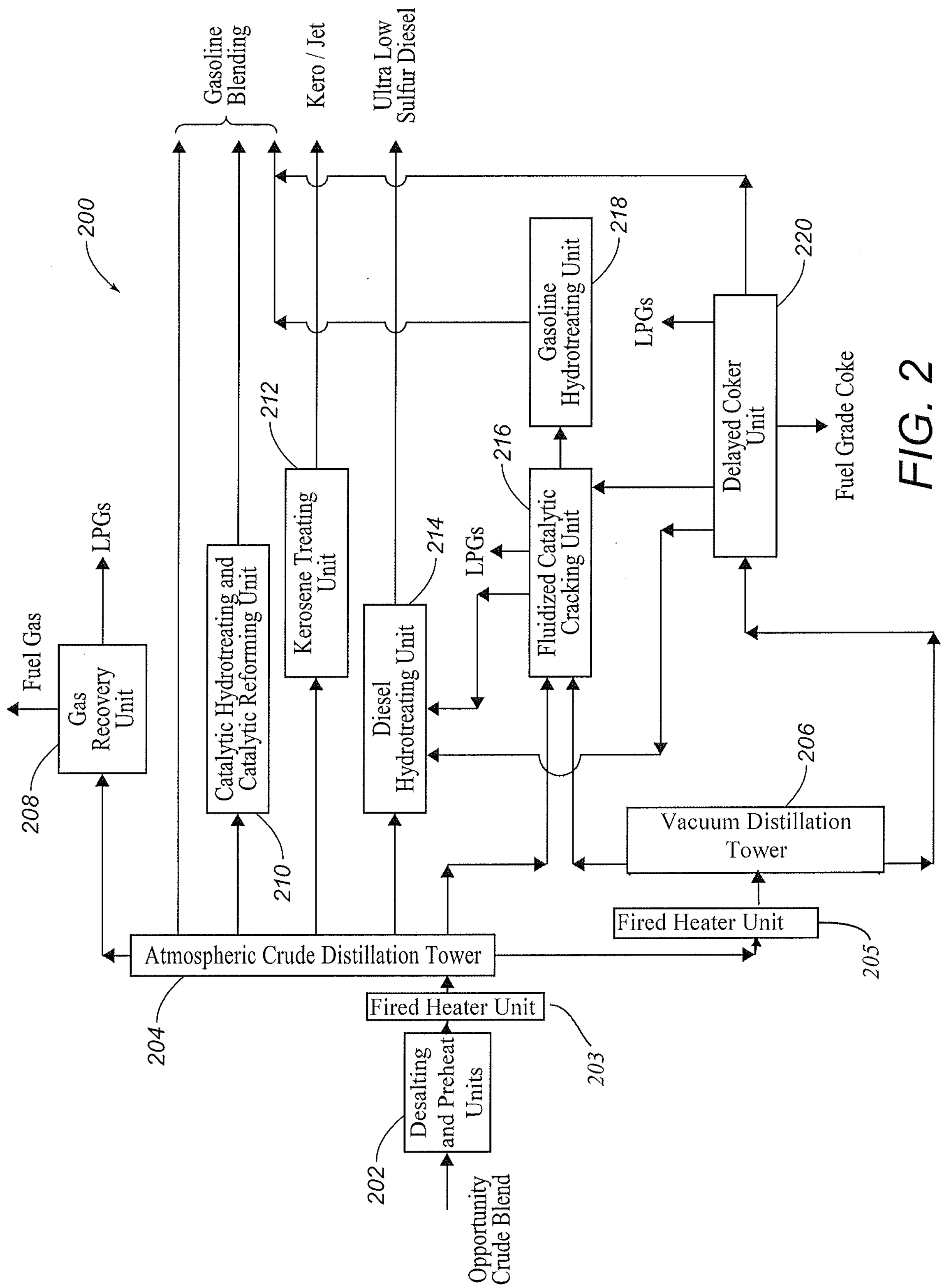
200
Opportunity Crude Blend
Desalting and Preheat Units
202
Fired Heater Unit
203
Atmospheric Crude Distillation Tower
204
Fired Heater Unit
205
Vacuum Distillation Tower
206
Gas Recovery Unit
208
Fuel Gas
LPGs
Catalytic Hydrotreating and Catalytic Reforming Unit
210
Kerosene Treating Unit
212
Diesel Hydrotreating Unit
214
Fluidized Catalytic Cracking Unit
216
LPGs
Gasoline Hydrotreating Unit
218
Delayed Coker Unit
220
LPGs
Fuel Grade Coke
Gasoline Blending
Kero / Jet
Ultra Low Sulfur Diesel

