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(54) **METHODS FOR RENEWABLE FUEL**

VERFAHREN FÜR ERNEUERBAREN KRAFTSTOFF

PROCÉDÉS POUR DU CARBURANT RENOUVELABLE

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(56) References cited:
WO-A2-2010/002792
US-A1- 2010 222 620
US-A1- 2011 224 471

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Description

FIELD OF THE INVENTION

[0001] The present disclosure generally relates to the introduction of a renewable fuel or renewable oil as a feedstock into refinery systems or field upgrading equipment. More specifically, the present disclosure is directed to methods of introducing a liquid thermally produced from biomass into a refinery fluid catalytic cracker (FCC), for co-processing with petroleum fractions, petroleum fraction reactants, and/or petroleum fraction feedstocks and the products, e.g., fuels, and uses and value of the products resulting therefrom.

BACKGROUND

[0002] Biomass has been a primary source of energy over much of human history. During the late 1800's and 1900's the proportion of the world's energy sourced from biomass dropped, as the commercial development and utilization of fossil fuels occurred, and markets for coal and petroleum products dominated. Nevertheless, some 15% of the world's energy continues to be sourced from biomass, and in developing countries the contribution of biomass is much higher at 38%. In addition, there has been a new awareness of the impact of the utilization of fossil fuels on the environment. In particular, the contribution of greenhouse gases, as a result of consuming fossil fuels.

[0003] Biomass, such as wood, wood residues, and agricultural residues, can be converted to useful products, *e.g.,* fuels or chemicals, by thermal or catalytic conversion. An example of thermal conversion is pyrolysis where the biomass is converted to a liquid and char, along with a gaseous co-product by the action of heat in essentially the absence of oxygen.

[0004] In a generic sense, pyrolysis is the conversion of biomass to a liquid and/or char by the action of heat, typically without involving any significant level of direct combustion of the biomass feedstock in the primary conversion unit.

[0005] Historically, pyrolysis was a relatively slow process where the resulting liquid product was a viscous tar and "pyroligneous" liquor. Conventional slow pyrolysis has typically taken place at temperatures below 400 °C, and over long processing times ranging from several seconds to minutes or even hours with the primary intent to produce mainly charcoal and producing liquids and gases as by-products.

[0006] A more modern form of pyrolysis, or rapid thermal conversion, was discovered in the late 1970's when researchers noted that an extremely high yield of a light, pourable liquid was possible from biomass. In fact, liquid yields approaching 80% of the weight of the input of a woody biomass material were possible if conversion was allowed to take place over a very short time period, typically less than 5 seconds.

[0007] The homogeneous liquid product from this rapid pyrolysis, which has the appearance of a light to medium petroleum fuel oil, can be considered renewable oil. Renewable oil is suitable as a fuel for clean, controlled combustion in boilers, and for use in diesel and stationary turbines. This is in stark contrast to slow pyrolysis, which produces a thick, low quality, two-phase tar-aqueous mixture in very low yields.

[0008] In practice, the short residence time pyrolysis of biomass causes the major part of its organic material to be instantaneously transformed into a vapor phase. This vapor phase contains both non-condensable gases (including methane, hydrogen, carbon monoxide, carbon dioxide and olefins) and condensable vapors. It is the condensable vapors that constitute the final liquid product, when condensed and recovered, and the yield and value of this liquid is a strong function of the method and efficiency of the downstream capture and recovery system.

[0009] Given the fact that there is a limited availability of hydrocarbon crude and an ever increasing demand for energy, particularly liquid transportation fuels, alternative sources are therefore required. The abundance and sustainability of biomass makes this renewable feedstock an attractive option to supplement the future demand for petroleum. The difficulty with biomass is the fact that it contains oxygen, unlike conventional hydrocarbon fuels, and historically has not been readily convertible into a form that can be easily integrated into existing hydrocarbon based infrastructure.

[0010] A significant amount of work has been done to investigate the production of liquid hydrocarbon fuels from biomass by various thermal and thermocatalytic schemes. US5,792,340; US5,961,786; Lappas et al., Biomass Pyrolysis in a Circulating Fluid Bed Reactor for the Production of Fuels and Chemicals, Fuel 81 (2002), 2087-2095); and Samolada et al., Catalyst Evaluation for Catalytic Biomass Pyroloysis, Fuel & Energy 2000, 14, 1161-1167, describe the direct processing of biomass or other oxygenated carbonaceous feedstocks in a circulating fluid bed reactor using a catalyst (zeolite FCC catalyst) as the solid circulating media in an effort to directly deoxygenate the biomass and produce transportation fuels or fuel blends, as well as other hydrocarbons. Although some hydrocarbon products were produced, the yields were unacceptably low, and there was a high yield of char or coke and by-product gas produced. In addition, there were frequent issues with reactor fouling and plugging, and other serious technical difficulties associated with catalyst performance. Not only were the liquid yields lower, much of liquid product produced would require further upgrading and treatment to enable any direct immediate use in place of fossil fuel-based hydrocarbons.

[0011] Given the above limitations, another alternative for hydrocarbon production from biomass is to convert solid biomass first into a thermally-produced or thermocatalytically-produced liquid, and then feed this neat liquid (i.e. 100%

liquid biomass product) into a circulating fluid bed reactor using a FCC catalyst or other appropriate catalyst as the solid circulating media (Adjaye et al., Production of Hydrocarbons by Catalytic Upgrading of a Fast Pyrolysis Bio-oil, Fuel Processing Technology 45 (1995), 185--192). Again, in this case, unacceptable hydrocarbon yields were achieved, reactor plugging and fouling was often evident, and much of the feedstock was converted to char/coke, gas and an oxygen-rich liquid that tended to separate into different liquid phases.

[0012] The use of catalytic cracking of a solid or liquid biomass, a biomass-derived vapor, or a thermally-produced liquid as a means to produce hydrocarbons from oxygenated biomass is technically complex, relatively inefficient, and produces significant amounts of low value byproducts. To solve the catalyst and yield issues, researchers looked at stand-alone upgrading pathways where biomass-derived liquids could be converted to liquid hydrocarbons using hydrogen addition and catalyst systems in conversion systems that were tailored specifically for the processing of oxygenated materials (Elliott, Historical Developments in Hydroprocessing Bio-oils, Energy & Fuels 2007, 21, 1792-1815). Although technically feasible, the large economies-of-scale and the technical complexities and costs associated with high-pressure multi-stage hydrogen addition (required for complete conversion to liquid hydrocarbon fuels) are severely limiting and generally viewed as unacceptable.

[0013] As a means to overcome the technical and economic limitations associated with full stand-alone biomass upgrading to transportation fuels, researchers (de Miguel Mercader, Pyrolysis Oil Upgrading for Co-Processing in Standard Refinery Units, Ph.D Thesis, University of Twente, 2010 ("Mercader"); Fogassy et al., Biomass Derived Feedstock Co-Processing with VGO for Hybrid Fule Production in FCC Units, Institut de Recherches sur la Catalyse et l'Environnement de Lyon, UMR5236 CNRS-UCBL ("Fogassy"); Gutierrez et al., Co-Processing of Upgraded Bio-Liquids in Standard Refinery Units - Fundamentals, 15th European Biomass Conference & Exhibition, Berlin May 7-11, 2007) are looking at various schemes for partial upgrading of the oxygenated biomass to reduce oxygen, followed by the co-processing of this intermediate biomass product with petroleum feedstocks in existing petroleum refinery operations. These initiatives are all focused on hydrodeoxygenation of the biomass-derived liquid prior to co-processing with petroleum, and are predicated on the consideration that hydrotreatment of the thermally produced liquid is necessary prior to petroleum co-processing in order to avoid rapid FCC catalyst deactivation and reactor fouling, and to preclude excessive coke and gas production. Hence, the published studies and prior art include the co-processing of petroleum in fluid catalytic cracking (FCC) refinery units with upgraded liquids that have been hydrotreated after their initial thermal production from biomass

[0014] US 2010/222620 and US 2011/224471 both disclose methods of preparing a fuel.

[0015] The early FCC units traditionally used dense phase bed reactor systems to enable good contact between the catalyst and the hydrocarbon feedstock. Long residence times were required to ensure sufficient conversion of the feedstock to the desired product. As catalyst systems improved and the catalyst became more active, the FCC was redesigned to incorporate a riser configuration. The riser configuration enabled contact times between the catalyst and hydrocarbon feedstock to be reduced to somewhere around 2 to 3 seconds (does not include any residence time in the reactor vessel or termination section).

[0016] One drawback of many, if not most of the early FCC designs was the riser termination systems that essentially linked the riser to an open reactor vessel that housed the solids separation devices. It had been recognized for several years that significant post riser thermal cracking occurs in commercial FCC units resulting in the substantial production of dry gas and other lower value products. The two mechanisms by which this occurs are through thermal and dilute catalytic cracking. Thermal cracking results from extended residence times of hydrocarbon vapors in the reactor disengaging area, and leads to high dry gas yields via non-selective free radical cracking mechanisms. Dilute phase catalytic cracking results from extended contact between catalyst and hydrocarbon vapors downstream of the riser. While much of this was eliminated in the transition from bed to riser cracking, there is still a substantial amount that can occur in the dilute phase due to significant catalyst holdup which occurs without an advanced termination system design.

[0017] Many FCC vendors and licensors offer advanced riser termination systems to minimize post-riser cracking, and many if not most units have implemented these in both new unit and revamp applications. In addition, some refiners have implemented their own "in-house" designs for the same purpose. Given the complexity and diversity of FCC units as well as new unit design differences, there are many variations of these advanced termination systems such as "closed" cyclones, "close-coupled" cyclones, "direct coupled" cyclones, "high containment systems", "vortex separation system", etc. There are differences in the specific designs, and some may be more appropriate for specific unit configurations than others, but all serve the same fundamental purpose of reducing the undesirable post-riser reactions.

[0018] Contact time of the catalyst with the feedstock is comprised of the residence time in the riser and often includes the residence time in the advanced riser termination system as described above. Typical riser residence times are about 2 to 3 seconds and the additional termination system residence time may be about 1 to 2 seconds. This leads to an overall catalyst contact time of about 3 to 5 seconds.

BRIEF SUMMARY OF THE APPLICATION

[0019] The method of the invention is defined in the appended claims.

[0020] In certain embodiments, the invention comprises increasing the mix-zone temperature in an FCC unit comprising injecting between 0.05-15 wt.% renewable fuel oil feedstock via a quench riser system downstream (after) of the introduction of a petroleum fraction feedstock injection nozzle.

DETAILED DESCRIPTION OF THE DRAWINGS

[0021] Many of the benefits of the materials, systems, methods, products, uses, and applications among others may be readily appreciated and understood from consideration of the description and details provided in this application inclusive of the accompanying drawings and abstract, wherein:

Figure 1: illustrates a fluid catalytic cracking (FCC) unit.
Figure 2A: illustrates a exemplary converter.
Figure 2B: illustrates a exemplary converter that has been retro-fitted with an injection port or two (102), with two different locations (which may be alternative locations or both used) suitable for introducing a renewable fuel oil (RFO) feedstock.
Figure 3: illustrates a riser quench technology.
Figure 4: illustrates a coking unit.
Figure 5: illustrates a feed injection system.
Figure 6: illustrates a FCC unit with dual risers.
Figure 7: is a graph presenting the influence of catalyst:oil ratio and RFO concentration in VGO on conversion (on a mass basis).
Figure 8: is a graph presenting the influence of catalyst:oil ratio and RFO concentration in VGO on overall conversion (on an equivalent energy input basis).
Figure 9: is a graph presenting the influence of catalyst:oil ratio and RFO concentration in VGO on gasoline yield (on an energy equivalent input basis).
Figure 10: is a graph depicting the influence of catalyst:oil ratio and RFO concentration in VGO on gasoline yield as a function of feed carbon content (on an equivalent carbon input basis).
Figure 11: is a graph depicting the influence of catalyst: oil ratio and RFO concentration in VGO on LPG yield (on an equivalent energy input basis).
Figure 12: is a graph depicting the influence of catalyst:oil ratio and RFO concentration in VGO on dry gas yield (on an equivalent energy input basis).
Figure 13: is a graph depicting the influence of catalyst:oil ratio and RFO concentration in VGO on LCO yield (on an equivalent energy input basis).
Figure 14: is a graph depicting the influence of catalyst:oil ratio and RFO concentration in VGO on HCO yield (on an equivalent energy input basis).
Figure 15: is a graph depicting the influence of catalyst:oil ratio and RFO concentration in VGO on coke yield (on an equivalent energy input basis)).
Figure 16: is a graph depicting gasoline yield as a function of RFO substitution and catalyst:oil ratio (on a 10,000 bbls/day, water free basis).
Figure 17: is graph depicting gallons of gasoline/ton of RFO asa function of RFO substitution and catalyst:oil ratio (on a wt.% contribution using reference VGO).
Figure 18: is a graph depicting the influence of catalyst:oil ratio and RFO concentration in VGO on gasoline yield (on volume input to the FCC unit basis).
Figure 19: is a graph depicting the influence of catalyst:oil ratio and RFO concentration in HGO on gasoline yield (on a 10,000 bbls/day feed basis)

DETAILED DESCRIPTION

[0022] In 2005, the Environmental Protection Agency (EPA) released its Renewable Fuel Standards (RFS1), which were the first renewable fuel mandates in the United States. The RFS called for 7.5B gallons of renewable fuel to be blended into gasoline by 2012. Two years later, the program was expanded under the Energy Independence and Security Act of (EISA) of 2007 to target 36B gallons of renewable fuel by 2022. In addition, EISA expanded the RFS to cover diesel fuels as well as gasoline (jet fuels were not initially included under RFS) and established individual volume targets for the different types of renewable fuel (e.g., RFS2 calls for 21B gallons of advanced biofuels by 2022).

[0023] In February 2010, the EPA submitted its final rule for RFS2, its revision to the previous renewable fuel standards

(RFS1). The ruling set forth volume targets for 36B gallons of renewable fuels produced in the US by 2022 with 21B being advanced biofuels (non-ethanol). Due to the lack of commercial cellulosic facilities in the U.S., the EPA conducts an annual review of total cellulosic capacity to evaluate the feasibility of its production targets and subsequently makes adjustments. The EPA has proposed cellulosic volumes of up to 12.9M gallons (up to 15.7M gallons on an ethanol equivalent basis) for 2012, well below its original 500M gallon target. Significant progress must be made in facilitating the scale-up cellulosic technologies in order for the U.S. to meet the 16B gallon production target for cellulosic fuels by 2022.

[0024] Part of the regulations include an incentive program that provides for an award of Renewable Identification Numbers (RIN) for the production of fuels in accordance with certain pathways that are designed to be environmentally less harmful than the traditional methods of producing fuels. Among the several approved pathways, there are some related to the use of cellulosic containing biomass (cellulosic biomass) that can earn Cellulosic Renewable Indentification Numbers (C-RIN's). The use of cellulosic biomass can also aid fuel producers in meeting their Renewable Volume Obligations (RVO) as well. One aspect of the current application may be that the use of unenriched renewable fuel oil in amounts of less than 6 wt.% such as at about 5 wt.% or about 3 wt.%; relative to the total weight of feedstock fed (for example, petroleum fraction and renewable feedstock) to a conversion unit employed to produce gasoline, among other fuels and by products, resulted not only in an opportunity to comply with the requirements to earn C-RIN's and/or RVO's but also an at least an equivalent yield of gasoline (on an equivalent input basis, for example, energy basis or carbon content basis). The equivalent yield of gasoline includes an increase yield of gasoline for example and increase of more than 0.5 wt.%, more than 0.75 wt.%, more than 1 wt. %, such as from 0.5 wt.% and 5.0 wt.% or from 1.25 wt.% and 3.0 wt.% on an equivalent input basis, for example, energy basis or carbon content basis.

[0025] Suitable biomass, biomass materials, or biomass components, include but are not limited to, wood, wood residues, sawdust, slash bark, thinnings, forest cullings, begasse, corn fiber, corn stover, empty fruit bunches (EFB), fronds, palm fronds, flax, straw, low-ash straw, energy crops, palm oil, non-food-based biomass materials, crop residue, slash, pre-commercial thinnings and tree residue, annual covercrops, switchgrass, miscanthus, cellulosic containing components, cellulosic components of separated yard waste, cellulosic components of separated food waste, cellulosic components of separated municipal solid waste (MSW), or combinations thereof. Cellulosic biomass, for example, includes biomass derived from or containing cellulosic materials. For example, the biomass may be one characterized as being compliant with U.S. renewable fuel standard program (RFS) regulations, or a biomass suitable for prepaing a cellulosic-renewable identification number-compliant fuel. In certain embodiments, the biomass may be characterized as being compliant with those biomass materials specified in the pathways for a D-code 1, 2, 3, 4, 5, 6, or 7-compliant fuel, in accordance with the U.S. renewable fuel standard program (RFS) regulations. For example, the biomass may be characterized as being compliant with those biomass materials suitable for preparing a D-code 3 or 7-compliant fuel, in accordance with the U.S. renewable fuel standard program (RFS) regulations or the biomass may be charachterized as being composed of only hydrocarbons (or renewable hydrocarbons).

[0026] A renewable fuel oil (also referred to herein as "RFO") refers to a biomass-derived fuel oil or a fuel oil prepared from the conversion of biomass. For example, in certain embodiments, the renewable fuel oil may be a cellulosic renewable fuel oil (also referred to herein as "cellulosic RFO"), and may be derived or prepared from the conversion of cellulosic-containing biomass. A further example of a suitable renewable fuel oil may be a non-hydrodeoxygenated, non-deoxygenated, non-hydrotreated, non-upgraded, non-catalytically processed, thermo-mechanically-processed renewable fuel oil which would be understood to mean a renewable fuel oil that may be derived from simply mechanically grinding a biomass, for example a cellulosic biomass, and then thermally processing the ground biomass, for example rapidly, to derive a liquid with no further processing steps to substantially alter the oxygen content, the water content, the sulfur content, the nitrogen content, the solids content or otherwise enrich the renewable fuel oil for processing into a fuel. Additionally, this non-hydrodeoxygenated, non-deoxygenated, non-hydrotreated, non-upgraded, non-catalytically processed, thermo-mechanically-processed renewable fuel oil could be blended with other batches of non-hydrodeoxygenated, non-deoxygenated, non-hydrotreated, non-upgraded, non-catalytically processed, thermo-mechanically-processed renewable fuel oil and/or other non-hydrodeoxygenated, non-deoxygenated, non-hydrotreated, non-upgraded, non-catalytically processed, thermo-mechanically-processed renewable fuel oil that have been derieved from other biomass to form blends of non-hydrodeoxygenated, non-deoxygenated, non-hydrotreated, non-upgraded, non-catalytically processed, thermo-mechanically-processed renewable fuel oil.

[0027] In particular, the the renewable fuel oil may be a liquid formed from a biomass comprising cellulosic material, wherein the only processing of the biomass may be a therma-mechanical process comprising grinding and rapid thermal processing, with no post processing or enrichment of the liquid prior to introduction into petroleum conversion unit). Specifically, no hydrodeoxygenation, no hydrotreating, no catalytic exposure or contact just unenriched renewable fuel oil derived by thermo-mechanically processing cellulosic containing biomass.

[0028] The renewable fuel oil is an unenriched liquid (also referred to as an unenriched renewable fuel oil) formed from ground-up biomass by a process, for example rapid thermal processing, wherein the resulting liquid may be at least 50wt.%, for example at least 60wt.%, at least 70wt.%, at least 75 wt.%, at 80wt.% or at least 85 wt.% of the total

weight of the processed biomass. In other words the liquid yield from the processed biomass may be at least 50wt.%, for example at least 60wt.%, at least 70wt.%, at least 75 wt.%, at 80wt.% or at least 85 wt.% of the total weight of the ground biomass being processed. Unenriched should be understood to refer to renewable fuel oil liquid that does not undergo any further pre- or post-processing including, specifically, no hydrodeoxygenation, no hydrotreating, no catalytic exposure or contact. In certain embodiments, unenriched renewable fuel oil may be prepared from the ground biomass and then transported and/or stored, and may be even heated or maintained at a given temperature; not exceeding 65.56°C (150°F), on its way to being introduced into the coversion unit at the refinery. The mechanical handling associated with transporting, storing, heating, and/or pre-heating of the unenriched renewable fuel oil is not be considered an enriching step. In certain embodiments, an unenriched renewable fuel oil may comprise one or more unenriched renewable fuels oils mixed from separate unenriched batches and/or unenriched batches resulting from different cellulosic biomass (for example, several different types of non-food biomass). In certain embodiments, these mixed compositions, which may be blended to purposefully provide or achieve certain charachterisitics in the combined unenriched renewable fuel oil, may still be considered unenriched renewable fuel oil provided that substantially all (for example greater than 80 wt. %, or greater than 90 wt.% such as greater than 95 wt.% or greater than 98 wt.% or greater than 99 wt.%) or all of the combined batches are unenriched renwable fuel oil.

[0029] In certain embodiments, the renewable fuel oil may have a pH in the range of 0.5 to 8.0. For example, the renewable fuel oil may have a pH in the range of 0.5 to 7.0, such as 0.5 to 6.5, 1.0 to 6.0, 2.0 to 5.0, 3.0 to 7.0, 1.0 to 4.0, or 2.0 to 3.5. In certain embodiments, the pH of the renewable fuel oil may be less than 8.0, such as less than 7.0, less than 6.5, less than 6.0, less than 5.5, less than 5.0, less than 4.5, less than 4.0, less than 3.5, less than 3.0, less than 2.5, or less than 2.0. In certain embodiments, the pH of the renewable fuel oil may be altered or modified by the addition of an external, non-biomass derived material or pH altering agent. In certain embodiments, the renewable fuel oil may be acidic. For example, the renewable fuel oil may have a pH in the range of between 0.5 to 7, such as between 1 to 7, between 1 to 6.5, between 2 to 5. between 2 to 3.5, between 1 to 4, between 2 to 6, or between 2 to 5. In certain embodiments, the renewable fuel oil has the pH resulting from the conversion of the biomass from which it may be derived, such as a biomass-derived pH.

[0030] In certain embodiments, the renewable fuel oil may have a solids content in the range less than 5 wt.%. For example, the renewable fuel oil may have a solids content of less than 4 wt.%, less than 3 wt.%, less than 2.5 wt.%, less than 2 wt.%, less than 1 wt.%, less than 0.5 wt.%, or less than 0.1 wt.%. In certain embodiments, the renewable fuel oil may have a solids content in the range of between 0.005 wt.% and 5 wt.%. For example, the renewable fuel oil may have a solids content in the range of between 0.005 wt.% and 4 wt.%, such as between 0.005 wt.% and 3 wt.%, between 0.005 wt.% and 2.5 wt.%, between 0.005 wt.% and 2 wt.%, between 0.005 wt.% and 1 wt.%, between 0.005 wt.% and 0.5 wt.%, between 0.05 wt.% and 4 wt.%, between 0.05 wt.% and 2.5 wt.%, between 0.05 wt.% and 1 wt.%, between 0.05 wt.% and 0.5 wt.%, between 0.5 wt.% and 3 wt.%, between 0.5 wt.% and 1.5 wt.%, or between 0.5 wt.% and 1 wt.%.

[0031] In certain embodiments, the renewable fuel oil may have an ash content of less than 0.5 wt.%. For example, the renewable fuel oil may have an ash content of less than 0.4 wt.%, such as less than 0.3 wt.%, less than 0.2 wt.%, less than 0.1 wt.%, less than 0.05 wt.%, less than 0.005 wt.%, or less than 0.0005 wt.%. In certain embodiments, the renewable fuel oil may have an ash content in the range of between 0.0005 wt.% and 0.5 wt.%, such as between 0.0005 wt.% and 0.2 wt.%, between 0.0005 wt.% and 0.05 wt.%, or between 0.0005 wt.% and 0.1 wt.%.

[0032] In certain embodiments, the renewable fuel oil may comprise a water content in the range of between 10-40 wt.%. For example, the renewable fuel oil may comprise a water content in the range of between 15-35 wt.%, such as between 15-30 wt.%, between 20-35 wt.%, between 20-30 wt.%, between 30-35 wt.%, between 25-30 wt.%, or between 32-33 wt.% water. In certain embodiments, the renewable fuel oil may comprise a water content in the range of less than 40 wt.%, such as less than 35 wt.%, or less than 30 wt.%. In certain embodiments, the renewable fuel oil may comprise a water content of at least 10 wt.%, such as at least 15 wt.%, at least 20 wt.%, or at least 25 wt.%.

[0033] In certain embodiments, the renewable fuel oil may comprise an oxygen content level higher than that of a petroleum fraction feedstock. For example, the renewable fuel oil may have an oxygen content level of greater than 20 wt.%, on a dry basis or moisture-free basis, such as an oxygen content level in the range of between 20-50 wt.%, between 35-40 wt.%, between 25-35 wt.%, between 20-30 wt.%, between 25-50 wt.%, between 20-40 wt.%, or between 20-35 wt.%, on a dry basis or moisture-free basis.

[0034] In certain embodiments, the renewable fuel oil may comprise a greater oxygen content level than carbon content level. For example, the renewable fuel oil may have a greater oxygen content level than carbon content level, on a moisture-containing basis. In certain embodiments, the renewable fuel oil may have in the range of between 35-80 wt.% carbon content and in the range of between 20-50 wt.% oxygen content, on a dry basis or moisture-free basis. For example, the renewable fuel oil may have in the range of between 50-60 wt.% carbon content and in the range of between 35-40 wt.% oxygen content, on a dry basis or moisture-free basis.

[0035] In certain embodiments, the renewable fuel oil may comprise a carbon content level of at least 40 wt.% of the carbon content contained in the biomass from which it may be derived. For example, the renewable fuel oil may comprise

a carbon content level of at least 45 wt.%, such as at least 50 wt.%, at least 55 wt.%, at least 60 wt.%, at least 65 wt.%, at least 70 wt.%, at least 75 wt.%, at least 80 wt.%, at least 85 wt.%, at least 90 wt.%, or at least 95 wt.% of the carbon content contained in the biomass from which it may be derived. In certain embodiments, the renewable fuel oil may comprise a carbon content level in the range of between 40 wt.% and 100 wt.% of the carbon content contained in the biomass from which it may be derived. For example, the renewable fuel oil may comprise a carbon content level in the range of between 40 wt.% and 95 wt.%, between 40 wt.% and 90 wt.%, between 40 wt.% and 80 wt.%, between 50 wt.% and 90 wt.%, between 50 wt.% and 75 wt.%, between 60 wt.% and 90 wt.%, between 60 wt.% and 80 wt.%, between 70 wt.% and 95 wt.%, between 70 wt.% and 80 wt.%, or between 70 wt.% and 90 wt.% of the carbon content contained in the biomass from which it may be derived. In certain embodiments, the renewable fuel oil may comprise a carbon content level lower than that of a petroleum fraction feedstock. For example, the renewable fuel oil may comprise a carbon content level in the range of between 35-80 wt.%, on a dry basis moisture-free basis, such as between 40-75 wt.%, between 45-70 wt.%, between 50-65 wt.%, between 50-60 wt.%, or between 54-58 wt.%, on a dry basis or moisture-free basis.

[0036] By way of example, Tables 1&2 provide analyses of several suitable renewable fuel oils which were prepared according to one or more of the procedures described in U.S. Patent No. 7,905,990, U.S. Pat. No. 5,961,786, and U.S. Pat. No. 5,792,340,

TABLE 1 - Analytical Results for Alcell Lignin - Mild Run (LS-3) & Severe Run (LS-4)

	LS-3	LS-4
Volatiles (wt%)	14.7	27.9
Moisture Content (wt%)	1.0	0.9
Ash content (wt%)	0.05	1.00
Elemental (wt%, MAF)		
Carbon	68.68	73.04
Hydrogen	7.16	6.52
Nitrogen	0.00	0.01
Oxygen (difference)	24.16	20.43
Hydroxyl (wt%)	7.54	7.50
Methoxyl (wt%)	15.68	1.02
Sequential Solubility (wtt%)		
Diethyl Ether	41.8	40.3
Ethyl Acetate	48.9	42.4
Methanol	0.2	0.6
Residue	9.1	16.7
Fractionation (wt%)		
Organic Acids	31.7	3.6
Phlernols & Neutrals	45.0	81.7
Residue	23.3	14.1
TABLE NOTE: Mild Run (LS-3) was rapid thermal processed at about 500°C and the Severe Run (LS-4) was rapid thermal processed ar about 700°C		

Table 2: Analytical Results of Renewable Fuel oil Derived from Wood Biomass

LABORATORY	1)	1)	2)	3)	3)	4)	5)	AVERAGE
SPECIFIC GRAVITY	1.19	1.20	1.21	1.217	1.226	1.186	1.188	1.20

(continued)

LABORATORY	1)	1)	2)	3)	3)	4)	5)	AVERAGE
WATER CONTENT (% by wt.)	26	27	21	20.5	21	28.1		23.9
CHAR CONTENT (% by wt.)	2.0	0.6		1.4	2.2	5.5	2.2	2.3
HIGHER HEATING (kJ/kg) [BTU/1b]	16903 [7267]	17003 [7310]	21503 [9245]	17503 [7525]	18503 [7955]	15202 [6536]	16002 [6880]	17503 [7525]
ELEMENTAL (%, MAF)								
CARBON	55.1		53.63	55.5	52.8	58.27	51.5	54.5
HYDROGEN	6.7		6.06	6.7	6.9	5.5	6.8	6.4
NITROGEN	0.15		0.24	0.1	<0.1	0.39	0.17	0.18
SULFUR			0.02			<0.14	0.07	<0.001
ASH (% by wt.)				0.13	0.15	0.22	0.13	0.16

[0037] In certain embodiments, the renewable fuel oil may comprise an energy content level of at least 30 % of the energy content contained in the biomass from which it may be derived. For example, the renewable fuel oil may comprise a energy content level of at least 45 %, such as at least 55.%, at least 60 %, at least 65 .%, at least 70.%, at least 75.%, at least 80.%, at least 85 %, at least 90.%, or at least 95.% of the energy content contained in the biomass from which it may be derived. In certain embodiments, the renewable fuel oil may comprise a energy content level in the range of between 50 % and 98 % of the energy content contained in the biomass from which it may be derived. For example, the renewable fuel oil may comprise a energy content level in the range of between 50 % and 90%, between 50% and 75 %, between 60 % and 90 %, between 60 % and 80 %, between 70 % and 95 %, between 70 % and 80 %, or between 70 % and 90 % of the energy content contained in the biomass from which it may be derived.