FIG. 2

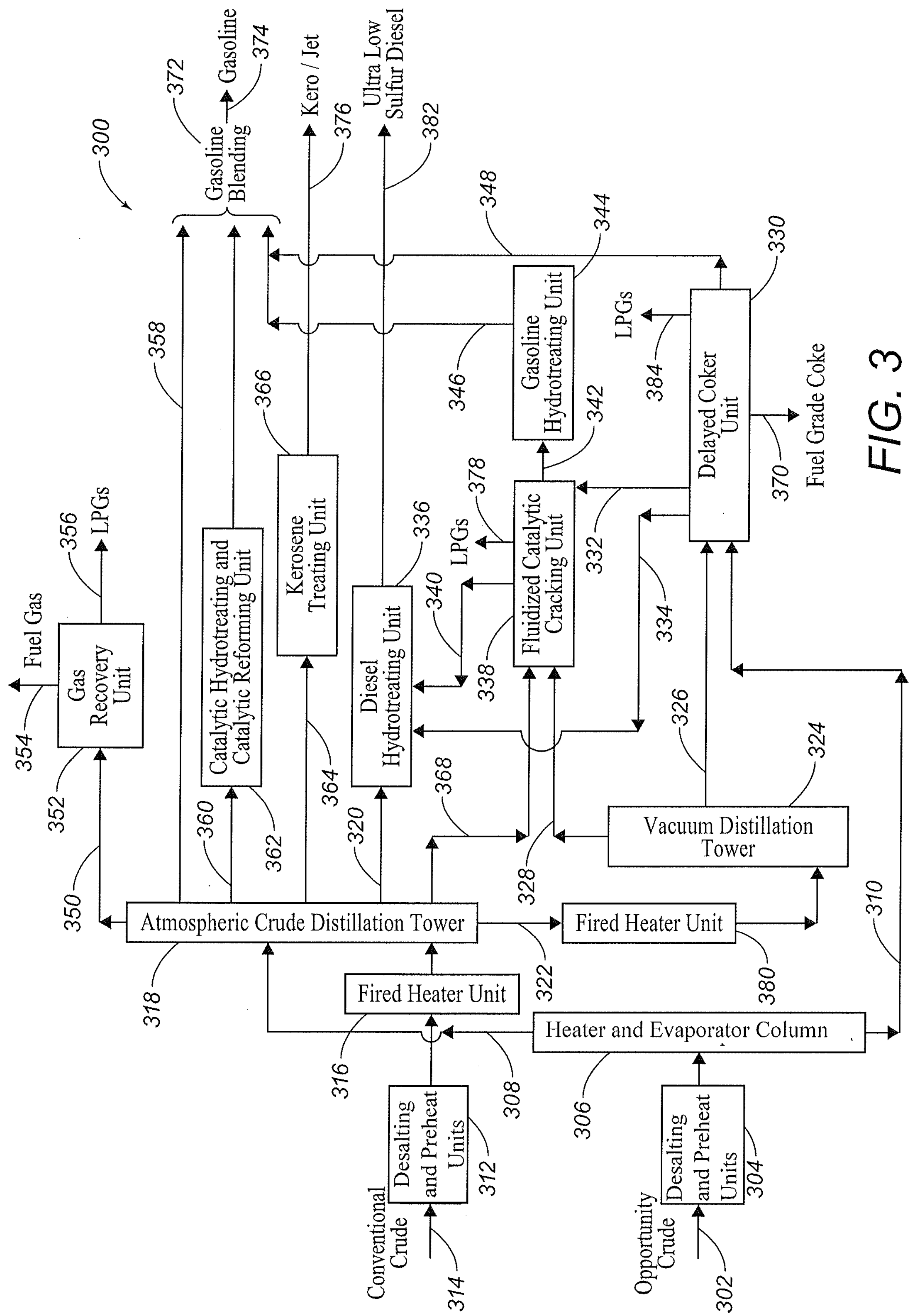
300
Gasoline Blending
372
374
Gasoline
Kero / Jet
376
Ultra Low Sulfur Diesel
382
348
344
330
358
366
Gasoline Hydrotreating Unit
346
LPGs
384
Delayed Coker Unit
Fuel Grade Coke
370
342
378
Fuel Gas
356
LPGs
Gas Recovery Unit
354
352
Catalytic Hydrotreating and Catalytic Reforming Unit
Kerosene Treating Unit
336
Diesel Hydrotreating Unit
340
LPGs
Fluidized Catalytic Cracking Unit
338
332
334
326
324
364
362
360
320
368
328
Vacuum Distillation Tower
350
Atmospheric Crude Distillation Tower
Fired Heater Unit
318
322
380
310
Fired Heater Unit
Heater and Evaporator Column
316
308
306
Desalting and Preheat Units
312
Desalting and Preheat Units
304
Conventional Crude
314
Opportunity Crude
302