[0038] In certain embodiments, the renewable fuel oil may comprise a energy content level lower than that of a petroleum fraction feedstock. For example, the renewable fuel oil may comprise a energy content level in the range of between 30-95 %, on a dry basis (moisture-free basis), relative to the energy content of a petroleum feedstock, such as between 40-90%, between 45-85 %, between 50-80 %, between 50-60 %, or between 54-58 %, on a dry basis or moisture-free basis, relative to the energy content of a petroleum feedstock. In certain embodiments, the renewable fuel oil may have an energy content in the range of between 30-90%, relative to the petroleum fraction feedstock energy content. For example, the renewable fuel oil may have an energy content of 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, relative to the petroleum fraction feedstock energy content. In certain embodiments, a unit of the renewable fuel oil may have an energy content suitable to generate between 0.5-1.5 units of cellulosic-renewable index number-compliant fuel, such as between 0.7-1.2 units, between 0.9-1.1 units of cellulosic-renewable index number-compliant fuel. In certain embodiments, a unit of the renewable fuel oil may have an energy content equivalent to between 0.5-1.5 volume units of ethanol, such as between 0.7-1.2 volume units, between 0.9-1.1 volume units of ethanol.

[0039] In certain embodiments, a refinery method and system may include an assembly for introducing renewable fuel, renewable fuel oil or biomass-derived thermally produced liquid, in low proportions into a petroleum conversion unit, a refinery FCC unit (know more formally as a fluidized catalytic cracker) or field upgrader operation with the contact time of the FCC catalyst being for a period of seconds, for example 0.5 to 15 seconds, such as 1 second, 1.5 seconds, 2 seconds, 2.5 seconds, 3 seconds, 3.5 seconds, 4 seconds, 5 seconds and time periods approximating these times for example approximately 3-5 seconds.

[0040] The renewable oil may be conditioned to enable introduction into the refinery process and can be made from several compositions. One such example may be renewable oil that was produced from the rapid thermal conversion of biomass under the conditions of 400 to 600° C at a processing residence time of less than 10 seconds either with or without the action of a catalyst. An example of a catalyst may be ZSM-5 or other FCC catalyst.

[0041] According to one embodiment, an amount of thermally produced renewable oil addition rate may be in the range greater than 1% by weight and less than 5% by weight.

[0042] In certain embodiments, a petroleum fraction feedstock, for example derived from upgrading petroleum, comprises a gas oil (GO) feedstock, a vacuum gas oil (VGO) feedstock, a heavy gas oil (HGO) feedstock, a middle distillate feedstock, a heavy-middle distillate feedstock, a hydrocarbon-based feedstock, or combinations thereof. For example,

the petroleum fraction feedstock comprises a gas oil feedstock, a vacuum gas oil (VGO) feedstock, a heavy gas oil (HGO) feedstock, or a middle distillate feedstock.

[0043] In certain embodiments, the processing of the petroleum fraction feedstock with the renewable fuel oil has a substantially equivalent or greater performance in preparing the fuel product, relative to processing solely the petroleum fraction feedstock in the absence of the renewable fuel oil. For example, processing a up to 20 wt.% of RFO with the remainder petroleum fraction feedstock, for example 2:98, 5:95, 10:90 weight ratio of renewable fuel oil to the petroleum fraction feedstock may have a substantially equivalent or greater performance in the resulting the fuel products, relative to processing solely the petroleum fraction feedstock in the absence of the renewable fuel oil. For example, processing in the range of between a 20:80 to 0.05:99.95 weight ratio of renewable fuel oil with petroleum fraction feedstock may resulting in an weight percent increase in gasoline of more than 0.1 wt.%, for example 0.5 wt.%, 1.0 wt.%, 1.5 wt.%, 2.0 wt.% or more, relative to processing solely the petroleum fraction feedstock in the absence of the renewable fuel oil.

[0044] According to the invention , the renewable oil includes all of the whole liquid produced from the thermal conversion of biomass, with preferably low water content. Alternatively, whole liquid produced from the thermal conversion of biomass may be phase separated to provide a predominately non-aqueous fraction as the feedstock for refinery systems. In addition, fractions can be taken from the unit operations of the downstream liquid collection system of thermal or catalytically converted biomass such as a primary condenser means, a secondary condenser, demister, filter, or an electrostatic precipitator.

[0045] According to one embodiment, the flash point of a renewable oil may be increased to reduce the volatile content of the liquid and subsequently co-processed in an FCC with a petroleum feedstock. The flash point would be increased above the range of 55-62 °C as measured by the Pensky-Martens closed cup flash point tester (e.g. ASTM D-93). Various methods and apparatus can be used to effectively reduce the volatile components, such as wiped film evaporator, falling film evaporator, flash column, packed column, devolatilization vessel or tank. Reduction of the some of the volatile components of the renewable can help to reduce undesirable components such as phenols from passing through the FCC reactor and ending up in the collected water stream.

[0046] In certain embodiments, the water content of the renewable fuel oil (RFO) feedstock that may be introduced into a refinery for co-processing with a petroleum fraction feedstock, may be in the range of 0.05 wt.% to 40 wt.%. For example, the water content of the renewable fuel oil (RFO) feedstock introduced into the refinery for co-processing with a petroleum fraction feedstock, may be in the range of 1 wt.% to 35 wt.%, such as 5 wt.% to 35 wt.%, 10 wt.% to 30 wt.%, 10 wt.% to 20 wt.%, 10 wt.% to 15 wt.%, 15 wt.% to 25 wt.%, 15 wt.% to 20 wt.%, 20 wt.% to 35 wt.%, 20 wt.% to 30 wt.%, 20 wt.% to 25 wt.%, 25 wt.% to 30 wt.%, or 30 wt.% to 35 wt.%. In certain embodiments, the water content of the renewable fuel oil (RFO) feedstock introduced into the refinery for co-processing with a petroleum fraction feedstock, may be at least 23 wt.% such as at least 25 wt.%, at least 28 wt.%, at least 30 wt.%, at least 31 wt.%, at least 32 wt.%, at least 33 wt.%, or at least 35 wt.%. In certain embodiments, the water content of the renewable fuel oil (RFO) feedstock introduced into the refinery for co-processing with a petroleum fraction feedstock, may be at least 1 wt.%, such as at least 10 wt.%, at least 15 wt.%, at least 20 wt.%, or at least 30 wt.%. In certain embodiments, the water content of the renewable fuel oil (RFO) feedstock introduced into the refinery for co-processing with a petroleum fraction feedstock, may be less than 38 wt.%, such as less than 35 wt.%, less than 34 wt.%, less than 30 wt.%, less than 25 wt.%, less than 20 wt.%, or less than 15 wt.%.

[0047] The hydrogen forms of zeolites used in FCC systems are powerful solid-based acids, and can facilitate a host of acid-catalyzed reactions, such as isomerisation, alkylation, and cracking. The specific activation modality of most zeolitic catalysts used in petrochemical applications involves quantum-chemical Lewis acid site reactions. The present system benefits from the characteristics of renewable oil, namely its TAN or acidic nature, that can lead to an improvement in cracking or the conversion of VGO *(i.e.,* a synergistic effect) in FCC operations. This results in a shift toward more light ends or desirable products and a reduction in undesirable products by way of example heavy cycle oil and clarified slurry oil.

[0048] Fluid catalytic cracking (FCC) may be a conversion process used in petroleum refineries. It may be widely used to convert the high-boiling, high-molecular weight hydrocarbon fractions of petroleum crude oils to more valuable gasoline, olefinic gases, and other products. Catalytic cracking produces more gasoline with a higher octane rating. It also produces byproduct gases that are more olefinic, and hence more valuable, than those produced by thermal cracking.

[0049] The feedstock to an FCC may be usually that portion of the crude oil that has an initial boiling point of 340°C or higher at atmospheric pressure and an average molecular weight ranging from about 200 to 600 or higher. This portion of crude oil may be often referred to as heavy gas oil. The FCC process vaporizes and breaks the long-chain molecules of the high-boiling hydrocarbon liquids into much shorter molecules by contacting the feedstock, at high temperature and moderate pressure, with a fluidized powdered catalyst.

[0050] Figure 1 illustrates a fluid catalytic cracking (FCC) unit. The schematic flow diagram of a typical modern FCC unit in Figure 1 is based upon a "side-by-side" configuration. The illustration depicts whre the renewable fuel oil feedstock **101** could be introduced into a system. The FFC could be designed to have two or more feedstock injection points at least one for the petroleum fraction feedstock and at least one for the renewable fuel oil feedstock or these feedstock

could be co-injected (by have them mixed upstream of the injection point) or the system could be fitted with multiple points of injection for either, both or mixtures of the feedstock. Alterntively, the FCC unit could be retro-fitted to include a way of introducing the reneweable fuel oil, for example adding an injection port proximate the riser or at some point in the process wherein the catalyst may be upflowing.

[0051] In figures 2A&B, unprocessed renewable oil feedstock **101** can be fed upstream or downstream of a gas oil (GO) feed inlet port **201.** Renewable oil feedstock **101** is introduced in this section of the riser thereby potentially imparting properties of the renewable oil (e.g., acid nature of the oil) onto the catalyst and promoting GO conversion as it may be introduced downstream of the renewable oil 101. Alternatively, the renewable oil can be introduced downstream of the GO fresh feed injection nozzles 201. Figure 2B, presents a retrofitted riser with a retro-fitted renewable oil feedstock injection port or ports **102.** The riser may be adapted to include multiple renewable oil feedstock injection port or ports **102** both before and after the introduction of the VGO. It may be retro-fitted to have only one additional renewable oil feedstock injection port **102** positioned either before or after the GO injection point or it may be retro-fitted to have a renewable oil feedstock injection port or ports **102** along the GO feedstock feed line.

[0052] In Figure 3 A riser quench system injects vaporizable oil into the riser above the VGO feed injection nozzles **201.** The recycle material may act as a heat sink as it may be vaporized by the catalyst. At constant riser outlet temperature, quench may increase the catalyst-to-oil ratio because the riser outlet temperature control point may be downstream of the quench location. Introduction of the quench oil may also increases the temperature in the mix zone and lower section of the riser, as shown in Figure 3. In an embodiment (or a retro-fitted embodiment) the renewable fuel oil feedstock may be injected into the quench line of the riser.

[0053] In some embodiment, it may be that the primary contaminants found in VGO, typically fed to an FCC, are vanadium, nickel and to a lesser degree, sodium and iron. The catalyst used in FCC may tend to absorb these contaminants which may then have a negative effect on the conversion of VGO in the reactor. An additional advantage of co-feeding a renewable fuel oil with a GO, for example VGO, to an FCC may be that the renewable oil contains little or none of these contaminants. Thereby, prolonging the useful life of the catalyst, and helping to maintain greater catalyst activity and improved conversion levels.

[0054] In certain embodiments, the system or apparatus may be employed for processing or co-processing the petroleum fraction feedstock, the renewable fuel oil, or combinations thereof, may include a refinery system, a conversion unit, such as a fluidized catalytic cracker (FCC), a FCC refinery system, a coker, a coking unit, a field upgrader unit, a hydrotreater, a hydrotreatment unit, a hydrocracker, a hydrocracking unit, or a desulfurization unit. For example, the system, apparatus or conversion may be or comprise an FCC unit operation; the system or apparatus is or comprises a coker; the system or apparatus is or comprises a hydrotreater; or the system or apparatus is or comprises a hydrocracker. In certain embodiments, the system or apparatus may be employed for processing or co-processing the petroleum fraction feedstock, the renewable fuel oil, or combinations thereof, may include a retro-fitted refinery system, such as a refinery system comprising a retro-fitted port for the introduction of a renewable fuel oil. For example, the system or apparatus employed may include a retro-fitted FCC refinery system having one or more retro-fitted ports for introducing a renewable fuel oil. The retro-fitted port, for example, may be stainless steel port, such as a 304 or 316 stainless steel port, titanium or some other alloy or combination of high durability, high corrosive envorinment material.

[0055] In certain embodiments, the system present includes an apparatus, and a method of using the same, for example a refinery system, such as a fluidized catalytic cracker (FCC), a FCC refinery system, a coker, a coking unit, a field upgrader unit, a hydrotreater, a hydrotreatment unit, a hydrocracker, a hydrocracking unit, a desulfurization unit, or a retro-fitted refinery system, in conjunction with providing, injecting, introducing, or processing the renewable fuel oil. For example, a refinery system for processing a petroleum fraction feedstock with a renewable fuel may include a retro-fitted refinery system, a fluidized catalytic cracker (FCC), a retro-fitted FCC, a coker, a retro-fitted coker, a field upgrader unit, a hydrotreater, a retro-fitted hydrotreater, a hydrocracker, or a retro-fitted hydrocracker.

[0056] In certain embodiments, the method may include introducing, injecting, feeding, co-feeding, a renewable fuel oil into a refinery system via a mixing zone, a nozzle, a retro-fitted port, a retro-fitted nozzle, a velocity steam line, or a live-tap. For example, the method may comprise processing a petroleum fraction feedstock with a renewable fuel oil. In certain embodiments, the processing may comprise co-injecting the petroleum fraction feedstock and the renewable fuel oil, such as co-feeding, independently or separately introducing, injecting, feeding, or co-feeding, the petroleum fraction feedstock and the renewable fuel oil into a refinery system. For example, the petroleum fraction feedstock and the renewable fuel oil may be provided, introduced, injected, fed, or co-fed proximate to each other into the reactor, reaction zone, reaction riser of the refinery system. In certain embodiments, the renewable fuel oil may be provided, introduced, injected, fed, co-fed into the reactor, reaction zone, or reaction riser of the refinery system proximate, upstream, or downstream to the delivery or injection point of the petroleum fraction feedstock. In certain embodiments, the petroleum fraction feedstock and the renewable fuel oil come in contact with each other upon introduction, delivery, injection, feeding, co-feeding into the refinery system, into the reactor, into the reaction zone, or into the reaction riser. In certain embodiments, the petroleum fraction feedstock and the renewable fuel oil come in contact with each other subsequent to entering the refinery system, the reactor, the reaction zone, or the reaction riser. In certain embodiments,

the petroleum fraction feedstock and the renewable fuel oil make first contact with each other subsequent to entering into, introduction into, injection into, feeding into, or co-feeding into the refinery system, the reactor, the reaction zone, or the reaction riser. In certain embodiments, the petroleum fraction feedstock and the renewable fuel oil are co-blended prior to injection into the refinery system.

[0057] The petroleum fraction feedstock and the renewable fuel oil may be introduced into the refinery system through different or similar delivery systems. For example, the petroleum fraction feedstock and the renewable fuel oil may be introduced into the refinery system through one or more independent or separate injection nozzles. The petroleum fraction feedstock and the renewable fuel oil may be introduced into the refinery system proximate or near to each other in a FCC reactor riser in the refinery system. The renewable fuel oil may be introduced into the refinery system above, below, near, or proximate the introduction point of the fossil fuel feedstock in the refinery system. In certain embodiments, one or more injection nozzles may be located in a FCC reactor riser in the refinery system suitable for introducing the fossil fuel feedstock or the renewable fuel oil. The renewable fuel oil may be introduced into the refinery system through a lift steam line located at the bottom of the FCC reactor riser. In certain embodiments, the petroleum fraction feedstock may be introduced into the refinery system at a first injection point and the renewable fuel oil may be introduced into the refinery system at a second injection point. For example, the first injection point may be upstream of the second injection point, the first injection point may be downstream of the second injection point, the first injection point may be proximate to the second injection point, the first injection point and the second injection point may be located in a reactor riser, such as an FCC reactor riser. In certain embodiments, a renewable fuel oil may be introduced below a reactor riser, such as an FCC reactor riser, during conversion of the petroleum fraction feedstock. For example, a renewable fuel oil may be injected via a quench riser system upstream, downstream, or proximate, from the introduction point of the petroleum fraction feedstock. In certain embodiments, a renewable fuel oil may be injected via a quench riser system located above, below, or proximate, a petroleum fraction feedstock injection nozzle.

[0058] In certain embodiments, the prepared fuel product may comprise a product of a fluidized catalytic cracker having a petroleum fraction and a renewable fuel oil as reactants, for example, a product of a fluidized catalytic cracker processing a petroleum fraction and a renewable fuel oil, a product of a fluidized catalytic cracker wherein the fluidized catalytic cracker receives a petroleum fraction and a renewable fuel oil, a processed product from a mixture of a petroleum fraction feedstock and a renewable fuel oil that have been in contact with a catalyst.

[0059] In certain embodiments, the prepared fuel product may comprise a fluidized catalytic cracker product composition derived from catalytic contact of a feedstock comprising a renewable fuel oil, for example a fuel composition derived from a petroleum fraction feedstock, and a renewable fuel oil feedstock, such as a fuel composition derived from 80-99.95 wt.% of a petroleum fraction feedstock, and 0.05- 20 wt.% of a renewable fuel oil feedstock, or a fuel composition derived from 80-99.95 vol.% of a petroleum fraction feedstock, and 20-0.05 vol.% of a renewable fuel oil.

[0060] Figure 4 illustrates a coking unit for use with the present system, according to one embodiment. A coker or coker unit may be a type of conversion unit that may be used in an oil refinery processing unit that converts the conditioned renewable oil feedstock 101. The process thermally cracks the long chain hydrocarbon molecules in the residual oil feed into shorter chain molecules.

[0061] A coke may either be fuel grade (high in sulphur and metals) or anode grade (low in sulphur and metals). The raw coke directly out of a coker may be often referred to as green coke. In this context, "green" means unprocessed. The further processing of green coke by calcining in a rotary kiln removes residual volatile hydrocarbons from the coke. A calcined petroleum coke may be further processed in an anode baking oven in order to produce anode coke of the desired shape and physical properties. The anodes are mainly used in the aluminum and steel industry.

[0062] Crude oil extracted from field operations, such as the Western Canadian oil sands, may be pre-processed before it may be fit for pipeline transport and utilization in conventional refineries. This pre-processing may be called 'upgrading' (performed by a field upgrader unit), the key components of which are as follows:

- Removal of water, sand, physical waste, and lighter products;
- Hydrotreating; and
- Hydrogenation through carbon rejection or catalytic hydrocracking (HCR).

[0063] As carbon rejection may be very inefficient and wasteful in most cases, catalytic hydrocracking may be preferred in some cases.

[0064] Hydrotreating and hydrocracking together may be known as hydroprocessing. The big challenge in hydroprocessing may be to deal with the impurities found in heavy crude, as they poison the catalysts over time. Many efforts have been made to deal with this to ensure high activity and long life of a catalyst. Catalyst materials and pore size distributions are key parameters that need to be optimized to handle these challenges and this varies from place to place, depending on the kind of feedstock present.

[0065] Hydrocracking may be a catalytic cracking process assisted by the presence of an elevated partial pressure of hydrogen gas. Similar to the hydrotreater, the function of hydrogen may be the purification of the hydrocarbon stream

from sulfur and nitrogen hetero-atoms.

[0066] Characteristics of a fast pyrolysis reactor for maximal oil production are the very rapid heating of the conditioned renewable feedstock, and rapid quenching of the produced vapors. A more detailed discussion of fast pyrolysis may be found in the Background section of this document.

[0067] Figure 5 illustrates an exemplary upgraded feed injection system for use with the present system, according to one embodiment. Feed nozzles that are modified for the properties of conditioned renewable fuel feedstock **101,** and nozzles can be converted to stainless steel, or other appropriate metallurgy, if they are not already and adjusted to inject renewable oil to provide an upgrade to existing systems.

[0068] According to one embodiment, conditioned renewable fuel oil may be utilized in FCC units that presently utilize a catalyst known as ZSM-5. ZSM-5 may be shown to be a favorable catalyst for the conversion of biomass to hydrocarbons.

[0069] Figure 6 illustrates an exemplary FCC unit with dual risers, according to one embodiment. A dual riser system may comprise a least one input element for introducing a petroleum fraction and at least one element for introducing a renewable fuel oil such that they can contact the catalyst and be co-processed. Another embodiment may include a dual riser system that may be retro-fitted to provide at least one element for introducing a renewable fuel oil such that they can contact the catalyst and be co-processed. Feedstock **101** including renewable fuel oil may be fed into a second riser of a two riser FCC (as shown in Figure 6).

[0070] Contact time of the catalyst with the feedstock may comprise the residence time in the riser and the residence time in the riser termination system. For example, in some embodiments the riser residence times may be about 2 to 3 seconds with the residence time in termination system may be an additional 1 to 2 seconds. This may lead to an overall catalyst contact time of about 3 to 5 seconds. For example, the feedstock may interact with the catalyst for greater than 2 second, for example greater than 3 seconds, greater than 4 seconds such as 3 to 7 seconds or 2 to 4 seconds or 3 to 5 seconds.

[0071] In another embodiment, a method and system for introducing renewable fuel or renewable fuel oil into a refinery FCC unit that may be simultaneously processing a petroleum fraction, with the contact time of the FCC catalyst being for a period of greater than 3 seconds, for example 3 to 7 seconds or 3 to 5 seconds.

[0072] In certain embodiments FCC units may use steam to lift the catalyst as well provide dilution media for residence time control. The lift steam can enter the FCC reactor riser from the bottom of the unit and/or through nozzles on the side of the reactor. These nozzles may be located below, above or co-located with the feedstock (either the RFO feed, GO feed or both RFO and GO feed) injection point.

[0073] In certain embodiments, it may be useful, because of the properties of renewable fuel oil, to employ a delivery system separate from the petroleum feedstock feed port (or assembly) for introducing the RFO material into an FCC unit. The separate delivery system may include transfer from storage, preheat and deliver the renewable oil to an appropriate injection point on the FCC. To ensure contact between the renewable oil and the hydrocarbon feedstock the point of introduction may be near to the petroleum feedstock injection nozzles which are typically located in the lower third of the FCC riser.

[0074] According to one embodiment, renewable oil may be introduced into the lift steam line at proximate the bottom of the FCC reactor riser, for example below the mid-point of the riser. In an alternative embodiment, the renewable oil may be introduced into the velocity steam line that could be located either upstream or downstream of the hydrocarbon injection point. According to a further embodiment, renewable oil may be introduced through an atomizing nozzle that may be inserted into the one or multiple steam lines or may be introduced into the recycle lift vapor line or lines.

[0075] According to one embodiment, the addition rate of renewable oil may be controlled by a separate delivery system (i.e., separate from the hydrocarbon delivery system) into the lower third of the FCC reactor riser. According to an alternative embodiment, the addition rate of renewable oil may be controlled by a separate delivery system into one or multiple lift steam lines. In a further embodiment, the addition rate of renewable oil may be controlled by a separate delivery system into an available port in the lower third of the FCC reactor riser. In another alternative embodiment, the addition rate of renewable oil may be controlled by a separate delivery system and introduced into one of the hydrocarbon nozzles or injectors either separately or with hydrocarbon.

EXAMPLES

[0076] Testing has been conducted using different equipment, various petroleum based feedstocks, and an FCC catalyst with various quantities of a renewable fuel liquid. The majority of the experiments involved the processing of a renewable fuel oil with a typical commercially-produced gas oil in an Advanced Cracking Evaluation (ACE) FCC unit. In addition, testing has been conducted in a fluid-bed Microactivity Test reactor (MAT) unit with a commercial equilibrium catalyst.

Example 1

Testing Equipment:

[0077] The co-processing of petroleum fraction feedstock with varying amounts of renewable fuel oil (RFO) (or the processing of the petroleum fraction feedstock alone as a comparator), were conducted in a Model R+ Kayser Technology Advanced Cracking Evaluation (ACE) FCC unit (herein referred to as "ACE testing unit" or "FCC unit"), using an FCC catalyst.

[0078] The ACE testing unit had hardware and software that enabled multiple runs to be accurately performed without operator intervention. The reactor consisted of a 1.6 cm ID stainless steel tube with a tapered conical bottom. A diluent (nitrogen), flowing from the bottom, fluidized the catalyst and also served as the stripping gas at the end of a catalytic run. The feedstock that was introduced in to the ACE testing unit to be cracked was fed from the top via an injector tube with its outlet tip near the bottom of the fluid bed. An injector position of approximately 2.86 cm, measured from the bottom of the reactor, was used.

[0079] The ACE testing unit used a cyclic operation of a single reactor (containing a batch of fluidized catalyst particles) to simulate each of the sections of a commercial FCC unit: (a) riser reactor - injection of feed over the catalyst; (b) catalyst stripper - catalyst stripping for a specified duration; (c) regeneration - catalyst regeneration with air at elevated temperatures.

[0080] The reactor remained in the furnace during catalyst addition and withdrawal. Each test run was performed under atmospheric pressure conditions, and a reactor temperature of 510°C (950°F). A constant load of 9 g of equilibrium catalyst and the Variable Time on Stream method of varying feed injection time at a constant injection rate of 1.2 g/min were used to obtain the desired catalyst-to-oil ratios. The fluidized bed regeneration temperature was maintained at 712°C (1313°F).

Feedstock or Feedstock Combinations:

[0081] The renewable fuel oil (RFO) feedstock utilized in the Examples below was produced from rapid thermal processing of a wood residue feedstock in a commercial fast pyrolysis process, according to any one of U.S. Patent No. 7,905,990, U.S. Pat. No. 5,961,786, and U.S. Pat. No. 5,792,340, each of which is herein incorporated by reference in their entirety. The properties of the renewable fuel oil (RFO) feedstock are summarized in Table 1.

Table 1

Parameter	Test Method	RFO
Water Content, wt.%	ASTM E203	26.98%
Viscosity @ 40°C. cSt	ASTM D445	58.9
Viscosity @ 40°C. cSt		
Ash Content. wt.%	EN 055	0.02%
Solids Content. wt.%	ASTM D7579	0.04%
Density @ 20°C, kg/dm^3	EN 064	1.1987
pH	ASTM E70-07	2.44
Carbon Content, wt.% as is	ASTM D5291	41.80%
Hydrogen Content, wt.% as is	ASTM D5291	7.75%
Nitrogen Content, wt.% as is	ASTM D5291	0.28%
Sulfur Content, wt.% as is	ASTM D5453	0.01%
Oxygen Content, wt.% as is	Bv Difference	50.14%
HHV (as is), cal/g	ASTM D240	4093.8
HHV (as is), MJ/kg	ASTM D240	17.1
HHV (as is), kJ/kg [BTU/lb]	ASTM D240	17140 [7369]

[0082] Separate, independent testings were conducted in an ACE testing unit that processed, or co-processed, the

following feedstock or feedstock combinations (by feeding or co-feeding):

(1) 100 wt.% non-hydrotreated vacuum gas oil (VGO) feedstock, as a petroleum fraction feedstock (herein referred to as "VGO feedstock");
(2) 98 wt.% VGO feedstock and 2 wt.% renewable fuel oil (RFO) feedstock;
(3) 95 wt.% VGO feedstock and 5 wt.% renewable fuel oil (RFO) feedstock; and
(4) 90 wt.% VGO feedstock and 10 wt.% renewable fuel oil (RFO) feedstock.

Each of these feedstock or feedstock combinations were processed or co-processed in the ACE testing unit at a constant cracking temperature of 510°C (950°F).

Catalyst-to-Oil Ratios:

[0083] For each feedstock or feedstock combination, several runs were conducted, independently employing different catatyst-to-oil ratios ("cat./oil ratios"): ranging from 4:1 to 11.25:1, specifically 4:1, 6:1, 8:1, 10:1, and 11.25:1.

Analysis:

[0084] Each of the liquid samples that were formed from the processing or co-processing of the feedstock or feedstock combinations in the ACE testing unit were collected and sent for analysis. Gas chromatographic analysis was conducted on the dry gas product. Coke content was determined by analyzing for the quantity of carbon dioxide produced from the regeneration step of the testing procedure. The ACE testing results for each run included conversion and yields of dry gas, liquefied petroleum gas (LPG, the C_3 - C_4), gasoline (C_5 - 221°C), light cycle oil (LCO, 221 - 343°C), heavy cycle oil (HCO, 343°C +), and coke. The conversion of the feedstock or feedstock combination was determined by calculating the difference between the amount of feedstock or feedstock combination and the amount of unconverted material defined as liquid product boiling above 221°C.

[0085] It may be known that the quality of the feedstock charged into an FCC unit can be the single greatest factor affecting product yields and quality. In the ACE tests, the same VGO feedstock material was used throughout the study. Therefore, the results disclosed herein can be used in relative terms, but may not necessarily represent absolute yields that would be achieved using other alternative FCC feedstocks. The results disclosed herein are, however, very indicative, particularly in showing yield and conversion trends relative to the VGO control test data.

Normalization or Equivalence of Feedstock and Feedstock Combinations:

[0086] The conversion and yield curves, expressed on an equivalent energy input or equivalent carbon input basis, demonstrate an unexpected effect resulting from the combination varying amounts of the renewable fuel oil (RFO) feedstock with the VGO feedstock in a FCC-type unit (the ACE testing unit). The renewable fuel oil (RFO) feedstock has about one half of the carbon and energy content of the VGO feedstock (for an equivalent mass). For example, when comparing the results from the feedstock combination of 98 wt.% VGO feedstock and 2 wt.% renewable fuel oil (RFO) feedstock against those of the 100 wt.% VGO feedstock, 2 wt.% of the renewable fuel oil (RFO) feedstock may be substituted in place of 2 wt.% of VGO feedstock, which means approximately 1% less carbon and 1% less energy are available in the FCC unit for subsequent conversion to the desired products. If the renewable fuel oil (RFO) feedstock carbon and energy were converted to gasoline in the same proportions as the VGO feedstock carbon and energy, then one would expect the gasoline yield to drop by 1%, in the case of the 2 wt.% renewable fuel oil (RFO) feedstock combination and when equal amounts of total mass or volume are fed into the FCC unit. However, the gasoline yield dropped by less than 1% in this case, a phenomenon that was observed for all substitution levels *(i.e.,* the 2 wt.%, 5 wt.%, and the 10 wt.% renewable fuel oil (RFO) feedstock combinations). Therefore, if the input may be expressed on an equivalent amount of carbon or energy into the FCC unit (i.e., keeping the carbon input or energy input constant regardless of whether neat VGO feedstock or combinations of VGO feedstock with renewable fuel oil (RFO) feedstock (blends) are fed), there may be a measurable increase in gasoline yield when renewable fuel oil (RFO) feedstock may be combined or blended in with the VGO feedstock. It may be important to note that when yields are expressed on a constant carbon or energy input into the FCC unit, implicit in this assumption may be that the total mass or volume input into the FCC would increase with the substitution of the renewable fuel oil (RFO) feedstock. In the case of the 2 wt.% renewable fuel oil (RFO) feedstock combination (blend), about 1% additional mass input to the FCC unit would be required to achieve the same carbon or energy input as 100% VGO feed. In terms of volume addition, when accounting for the density differences between VGO and RFO, less than 1% additional volume of a 2 wt.% renewable fuel oil (RFO) feedstock combination (blend) to the FCC unit would result to achieve the same carbon or energy input into the FCC unit as neat VGO feedstock.