FIG. 3

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/33781

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - C10G 7/00 (2012.01)
USPC - 208/50; 208/357
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)
USPC: 208/50; 208/357

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC: C10G 7/00 (2012.01)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST (USPT, PGPUB, EPAB, JPAB); Google Scholar/Patent
Search terms: delayed, coker, vacuum, resid, opportunity, crude

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>---<br>Y | US 3,480,540 A (Eng et al.) 25 November 1969 (25.11.1969); entire document, especially Figure and col. 1 | 1-4 and 6<br>--------------<br>5, 7, and 8 |
| Y | US 6,332,975 B1 (Abdel-Halim et al.) 25 December 2001 (25.12.2001); entire document, especially cols. 8 and 10 | 5 |
| Y | US 5,124,027 A (Beaton et al.) 23 June 1992 (23.06.1992); entire document, especially cols. 7, 8, 10, and Fig. 2 | 7 and 8 |

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

* 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 |
|---|---|
| 29 August 2012 (29.08.2012) | 14 SEP 2012 |

| Name and mailing address of the ISA/US | Authorized officer: |
|---|---|
| Mail Stop PCT, Attn: ISA/US, Commissioner for Patents<br>P.O. Box 1450, Alexandria, Virginia 22313-1450<br>Facsimile No. 571-273-3201 | Lee W. Young<br>PCT Helpdesk: 571-272-4300<br>PCT OSP: 571-272-7774 |

**INTERNATIONAL SEARCH REPORT**

International application No. PCT/US 12/33781

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: claims 1-8 directed to a method for processing an opportunity crude, comprising:
separating the opportunity crude into a light material and a heavy material; and
processing the heavy material using a delayed coker.

Group II: claims 9-17 and 25-32 directed to a method for processing an opportunity crude, comprising:
at least one of a pre-flash heater and an evaporator column for separating the opportunity crude into a light material and a heavy material; and
processing only the light material and a conventional crude using an atmospheric crude distillation process.
-----------------See Supplemental Sheet--------------

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-8

**Remark on Protest**

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Continuation of Box III Observations where unity of invention is lacking

Group III: claims 18-24 directed to a system for processing an opportunity crude, comprising:
at least one of a pre-flash heater and an evaporator column for separating the opportunity crude into a light material and a heavy material; and
a delayed coker for processing the heavy material.

The inventions listed as Groups I-III do not relate to a single general inventive concept under PCT Rule 13.1 because under PCT Rule 13.2 they lack the same or corresponding technical features for the following reasons:

Group I does not include the at least one of a pre-flash heater and an evaporator column for separating the opportunity crude into a light material and a heavy material of groups II and III.

Groups II does not include the delayed coker of groups I and III.

Groups I and III do not include the processing only the light material and a conventional crude using an atmospheric crude distillation process of group II.

The common features of the above groups are taught by US 4,454,023 A (Lutz) (12 June 1984):
a system for processing an opportunity crude (col 1, ln 7-13) of groups I, II and III, comprising:
at least one of a pre-flash heater (fig 2; feedstock heater 12) and an evaporator column for separating the opportunity crude into a light material and a heavy material (fig. 2; feedstock flash zone and visbreaker flash zone) of groups II and III; and
delayed coker for processing the heavy material(col 9, ln 15-20; a skilled artisan would have known to use the heavy fraction for a delayed coker) of groups I and III; therefore the common feature is not an improvement over the prior art.

Groups I-III therefore lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.