[0087] The conversion and yield curves disclosed herein were generated using the mass yield experimental data that was generated from the ACE testing unit, coupled with the energy and carbon contents of the input feedstocks. In the case of energy-equivalent input basis, the mass yields were divided by the feedstock energy input, which may be a function of the proportion of the renewable fuel oil (RFO) feedstock addition, using barrel of oil equivalent (BOE) as the energy units (i.e., 5.8 million BTU). The gasoline yield may be presented both on the basis of energy input equivalence and carbon input equivalence. Carbon equivalence may be effectively the same as an energy-input basis, and may be calculated from the generated mass data in a similar manner, but may be generally a more clear and understandable expression than equivalent energy basis.

[0088] The Figures discussed in this section highlight the conversion of neat VGO feedstock and renewable fuel oil (RFO) feedstock combinations or blends (2 wt.%, 5 wt.%, and 10 wt.%), as well as the respective yields of gasoline, LPG, dry gas, light cycle oil (LCO), heavy cycle oil (HCO) and coke, as a function of the Catalyst-to-Oil ratio (cat./oil ratio) in the ACE testing unit. The effects of combining or blending the varying amounts of the renewable fuel oil (RFO) feedstock with the VGO feedstock on the gasoline octane numbers (both research-grade octane and motor-grade octane numbers) are also disclosed herein.

Effect of RFO Blends on Conversion.

[0089] For the purposes of this example, the feedstock conversion, shown in Figures 7 and 8, is the input mass of VGO or RFO/VGO blend minus the mass yields of both Light Cycle Oil (LCO) and Heavy Cycle Oil (HCO). ACE conversion data was generated with the FCC reaction temperature, the catalyst weight, and the catalyst contact time all fixed for a given VGO or RFO blend feedstock, and the only variable was the catalyst:oil ratio.

[0090] Figure 7 illustrates the general increase in conversion of all of the feeds at greater catalyst:oil ratios, on a mass basis. For the purposes of this example, in all cases, with the addition of RFO to the VGO feedstock, there was a shift in the curves resulting in an increase mass conversion. In other words, less LCO and HCO are produced as the amount of RFO in the VGO blend may be increased. At a catalyst:oil ratio of 8:1 there may be an increase of conversion relative to the VGO conversion from approximately 0.7 to 1.4% as the RFO blend in VGO goes from 2 to 10 wt.%. As indicated previously, since the energy content of the RFO may be about half that of the VGO another way to represent the conversion may be on energy input equivalency basis. In Figure 8 the conversion of the VGO/RFO feedstock was found to dramatically increase as the substitution rate of RFO was increased.

Effect of RFO Blends on Gasoline Yields.

[0091] The primary purpose of FCC operations may be to produce optimal gasoline yields, and for the purposes of this study, the gasoline fraction may be defined as the C_5 - 221°C boiling point. Figure 9 depicts the gasoline yield as a function of catalyst:oil ratio for the various feeds. The yields of gasoline were found to initially increase as the catalyst:oil ratio increased, up to a maximum at a catalyst:oil ratio of about 7:1 to 8:1. Further increases in the catalyst:oil ratio resulted in a decrease in gasoline yield which may be attributed to overcracking under the set reactor conditions.

[0092] With respect to the gasoline yield for the various blends of RFO in this study, there was a significant increase in net gasoline production when an equivalent amount of VGO and RFO/VGO, in terms of input energy, may be processed in the FCC. In general, as the blend of RFO in the VGO feed may be increased, from 2 wt.% to 10 wt.%, there may be a measurable and consistent increase in gasoline yield. In addition, for this example, it appears that the maximum gasoline yield occurs at a slightly lower catalyst:oil ratio (at approximately 7:1) as compared to the reference VGO feed (approximately 8:1).

[0093] The gasoline yield can also be represented in terms of the amount of carbon in the feedstock that may be converted to gasoline. Similar to the energy content basis, RFO has a lower carbon content than VGO. Therefore, in this example, less carbon may be delivered to the FCC unit (and less carbon may be made available for conversion to gasoline) as the RFO proportion may be increased. The synergistic effect of RFO co-processing can be readily illustrated if the gasoline yields are based on the amount of input carbon that may be converted to gasoline.

[0094] More specifically, as was the case with energy content, in this experiment the RFO has approximately one half of the carbon content of VGO. The reference VGO has a carbon content of approximately 87 wt.%, while the carbon contents of the 2 wt.%, 5 wt.% and 10 wt.% RFO blends are 86.1%, 84.7% and 82.5%, respectively. The gasoline yields, expressed on an equivalent carbon input basis, are presented in Figure 10 as a function of catalyst:oil ratio in the ACE testing unit. In this example, there may be a significant and consistent increase in the gasoline yield as the substitution of RFO may be increased from 2 wt.% to 10 wt.%. These yields suggest that more carbon in the VGO may be going to gasoline production then would otherwise be the case, without the addition of the RFO in the blend. RFO may be synergistically affecting either the cracking chemistry or catalyst activity in favor of the gasoline product.

Effect of RFO Blends on Liquid Petroleum Gas (LPG) Yield.

[0095] In FCC operation, LPG (defined as C_3 + C_4 hydrocarbons) may be considered a valuable product since it consists of components that can be used as alkylation and petrochemical feedstocks. In this example, an increase in the RFO blends in VGO results in an increase in LPG yields (on a constant input energy basis), and this effect shown in Figure 11. This trend also holds on the basis of constant carbon input to the FCC, suggesting that RFO addition preferentially causes higher carbon conversion to LPG.

Effect of RFO Blends on Dry Gas Yield.

[0096] In this example, the dry gas may be defined as the total of H_2, H_2S, carbon oxides, and C_1 - C_2 hydrocarbons. Good operation of the FCC may keep these products to a minimum as excessive dry gas production may cause downstream plant operation limitations with respect to gas compression. The effects on dry gas yields are shown in Figure 12 and, as expected, the dry gas yield increases as the catalyst:oil ratio increases. On an equivalent energy input basis (i.e., the RFO/VGO blend test having a similar energy input as the reference VGO energy input), there was an increase in dry gas make as the addition rate of RFO increased. In this example, the predominant dry gas components for all cases were ethylene, methane and ethane.

Effect of RFO Blends on Light Cycle Oil (LCO) Yield.

[0097] In this example, the Light Cycle Oil (LCO) may be defined as those liquids that boil between 221 - 343°C, and the value of this product may be dependent on the location and purpose of the refinery. Typically, in North America LCO may be not considered to be as desirable. However, where and when gasoline may be not in high demand, the FCC unit may be used as a source of middle distillate LCO that can be upgraded to diesel and No. 2 fuel oil. In this example, the effect of RFO blends on the production of LCO on an equivalent input energy basis (Figure 13) was found to be relatively neutral at a level of 2 wt.% RFO addition, while at 5 wt.% and 10 wt.% RFO addition, there was a measurable increase in the production of LCO, expressed on an equivalent energy input (or carbon input) basis.

Effect of RFO Blends on Heavy Cycle Oil (HCO) Yields.

[0098] In this example, the Heavy Cycle Oil (HCO) may be defined as those liquids that distil between 343°C and 525°C. This material may be generally considered by refineries to be relatively undesirable; an unconverted product with comparatively high aromatics and potentially high sulfur content. If possible, HCO production from VGO in an FCC unit should be minimized. In this example, as Figure 14 shows, the HCO production rate may be not significantly affected by the addition of 2 wt.% or 5 wt.% RFO (by mass) in the VGO feedstock, while at 10 wt.% RFO substitution, an increase in the production of HCO may be clearly apparent, on an equivalent energy input basis.

Effect of RFO Blends on Coke Yields.

[0099] In FCC operation, coke may be generally utilized to supply the necessary process heat to drive the reactions. However, an increasing amount of coke production may eventually upset the heat balance of the FCC unit, resulting in higher temperatures in the catalyst regenerator. The effect of RFO blends on coke production in this example may be shown in Figure 15.

[0100] Figure 15 illustrates that coke yield in this example may be not dramatically effected at the lower blends of RFO (i.e., 2 wt.% and 5 wt.% by mass), while the blend of 10 wt.% RFO results in a measurable increase in the coke production.

Effect of RFO Blends on Gasoline Yields on a 10,000 bbl/day Input Basis.

[0101] The primary purpose of FCC operations may be to typically produce optimal gasoline yields, and for the purposes of this study, the gasoline fraction may be defined as the C_5 - 221°C boiling point. Figure 16 depicts the gasoline yield as a function of catalyst: oil ratio for the various feeds using a consistent 10,000 bbl/day input of the various feedstock blends on an RFO water free basis. Despite the fact that the amount of energy and carbon in the 10,000 bbl/day feed input of the RFO/VGO blends was less than the reference VGO, the yields of gasoline in this example were found to be unexpectedly higher than the reference VGO feedstock case. In particular, in this example there was a dramatic improvement in gasoline yield at the higher levels of RFO substitution.

Estimate of the Gallons of Gasoline Produced per ton of RFO.

[0102] Using the gallons of gasoline produced per ton of the reference VGO and comparing to the gallons of gasoline produced per ton of RFO/VGO blend an estimate of the contribution of gallons of gasoline produced per ton of RFO was made. Figure 17 illustrates the gallons of gasoline per ton of RFO as a function of the level of RFO substitution. In this example, as the level of substitution went from 2 wt.% to 10 wt.% the gallons of gasoline produced per ton of RFO increased. Translating back to the original biomass the yield of gasoline per ton of biomass was in excess of 90 gals/ton of biomass at the higher RFO levels of substitution.

Volume of Feed Input for an Energy Equivalent RFO/VGO Blend.

[0103] Refineries typically operate on a volume basis when handling, transferring, feeding and processing petroleum liquids. Accordingly, to make a fair and equitable comparison when studying the effect of RFO addition to VGO on gasoline yields, it may be important to measure the yields on either an energy-equivalent or carbon-equivalent input basis (i.e., what are the respective gasoline yields from VGO and RFO blends from the identical amounts of input carbon or input energy). In addition, since the RFO in this example contains roughly half the carbon and energy content of VGO, in this example a small amount of additional total feedstock volume had to be delivered to the FCC, as RFO may be blended into the VGO, in order to maintain an equivalent amount of input carbon or energy.

[0104] In regards to how much additional volume of RFO/VGO blends, in this example, had to be added to maintain constant carbon or energy input to the FCC unit, is illustrated in Figure 18. In this example, a surprisingly small amount of additional volume of RFO/VGO blend was only needed to be added to compensate. This volume may be minimal, in this example, as the RFO may be much denser than VGO, so additional mass of VGO may be added with a proportionately less impact on total volume increase.

[0105] Figure 18 indicates that, in this example, a 2 wt.% blend of RFO in VGO only required a 0.8% increase in volume to deliver the same energy or carbon to the FCC as neat (100%) VGO. In other words, for every 100 barrels of neat VGO, 100.8 barrels of 2 wt.% RFO blend would be required to deliver equivalent amounts of energy or carbon to the FCC unit. What is unexpected in this example, is that the gasoline yield increases much more than 0.8% over the typical range of FCC operating conditions that were tested in the ACE testing unit.

[0106] In this example, the 5 wt.% RFO blend in VGO, an addition of only 2% volume would preserve the same energy or carbon input as neat VGO. For every 100 barrels of neat VGO, 102 barrels of 5 wt.% RFO blend would be delivered to the FCC in order to maintain equivalent energy or carbon input. Once again, the gasoline yield is much greater than 2% over the range of ACE tests.

Example 2

[0107] Testing Equipment: The co-processing of renewable fuel oil (RFO) with petroleum fraction feedstock (or the processing of the petroleum fraction feedstock alone as a comparator), was conducted in a fluid-bed Microactivity Test reactor (MAT) unit (herein referred to as "MAT testing unit"), using a commercially available equilibrium catalyst.

[0108] A biomass-derived liquid having properties similar to that shown in Table 1 was obtained from a commercial rapid thermal conversion plant where residual wood was thermally cracked at mild temperature in a short duration (typically less than 5 seconds) with about 70 to 80 wt.% liquid yield. A heavy gas oil (HGO) and a 5 wt.% RFO blend were cracked in a MAT testing unit at 510°C (950°F) with a constant oil injection time of 30 s using similar equilibrium catalyst as the case of Example 1.

[0109] In this example, dry gas is composed of H_2, H_2S, CO, CO_2, and C_1-C_2 hydrocarbons. The dry gas yield increased exponentially with conversion. At a given conversion in this example, the two feeds gave almost identical dry gas yields. Only CO_2 but not CO was detected during cracking of the two feeds with 0.02-0.08 wt.% CO_2 yield higher for the blend at 65-75 wt.% conversion indicating the decomposition or combustion of the oxygenates in the blend. However, the blend produced less H_2 by 0.06 wt.% throughout the entire conversion in this study possibly due to water formation.

[0110] Generally, gasoline (C_5-221°C boiling point) is the major and the most desirable product in FCC operation. In this example, it was found that at a given conversion, the blend lowered the gasoline yield by less than 1 wt.% until the conversion was higher than 70 wt.%. Note that the blend itself contained 1.33 (calculated from RFO analysis) to 1.90 wt.% (Table 1) H_2O which could partially explain the drop in gasoline. Overcracking was observed for this particular blend at 75-80 wt.% conversion.

[0111] The gasoline yield may also be expressed in terms of volumetric flow per hour (Figure 19). In this example, unexpectedly, the yield of gasoline was shown to be greater for the RFO/HFO blend as compared to the yield of gasoline from the processing of the reference HFO over a catalyst:oil ratio of 4 to 9:1 (i.e., the usual operating range for a FCC unit).

Coke.

[0112] In FCC operation, coke is generally necessary to supply heat for feed preheating and cracking. However, too much coke can seriously poison the catalyst and overload the air blower during catalyst regeneration, causing excessively high temperatures in the regenerator. During the testing it was found that, similar to the dry gas, both feeds gave almost identical coke yield at a given conversion although the blend had 0.27 wt.% higher Conradson Carbon Residue.

Oxygen.

[0113] For the purposes of this example, the oxygen distribution in the gaseous and liquid products also is of note. For instance, after cracking, most of the oxygen in the blend in this example appeared as H_2O (74.6-94.1 wt.%), with the rest forming CO_2 (0.7-5.3 wt.%). The liquid products were analyzed for oxygen content and found to be below the detection limit (0.25 wt.%).

[0114] For the purposes of this example, it was generally observed that: (1) catalytic cracking of the blend containing 5 wt.% RFO resulted in the formation of water and carbon dioxide; (2) at a given severity and compared with the base oil, the blend gave 1-3 wt.% higher conversion which increased with catalyst:oil ratio; (3) at a given conversion, the blend gave lower yields of LPG and gasoline than the base oil, while other yields, including those of dry gas, light cycle oil (diesel), heavy cycle oil (heavy fuel oil), and coke, were almost the same for the two feeds, but among the dry gas components, higher CO_2 but lower H_2 yields were observed for the blend; (4) an examination of the gasoline yield in terms of refinery flows (i.e., volumetric yield based on a set volume of feed - example 10,000 bbl/day) indicated that the yield of gasoline was greater for the RFO blend than the reference HFO over lower catalyst: oil ratios, and that on a water-free RFO basis the yields of gasoline and other valuable components were found to be greater than the reference HFO; (5) after cracking, most of the oxygen in the blend appeared as H_2O with the rest in the form of CO_2, and that the liquid products were analyzed for oxygen content and found to be below the detection limit; and (6) when yields of an RFO blend and HGO are compared on the basis of equivalent energy input to the MAT system, gasoline and LPG yields from the RFO blend are higher than corresponding yields from 100% HGO.

Example 3

[0115] A series of samples of a vacuum gas oil (VGO) and a 5 wt.% renewable fuel oil (RFO) blend were cracked in the MAT testing unit (reactor bed, Fluid-2) under similar conditions as in Example 2. The VGO employed in Table 2, labeled FHR CAT Feed, had a density of 0.9196 g/mL at 15.6 °C. The RFO itself had a density of 1.198 g/mL, and a water content of 26.58 (wt.%). The 5 wt.% RFO in VGO blend employed in Table 3, labeled 5 wt% RFO in FHR CF, had a density of 0.9243 g/mL at 15.6 °C. In 45.36kg (100lbs)of the 5 wt.% RFO in VGO blend employed the water content was about 602.82kg (1.329 lbs).. The analysis, characterization, and results for the VGO samples are presented in Tables 2, 3 (on an as fed basis), and Table 4 (refinery flows summary), while the analysis, characterization, and results for the 5 wt.% RFO in VGO blend are presented in Tables 5, 6 (on an as fed basis), Table 7 (on a water-free feed basis), Table 8 (refinery flows summary) and Table 9 is a calculation of gallons of gasoline attributed to the input of RFO.

TABLE 2

Run Number	C-1	C-2	C-3	C-4	C-5	C-6
Feed	FHR CAT Feed					
Catalyst	Grace EC-2007					
Coke Determination	In situ	In situ	In situ	In situ	In situ	In situ
Catalyst contact time (sec)	30	30	30	30	30	30
Catalyst Charge (g)	8.9321	8.9321	8.9321	8.9321	8.9321	8.9321
Feed Charge (g)	1.8471	1.5069	1.0551	0.9328	0.7410	0.7292
Catalyst/Oil ratio (g/g)	4.836	5.927	8.466	9.576	12.054	12.249
WHSV (g/h/g)	24.82	20.24	14.17	12.53	9.96	9.80
Liquid yield (incl. H2O) (wt.%)	73.29	73.14	64.01	62.01	60.00	58.76
IBP/221 °C per Sim Dist (wt.%)	45.3667	49.8000	54.5676	57.7297	58.6757	58.4865
IBP/343 °C per Sim Dist (wt.%)	76.0000	79.8889	83.6486	85.9737	86.1923	86.2121

(continued)

Normalized Mass Balance (wt.% of feed)						
H2	0.14	0.16	0.22	0.24	0.24	0.26
H2S	0.00	0.00	0.00	0.00	0.00	0.00
CO	0.00	0.00	0.00	0.00	0.00	0.00
CO2	0.15	0.15	0.28	0.30	0.33	0.39
C1	0.33	0.36	0.58	0.74	0.66	0.77
C2	0.23	0.25	0.38	0.45	0.40	0.46
C2=	0.35	0.40	0.57	0.58	0.66	0.65
Total Dry Gas	1.20	1.33	2.04	2.31	2.28	2.53
C3	0.75	0.63	0.92	1.06	0.99	1.48
C3=	2.69	2.90	3.72	3.69	4.02	3.91
i-C4	3.11	3.34	4.16	4.26	4.76	4.62
n-C4	0.68	0.73	0.96	1.01	1.04	1.09
i-C4=	0.78	0.86	1.06	1.01	1.01	1.04
n-C4=	2.65	2.87	3.53	3.37	3.48	3.34
Total LPG	10.65	11.33	14.34	14.41	15.31	15.48
Gasoline (C5-221°C)	44.00	46.41	48.72	50.36	50.94	50.69
LCO (221°-343°C)	22.94	22.19	18.91	17.70	16.65	16.44
HCO (343°C+)	18.47	15.49	11.46	9.69	9.35	9.23
Coke	2.74	3.26	4.54	5.53	5.47	5.63
H2O	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.0	100.0	100.0	100.0	100.0	100.0
Conversion	58.59	62.33	69.64	72.61	73.99	74.32

TABLE 3

Run Number	C-1	C-2	C-3	C-4	C-5	C-6
Hydrocarbon Types in 200°C - Gasoline (by New PIONA), wt.%						
Total s-Naphthenes	13.73	13.17	11.49	10.50	7.26	9.53
Total s-i-Paraffins	23.06	22.20	18.28	16.59	20.61	15.06
Total s-n-Paraffins	5.07	4.96	3.98	3.93	3.35	3.46
Total us-Naphthenes	6.69	6.69	5.84	5.60	4.60	4.72
Total us-i-Paraffins	8.43	8.72	8.00	7.48	7.16	6.72
Total us-n-Paraffins	2.29	2.44	2.32	2.10	1.85	1.72
Total Aromatics	40.72	41.81	50.09	53.80	55.16	58.78
Total compounds	100.00	100.00	100.00	100.00	100.00	100.00
Gasoline Specific Gravity	0.7837	0.7837	0.7930	0.7920	0.7956	0.8071
Research Octane No. (RON)	92.14	92.64	96.09	97.12	94.43	96.12
Motor Octane No. (MON)	83.57	83.59	85.14	85.14	80.03	84.19

(continued)

Run Number	C-1	C-2	C-3	C-4	C-5	C-6
Hydrocarbon Types in 200°C - Gasoline (by New PIONA), wt.%						
Benzene (C6-Aromatics)	1.07	1.15	1.40	1.42	1.45	1.26
Toluene (C7-Aromatics)	4.92	5.23	6.84	6.77	7.25	7.52
Xylenes+Ethylbenzene (C8-Aromatics)	12.33	12.89	16.36	16.11	18.97	19.98
C9-Aromatics	20.42	20.85	23.95	23.58	26.31	28.57
C10-Aromatics	1.98	1.69	1.54	1.43	1.18	1.45
TLP Organic Sulfur (mg/L)	1236	1262	1331	1369	1386	1391
Sulfur Distribution by bp (mg/L)						
Gasoline	23.1	23.80	26.10	37.80	48.50	38.60
LCO	483.7	518.90	611.60	643.80	672.20	670.90
HCO	729.3	719.40	693.60	687.10	665.30	681.70
TLP Nitrogen (wppm)	507	480	439	357		387
Nitrogen Distribution by bp (wppm)						
Gasoline	35.0	43.4	49.5	55.2		40.7
LCO	163.9	168.8	175.2	142.1		165.1
HCO	308.5	267.8	214.0	159.9		180.6

TABLE 4

Run Number	C-1	C-2	C-3	C-4	C-5	C-6
Dry Gas (lbs/hr)	1415.0	1579.5	2357.9	2702.1	2623.1	2872.5
C3 (bbls/hr)	5.7	4.8	6.9	8.0	7.5	11.2
C3= (bbls/hr)	19.7	21.3	27.3	27.1	29.6	28.7
C4 (bbls/hr)	25.5	27.3	34.4	35.5	39.0	38.4
C4= (bbls/hr)	21.7	23.6	29.1	27.8	28.5	27.7
C5-429 F Cut (bbls/hr)	215.2	226.9	235.5	243.7	245.4	240.7
429-650F Cut (bbls/hr)	91.7	88.7	75.6	70.7	66.6	65.7
650 F Cut (bbls/hr)	64.8	54.3	40.2	34.0	32.8	32.4
Coke (lbs/hr)	3679.6	4376.5	6097.4	7429.4	7340.2	7551.3
CO (lbs/hr)	0	0	0	0	0	0
CO2 (lbs/hr)	198.0	206.0	375.2	401.2	436.7	528.5
H2O (lbs/hr)	0	0	0	0	0	0
Dry Gas + CO + CO2 (lbs/hr)	1613.0	1785.6	2733.0	3103.3	3059.8	3401.0
Value/Cost	1.022	1.046	1.055	1.059	1.060	1.045

TABLE 5

Run Number	E-1	E-2	E-3	E-4	E-5	E-6	E-7
Feed	5 wt% RFO in FHR CF						
Catalyst	Grace EC-2007						
Coke Determination	In situ	In situ	In situ	In situ	In situ	In situ	In situ
Catalyst contact time (sec)	30	30	30	30	30	30	30
Catalyst Charge (g)	8.9321	8.9321	8.9321	8.9321	8.9321	8.9321	8.9321
Feed Charge (g)	2.0647	1.4407	1.1440	0.9075	0.8035	0.7163	0.6899
Catalyst/Oil ratio (g/g)	4.326	6.200	7.808	9.843	11.116	12.470	12.947
WHSV (g/h/g)	27.74	19.36	15.37	12.19	10.79	9.62	9.27
Liquid yield (incl. H2O) (wt %)	73.49	67.17	66.36	60.77	59.56	59.33	60.43
IBP/221 °C per Sim Dist (wt %)	46.0370	50.7273	54.7000	57.2333	57.0741	59.8649	59.5294
IBP/343 °C per Sim Dist (wt %)	77.1481	81.2593	83.5676	86.0769	85.7838	87.5161	86.5676
Normalized Mass Balance (wt.% of feed)							
H2	0.09	0.13	0.15	0.17	0.19	0.25	0.21
H2S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	0.29	0.24	0.29	0.41	0.46	0.42	0.45
C1	0.29	0.41	0.48	0.60	0.80	0.92	0.81
C2	0.23	0.31	0.34	0.41	0.50	0.55	0.49
C2=	0.39	0.53	0.59	0.66	0.71	0.68	0.74
Total Dry Gas	1.29	1.61	1.84	2.26	2.66	2.82	2.69
C3	0.64	0.73	0.81	1.00	1.49	1.76	1.53
C3=	2.58	3.27	3.50	3.76	3.73	3.79	3.87
i-C4	2.87	3.72	3.89	4.35	4.23	4.64	4.68
n-C4	0.63	0.83	0.86	1.01	1.05	1.16	1.12
i-C4=	0.75	0.93	0.94	1.01	1.00	0.99	1.00
n-C4=	2.54	3.21	3.17	3.32	3.31	3.33	3.26
Total LPG	10.01	12.69	13.18	14.45	14.81	15.67	15.47
Gasoline (C5-221°C)	43.97	46.61	48.56	49.48	48.76	49.05	48.64
LCO (221°-343°C)	22.89	20.40	18.88	17.07	16.61	15.94	15.92
HCO (343°C+)	17.17	12.93	11.32	9.42	9.10	8.28	8.94
Coke	3.00	3.93	4.30	5.30	6.00	6.12	6.25
H2O	1.67	1.84	1.92	2.03	2.07	2.11	2.09
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Conversion	59.94	66.67	69.80	73.51	74.30	75.78	75.14

TABLE 6

Run Number	E-1	E-2	E-3	E-4	E-5	E-6	E-7
Hydrocarbon Types in 200°C - Gasoline (by New PIONA), wt.%							
Total s-Naphthenes	13.45	12.57	11.52	11.06	7.38	6.67	9.64
Total s-i-Paraffins	22.44	19.31	17.53	17.15	18.84	17.71	16.41
Total s-n-Paraffins	5.11	4.54	4.14	3.74	3.45	3.28	3.37
Total us-Naphthenes	6.86	6.23	5.92	5.34	5.17	4.02	4.63
Total us-i-Paraffins	9.09	8.16	8.00	7.10	6.79	7.09	7.71
Total us-n-Paraffins	2.40	2.24	2.47	1.95	2.00	1.57	2.14
Total Aromatics	40.65	46.95	50.41	53.66	56.37	59.67	56.12
Total compounds	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Gasoline Specific Gravity	0.7828	0.7917	0.7834	0.7996	0.8011	0.8069	0.7992
Research Octane No. (RON)	92.09	93.31	94.84	96.50	93.54	94.71	99.93
Motor Octane No. (MON)	83.33	84.34	84.51	85.18	80.64	81.03	86.37
Benzene (C6-Aromatics)	1.12	1.15	1.32	1.39	1.47	1.34	1.55
Toluene (C7-Aromatics)	4.93	5.84	6.03	7.22	7.72	7.83	7.99
Xylenes+Ethylbenzene (C8-Aromatics)	12.21	14.70	14.89	18.25	18.70	20.29	19.12
C9-Aromatics	20.48	23.44	22.56	25.52	26.60	28.41	25.97
C10-Aromatics	1.91	1.83	1.62	1.28	1.88	1.79	1.48
TLP Organic Sulfur (mg/L)	1204	1229	1228			1335	1323
Sulfur Distribution by bp (mg/L)							
Gasoline	23.1	33.80	33.90			37.10	36.50
LCO	469.2	510.20	549.40			657.10	651.30
HCO	711.7	685.40	644.70			640.80	634.80
TLP Nitrogen (wppm)	525	502	451	407	381	378	410
Nitrogen Distribution by bp (wppm)							
Gasoline	35.7	57.2	33.1	30.4	51.8	46.2	33.4
LCO	169.7	175.6	161.7	168.4	152.8	161.4	175.8
HCO	319.8	269.5	256.0	208.5	176.8	170.4	200.5

TABLE 7

Run Number	E-1	E-2	E-3	E-4	E-5	E-6	E-7
Feed	5 wt% RFO in FHR CF						
Catalyst	Grace EC-2007						
Coke Determination	In situ	In situ	In situ	In situ	In situ	In situ	In situ
Catalyst contact time (sec)	30	30	30	30	30	30	30

(continued)

Run Number	E-1	E-2	E-3	E-4	E-5	E-6	E-7
Feed	5 wt% RFO in FHR CF						
Catalyst	Grace EC-2007						
Catalyst Charge (g)	8.9321	8.9321	8.9321	8.9321	8.9321	8.9321	8.9321
Feed Charge (g)	2.0647	1.4407	1.1440	0.9075	0.8035	0.7163	0.6899
Catalyst/Oil ratio (g/g)	4.326	6.200	7.808	9.843	11.116	12.470	12.947
WHSV (g/h/g)	27.74	19.36	15.37	12.19	10.79	9.62	9.27
Liquid yield (incl. H2O) (wt %)	73.49	67.17	66.36	60.77	59.56	59.33	60.43
IBP/221 °C per Sim Dist (wt %)	46.0370	50.7273	54.7000	57.2333	57.0741	59.8649	59.5294
IBP/343 °C per Sim Dist (wt %)	77.1481	81.2593	83.5676	86.0769	85.7838	87.5161	86.5676
Normalized Mass Balance (wt.% of feed)							
H2	0.09	0.13	0.15	0.18	0.19	0.26	0.22
H2S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	0.30	0.24	0.29	0.42	0.47	0.43	0.45
C1	0.30	0.41	0.48	0.61	0.81	0.93	0.82
C2	0.23	0.31	0.34	0.41	0.51	0.56	0.49
C2=	0.39	0.54	0.60	0.67	0.72	0.69	0.75
Total Dry Gas	1.31	1.64	1.87	2.29	2.69	2.86	2.73
C3	0.65	0.74	0.82	1.01	1.51	1.79	1.55
C3=	2.62	3.32	3.55	3.81	3.78	3.85	3.92
i-C4	2.91	3.77	3.94	4.41	4.29	4.70	4.75
n-C4	0.64	0.84	0.87	1.02	1.07	1.18	1.13
i-C4=	0.76	0.94	0.96	1.03	1.01	1.00	1.02
n-C4=	2.57	3.25	3.21	3.36	3.35	3.38	3.30
Total LPG	10.15	12.86	13.36	14.64	15.01	15.89	15.67
Gasoline (C5-221°C)	44.56	47.24	49.21	50.14	49.42	49.71	49.30
LCO (221°-343°C)	23.20	20.67	19.13	17.30	16.83	16.15	16.14
HCO (343°C+)	17.40	13.10	11.47	9.55	9.22	8.39	9.06
Coke	3.04	3.98	4.36	5.37	6.08	6.20	6.34
Total	99.7	99.5	99.4	99.3	99.3	99.2	99.2

TABLE 8

Run Number	E-1	E-2	E-3	E-4	E-5	E-6	E-7
Dry Gas (lbs/hr)	1355.6	1867.8	2109.3	2511.4	2980.3	3265.7	3043.6
C3 (bbls/hr)	4.9	5.6	6.2	7.6	11.4	13.5	11.7
C3= (bbls/hr)	19.2	24.3	26.0	27.9	27.7	28.2	28.8
C4 (bbls/hr)	23.8	30.9	32.3	36.4	36.0	39.4	39.5

(continued)

Run Number	E-1	E-2	E-3	E-4	E-5	E-6	E-7
C4= (bbls/hr)	21.1	26.5	26.3	27.8	27.6	27.7	27.3
C5-429 F Cut (bbls/hr)	217.8	228.3	240.4	239.9	236.0	235.7	236.0
429-650 F Cut (bbls/hr)	92.6	82.5	76.3	69.0	67.1	64.4	64.4
650 F Cut (bbls/hr)	60.9	45.9	40.2	33.4	32.3	29.4	31.7
Coke (lbs/hr)	4072.9	5337.2	5841.3	7192.0	8144.4	8315.0	8494.0
CO (lbs/hr)	0	0.0	0.0	0.0	0.0	0.0	0.0
CO2 (lbs/hr)	399.3	325.0	392.4	560.5	630.3	571.2	608.5
H2O (lbs/hr)	2273.7	2493.5	2611.4	2756.1	2808.5	2867.5	2841.7
Dry Gas + CO + CO2 (lbs/hr)	1754.9	2192.8	2501.7	3071.9	3610.6	3837.0	3652.1
Value/Cost	1.023	1.043	1.059	1.045	1.031	1.028	1.029
Water in Feed	1798.8	1798.8	1798.8	1798.8	1798.8	1798.8	1798.8
Oxygen in Feed Water	1599.0	1599.0	1599.0	1599.0	1599.0	1599.0	1599.0
Oxygen in Feed	2705	2705	2705	2705	2705	2705	2705
Oxygen in Total Prod. Water	2021.1	2216.5	2321.2	2449.8	2496.5	2548.9	2525.9
Oxygen % in water	74.7%	81.9%	85.8%	90.6%	92.3%	94.2%	93.4%
FCC Produced Water	474.9	694.7	812.5	957.2	1009.7	1068.7	1042.8
Delta CO2 produced from RFO	201.3	118.9	17.2	159.3	193.6	42.7	80.0
Oxygen in Produced Water	422.1	617.5	722.3	850.9	897.5	950.0	927.0
Oxygen in Delta CO2	146.4	86.5	12.5	115.8	140.8	31.1	58.2
Oxygen in TLP (.26 DL)	312.5	312.5	312.5	312.5	312.5	312.5	312.5
TOTAL Oxygen	881.0	1016.5	1047.3	1279.2	1350.8	1293.5	1297.7
Delta Oxygen	-225.1	-89.6	-58.8	173.1	244.7	187.4	191.6
Oxygen Balance (%)	91.68	96.69	97.83	106.40	109.05	106.93	107.08
Amount of CO to Balance O2	393.9	156.8	102.9	-303.0	-428.2	-328.0	
Amount of H2O to Balance O2	253.2	100.8	66.1	-194.8	-275.3	-210.9	-215.5
Total H2O	2526.9	2594.3	2677.5	2561.3	2533.2	2656.7	2626.2

TABLE 9

Calculation of Gallons of Gasoline Attributed to the input of RFO (on a 10,000 bbl/day input basis)								
Canmet MAT test								
Catalyst/Oil Ratio (approximated from curve-fitted line)		4	5	6	7	8	9	10

(continued)

Calculation of Gallons of Gasoline Attributed to the input of RFO (on a 10,000 bbl/day input basis)								
Canmet MAT test								
Gasoline Make (Ref. GO)	bbls/hr	208.53	217.58	225.27	231.63	236.63	240.29	242.60
10,000 bbls/day basis								
134245 lbs/hr								
Gasoline Make (Ref. GO)	bbls/ton	3.11	3.24	3.36	3.45	3.53	3.58	3.61
Gasoline Make (5wt% RFO)	bbls/hr	215.22	222.79	228.98	233.80	237.26	239.35	240.07
10,000 bbls/day								
9,612 bbls/day Ref. GO and								
388 bbls/day RFO								
Gasoline Make attributed to	bbls/hr	200.44	209.14	216.53	222.64	227.45	230.96	233.19
Ref. GO (bbls/hr) vol. basis								
Gasoline Make attributed to	bbls/hr	14.78	13.65	12.45	11.17	9.81	8.39	6.88
RFO by difference								
Gasoline Make 5wt%RFO	bbls/ton RFO	4.35	4.02	3.67	3.29	2.89	2.47	2.03
Gasoline Make 5wt%RFO	gals/ton of RFO	182.9	168.9	154.0	138.2	121.4	103.8	85.2
(gals/ton of RFO)								
Gasoline Make 5wt%RFO	gals/ton of biomass	128.0	118.2	107.8	96.7	85.0	72.6	59.6
assume 70wt% yield								

[0116] In the description above, for purposes of explanation only, specific embodiments have been presented and/or exemplified. It should be understood that variations of various aspects of an embodiment may be combined with other stated components, embodiments, ranges, types, etc.. For example, there are embodiments that discuss the processing of an RFO and it should be understood that any and all of the types of RFO's discussed and/or presented herein may be substituted and/or combined into such embodiments even though an embodiment may not be specifically presented with the particular type of RFO in the description.

Claims

1. A method of preparing a fuel comprising co-processing in a fluidized catalytic cracking unit (FCC) a petroleum fraction feedstock with a renewable fuel oil feedstock in the presence of a catalyst,

   wherein the renewable fuel oil is an unenriched renewable fuel oil formed from ground-up biomass by a rapid thermal processing, wherein the unenriched renewable fuel oil does not undergo any further pre- or post-processing including no hydrodeoxygenation, no hydrotreating, no catalytic exposure or contact, wherein the renewable fuel oil includes all of the whole liquid produced from the thermomechanical conversion of the biomass, wherein the unenriched renewable fuel oil is used in an amount of less than 6 wt.%, less than about 5 wt.% or less than about 3 wt.% relative to the total weight of feedstock fed, and
   wherein the petroleum fraction feedstock comprising a gas oil (GO) feedstock, a vacuum gas oil (VGO) feedstock, or a heavy gas oil (HGO) feedstock.

2. The method of claim 1, wherein the renewable fuel oil is a liquid formed from ground-up biomass by rapid thermal processing, wherein the resulting liquid is at least 60 wt.%, at least 70 wt.%, at least 75 wt.%, at 80 wt.% or at least 85 wt.% of the total weight of the processed biomass.

3. The method of claim 2, wherein the resulting liquid is at least 70 wt.%, at least 75 wt.%, at 80 wt.% or at least 85 wt.% of the total weight of the processed biomass

4. The method of claim 1, wherein the renewable fuel oil has a pH in the range of 0.5 to 8.

5. The method of claim 1, wherein the renewable fuel oil has a solids content of less than 5 wt.%.

6. The method of claim 1, wherein the cellulosic biomass comprises wood, wood residues, sawdust, slash bark, thinnings, forest cullings, bagasse, corn fiber, corn stover, empty fruit bunches (EFB), fronds, palm fronds, flax, straw, low-ash straw, energy crops, palm oil, non-food-based biomass materials, crop residue, slash, pre-commercial thinnings and tree residue, annual covercrops, switch grass, miscanthus, cellulosic containing components, cellulosic components of separated yard waste, cellulosic components of separated food waste, cellulosic components of separated municipal solid waste (MSW), or combinations thereof.

7. The method of claim 6, wherein the cellulosic biomass comprises slash bark, thinnings, bagasse, corn fiber, corn stover, empty fruit bunches (EFB), fronds, palm fronds, flax, straw, low-ash straw, energy crops, palm oil, non-food-based biomass materials, crop residue, slash, pre-commercial thinnings, annual covercrops, switch grass, miscanthus, cellulosic containing components, cellulosic components of separated yard waste, cellulosic components of separated food waste, cellulosic components of separated municipal solid waste (MSW), or combinations thereof.

8. The method of claim 6, wherein the cellulosic biomass comprises slash bark, thinnings, empty fruit bunches (EFB), fronds, palm fronds, flax, palm oil, non-food-based biomass materials, crop residue, slash, pre-commercial thinnings, annual covercrops, switch grass, miscanthus, cellulosic containing components, cellulosic components of separated yard waste, cellulosic components of separated food waste, cellulosic components of separated municipal solid waste (MSW), or combinations thereof.

9. The method of claim 1, wherein the petroleum fraction feedstock and the renewable fuel oil feedstock are introduced into the FCC unit through one or more independent or separate injection nozzles.

10. The method of claim 1, wherein the mix-zone temperature in the FCC unit is increased by injecting between 0.05 to 15 wt.% renewable fuel oil feedstock via a quench riser system downstream of the introduction of a petroleum fraction feedstock injection nozzle.

11. The method of claim 1, wherein the unenriched renewable fuel oil has a temperature not exceeding 65.5 °C (150 °F) on its way to being introduced into the FCC unit.

12. The method of claim 1, wherein the amount of renewable fuel oil is in the range of greater than 1% by weight and less than 5% by weight.

Patentansprüche

1. Verfahren zum Herstellen eines Kraftstoffs, umfassend das gleichzeitige Verarbeiten eines Ausgangsmaterials aus Erdölfraktion mit einem Ausgangsmaterial aus erneuerbarem Kraftstofföl in Gegenwart eines Katalysators in einer FCC-Einheit (FCC - *Fluidized Catalytic Cracker),*

   wobei es sich bei dem erneuerbaren Kraftstofföl um ein unangereichertes erneuerbares Kraftstofföl handelt, das durch eine schnelle thermische Verarbeitung *(Rapid Thermal Processing)* aus zermahlener Biomasse gebildet wird, wobei das unangereicherte erneuerbare Kraftstofföl keiner weiteren Vor- oder Nachverarbeitung unterzogen wird, einschließlich keiner Hydrodeoxygenierung, keiner Hydrobehandlung, keiner Katalytsatorexposition oder keines Katalytsatorkontakts, wobei das erneuerbare Kraftstofföl die gesamte Flüssigkeit umfasst, die aus der thermomechanischen Umwandlung der Biomasse hergestellt wird,
   wobei das unangereicherte erneuerbare Kraftstofföl in einer Menge von weniger als 6 Gew.-%, weniger als etwa 5 Gew.-% oder weniger als etwa 3 Gew.-%, bezogen auf das Gesamtgewicht des zugeführten Ausgangsmaterials, verwendet wird und
   wobei das Ausgangsmaterial aus Erdölfraktion ein Ausgangsmaterial aus Gasöl (GO), ein Ausgangsmaterial aus Vakuumgasöl (VGO) oder ein Ausgangsmaterial aus Schwergasöl (HGO) umfasst.

2. Verfahren nach Anspruch 1, wobei es sich bei dem erneuerbaren Kraftstofföl um eine Flüssigkeit handelt, die durch schnelle thermische Verarbeitung aus zermahlener Biomasse gebildet wird, wobei die erhaltene Flüssigkeit mindestens 60 Gew.-%, mindestens 70 Gew.-%, mindestens 75 Gew.-%, mindestens 80 Gew.-% oder mindestens 85 Gew.-% des Gesamtgewichts der verarbeiteten Biomasse ausmacht.

3. Verfahren nach Anspruch 2, wobei die erhaltene Flüssigkeit mindestens 70 Gew.-%, mindestens 75 Gew.-%, mindestens 80 Gew.-% oder mindestens 85 Gew.-% des Gesamtgewichts der verarbeiteten Biomasse ausmacht.

4. Verfahren nach Anspruch 1, wobei das erneuerbare Kraftstofföl einen pH-Wert im Bereich von 0,5 bis 8 aufweist.

5. Verfahren nach Anspruch 1, wobei das erneuerbare Kraftstofföl einen Feststoffgehalt von weniger als 5 Gew.-% aufweist.

6. Verfahren nach Anspruch 1, wobei die cellulosehaltige Biomasse Holz, Holzreste, Sägemehl, Rindenmulch, Durchforstungsabfälle, Waldkeulungen, Bagasse, Maisfaser, Maisstroh, leere Fruchtstände *(Empty Fruit Bunches* - EFB), Wedel, Palmwedel, Flachs, Stroh, Stroh mit niedrigem Aschegehalt, Energiepflanzen, Palmöl, nicht auf Lebensmitteln beruhende Biomassematerialien, Pflanzenreste, Mulch, Durchforstungsabfälle und Baumreste vor der industriellen Nutzung, einjährige Deckpflanzen, Rutenhirse, Miscanthus, cellulosehaltige Bestandteile, cellulosehaltige Bestandteile getrennter Gartenabfälle, cellulosehaltige Bestandteile getrennter Lebensmittelabfälle, cellulosehaltige Bestandteile getrennter Siedlungsabfälle *(Municipal Solid Waste* - MSW) oder Kombinationen davon umfasst.

7. Verfahren nach Anspruch 6, wobei die cellulosehaltige Biomasse Rindenmulch, Durchforstungsabfälle, Bagasse, Maisfaser, Maisstroh, leere Fruchtstände (*Empty Fruit Bunches* - EFB), Wedel, Palmwedel, Flachs, Stroh, Stroh mit niedrigem Aschegehalt, Energiepflanzen, Palmöl, nicht auf Lebensmitteln beruhende Biomassematerialien, Pflanzenreste, Mulch, Durchforstungsabfälle vor der industriellen Nutzung, einjährige Deckpflanzen, Rutenhirse, Miscanthus, cellulosehaltige Bestandteile, cellulosehaltige Bestandteile getrennter Gartenabfälle, cellulosehaltige Bestandteile getrennter Lebensmittelabfälle, cellulosehaltige Bestandteile getrennter Siedlungsabfälle *(Municipal Solid Waste* - MSW) oder Kombinationen davon umfasst.

8. Verfahren nach Anspruch 6, wobei die cellulosehaltige Biomasse Rindenmulch, Durchforstungsabfälle, leere Fruchtstände *(Empty Fruit Bunches* - EFB), Wedel, Palmwedel, Flachs, Palmöl, nicht auf Lebensmitteln beruhende Biomassematerialien, Pflanzenreste, Mulch, Durchforstungsabfälle vor der industriellen Nutzung, einjährige Deckpflanzen, Rutenhirse, Miscanthus, cellulosehaltige Bestandteile, cellulosehaltige Bestandteile getrennter Gartenabfälle, cellulosehaltige Bestandteile getrennter Lebensmittelabfälle, cellulosehaltige Bestandteile getrennter Siedlungsabfälle *(Municipal Solid Waste* - MSW) oder Kombinationen davon umfasst.

9. Verfahren nach Anspruch 1, wobei das Ausgangsmaterial aus Erdölfraktion und das Ausgangsmaterial aus erneuerbarem Kraftstofföl über eine oder mehrere unabhängige oder getrennte Einspritzdüsen in die FCC-Einheit eingebracht werden.

10. Verfahren nach Anspruch 1, wobei die Mischzonentemperatur in der FCC-Einheit durch Einspritzen von 0,05 bis 15 Gew.-% Ausgangsmaterial aus erneuerbarem Kraftstofföl über ein Quench-Riser-System erhöht wird, das der Einbringung einer Einspritzdüse für Ausgangsmaterial aus Erdölfraktion nachgelagert ist.

11. Verfahren nach Anspruch 1, wobei das unangereicherte erneuerbare Kraftstofföl auf seinem Weg zur Einbringung in die FCC-Einheit eine Temperatur aufweist, die 65,5 °C (150 °F) nicht übersteigt.

12. Verfahren nach Anspruch 1, wobei die Menge an erneuerbarem Kraftstofföl im Bereich von über 1 Gew.-% und unter 5 Gew.-% liegt.

Revendications

1. Procédé de préparation d'un carburant comprenant le co-traitement, dans une unité de craquage catalytique en lit fluidisé (*Fluidized Catalytic Cracker* - FCC), d'une charge d'alimentation de fraction de pétrole avec une charge d'alimentation de fioul renouvelable en présence d'un catalyseur,

dans lequel le fioul renouvelable est un fioul renouvelable non enrichi formé par traitement thermique rapide à partir de biomasse broyée, le fioul renouvelable non enrichi ne subissant aucun autre prétraitement ou post-traitement, y compris aucune hydrodésoxygénation, aucun hydrotraitement, aucune exposition ni aucun contact catalytique, le fioul renouvelable comportant la totalité de tout le liquide produit à partir de la conversion thermomécanique de la biomasse,
dans lequel le fioul renouvelable non enrichi est utilisé dans une quantité inférieure à 6 % en poids, inférieure à environ 5 % en poids ou inférieure à environ 3 % en poids par rapport au poids total de la charge d'alimentation alimentée, et
dans lequel la charge d'alimentation de fraction de pétrole comprend une charge d'alimentation de gazole (GO), une charge d'alimentation de gazole sous vide (VGO), ou une charge d'alimentation de gazole lourd (HGO).

2. Procédé selon la revendication 1, dans lequel le fioul renouvelable est un liquide formé par traitement thermique rapide à partir de biomasse broyée, le liquide obtenu représentant au moins 60 % en poids, au moins 70 % en poids, au moins 75 % en poids, au moins 80 % en poids ou au moins 85 % en poids du poids total de la biomasse traitée.

3. Procédé selon la revendication 2, dans lequel le liquide obtenu représente au moins 70 % en poids, au moins 75 % en poids, au moins 80 % en poids ou au moins 85 % en poids du poids total de la biomasse traitée.

4. Procédé selon la revendication 1, dans lequel le fioul renouvelable présente un pH compris entre 0,5 et 8.

5. Procédé selon la revendication 1, dans lequel le fioul renouvelable présente une teneur en matières sèches inférieure à 5 % en poids.

6. Procédé selon la revendication 1, dans lequel la biomasse cellulosique comprend du bois, des résidus de bois, de la sciure, du paillis d'écorces, des déchets de taille, des déchets de coupe d'écrémage des forêts, de la bagasse, de la fibre de maïs, de la canne de maïs, des rafles de fruits (*Empty Fruit Bunches* - EFB), des frondes, des frondes de palmier, du lin cultivé, de la paille, de la paille à faible teneur en cendres, des cultures énergétiques, de l'huile de palme, des matières issues de biomasse d'origine non alimentaire, des résidus de cultures, des déchets d'abattage, des déchets et résidus d'arbres d'éclaircies précommerciales, du couvert végétal annuel, du panic érigé, du miscanthus, des composants contenant de la cellulose, des composants cellulosiques de déchets de jardin triés, des composants cellulosiques de déchets alimentaires triés, des composants cellulosiques de déchets ménagers triés *(Municipal Solid Waste* - MSW), ou des combinaisons de ceux-ci.

7. Procédé selon la revendication 6, dans lequel la biomasse cellulosique comprend du paillis d'écorces, des déchets de taille, de la bagasse, de la fibre de maïs, de la canne de maïs, des rafles de fruits (*Empty Fruit Bunches* - EFB), des frondes, des frondes de palmier, du lin cultivé, de la paille, de la paille à faible teneur en cendres, des cultures énergétiques, de l'huile de palme, des matières issues de biomasse d'origine non alimentaire, des résidus de cultures, des déchets d'abattage, des déchets d'éclaircies précommerciales, du couvert végétal annuel, du panic érigé, du miscanthus, des composants contenant de la cellulose, des composants cellulosiques de déchets de jardin triés, des composants cellulosiques de déchets alimentaires triés, des composants cellulosiques de déchets ménagers triés *(Municipal Solid Waste* - MSW), ou des combinaisons de ceux-ci.

8. Procédé selon la revendication 6, dans lequel la biomasse cellulosique comprend du paillis d'écorces, des déchets de taille, des rafles de fruits (*Empty Fruit Bunches* - EFB), des frondes, des frondes de palmier, du lin cultivé, de l'huile de palme, des matières issues de biomasse d'origine non alimentaire, des résidus de cultures, des déchets d'abattage, des déchets d'éclaircies précommerciales, du couvert végétal annuel, du panic érigé, du miscanthus, des composants contenant de la cellulose, des composants cellulosiques de déchets de jardin triés, des composants cellulosiques de déchets alimentaires triés, des composants cellulosiques de déchets ménagers triés (*Municipal Solid Waste* - MSW), ou des combinaisons de ceux-ci.

9. Procédé selon la revendication 1, dans lequel la charge d'alimentation de fraction de pétrole et la charge d'alimentation de fioul renouvelable sont introduites dans l'unité de FCC par une ou plusieurs buses d'injection indépendantes ou séparées.

10. Procédé selon la revendication 1, dans lequel la température de la zone de mélange dans l'unité de FCC est augmentée en injectant entre 0,05 et 15 % en poids de charge d'alimentation de fioul renouvelable par le biais d'un système de colonne de craquage à tour de trempe en aval de l'introduction d'une buse d'injection de charge d'alimentation de fraction de pétrole.

11. Procédé selon la revendication 1, dans lequel le fioul renouvelable non enrichi présente une température ne dépassant pas 65,5 °C (150 °F) lorsqu'il est sur le point d'être introduit dans l'unité de FCC.

12. Procédé selon la revendication 1, dans lequel la quantité de fioul renouvelable est comprise dans la plage allant de plus de 1 % en poids à moins de 5 % en poids.

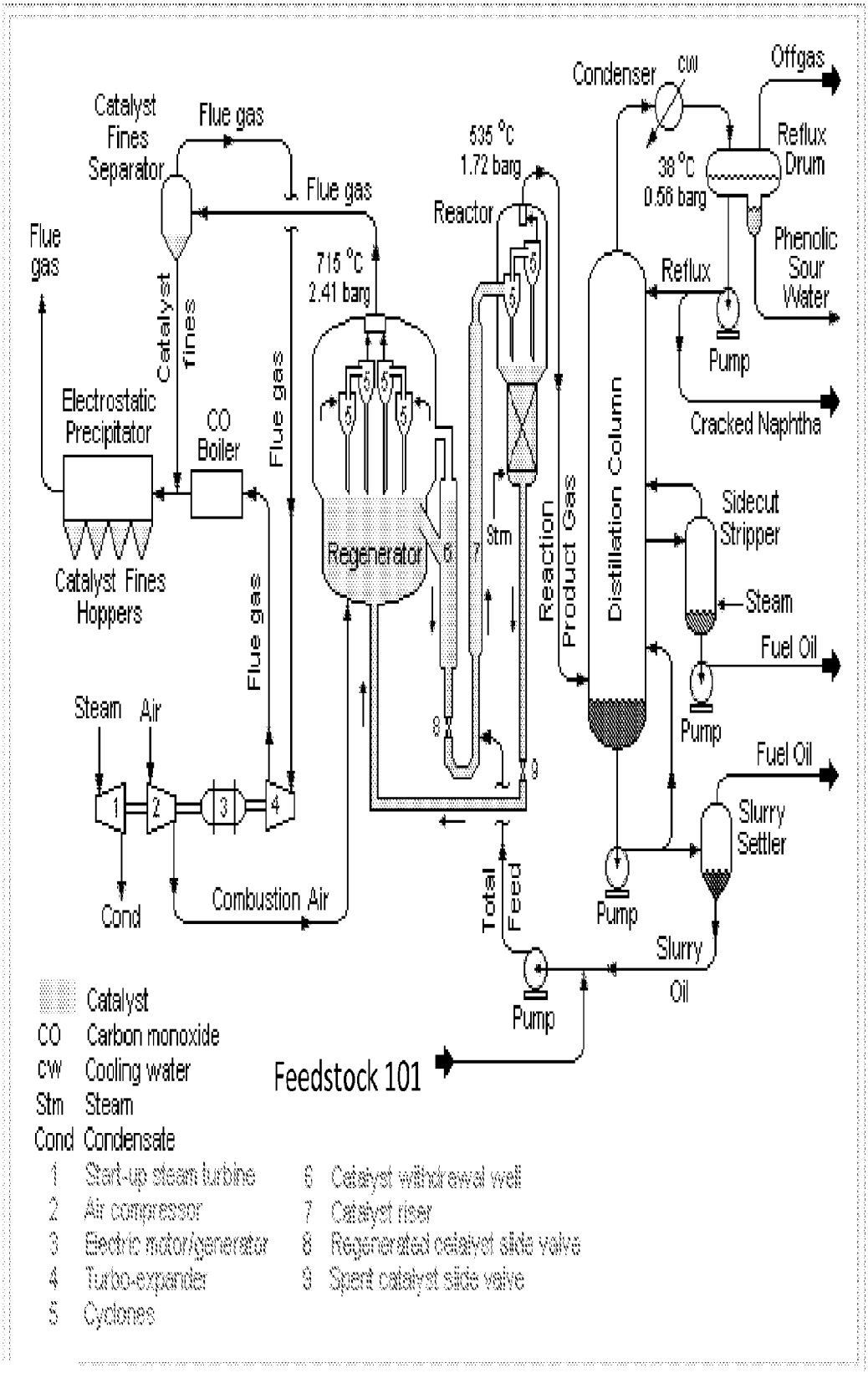


Figure 1 : A schematic flow diagram of a Fluid Catalytic Cracking unit as used in petroleum refineries

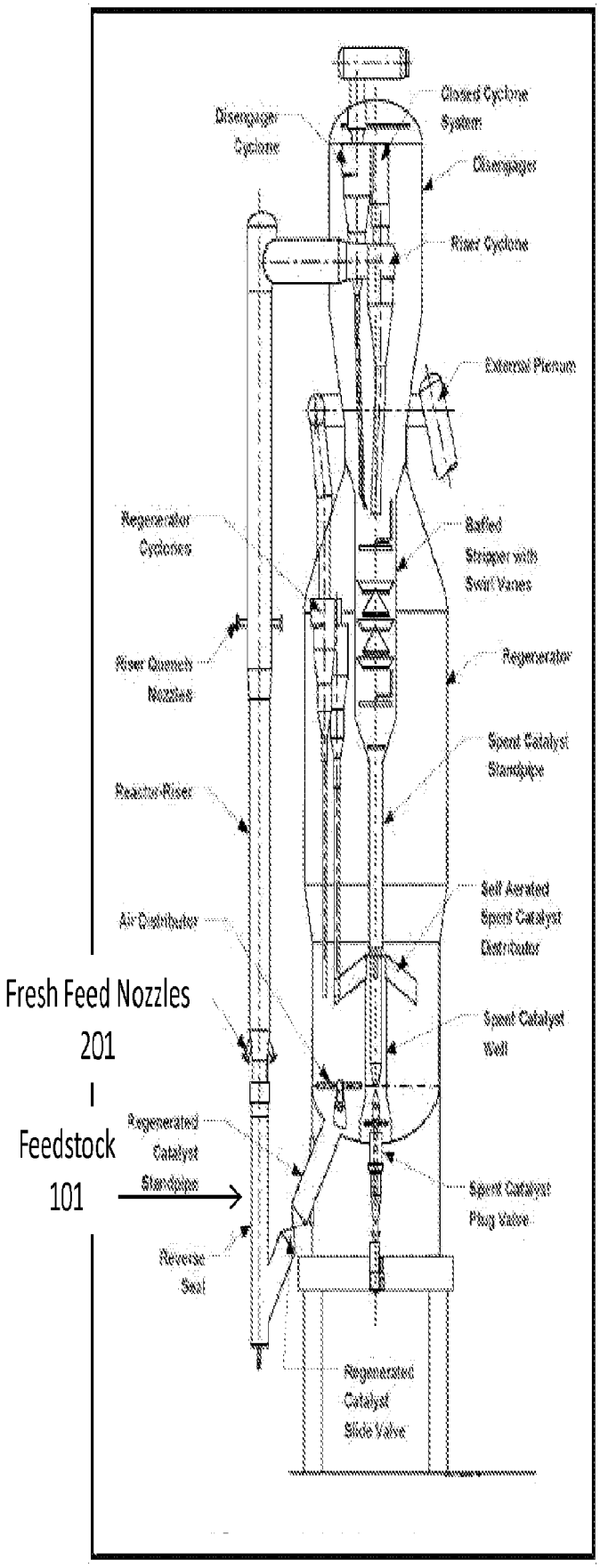

Closed Cyclone System
Disengager Cyclone
Disengager
Riser Cyclone
External Plenum
Regenerator Cyclones
Baffled Stripper with Swirl Vanes
Riser Quench Nozzles
Regenerator
Spent Catalyst Standpipe
Reactor Riser
Self Aerated Spent Catalyst Distributor
Air Distributor
Fresh Feed Nozzles
201
Spent Catalyst Well
Feedstock
101
Regenerated Catalyst Standpipe
Spent Catalyst Plug Valve
Reverse Seal
Regenerated Catalyst Slide Valve

Figure 2A

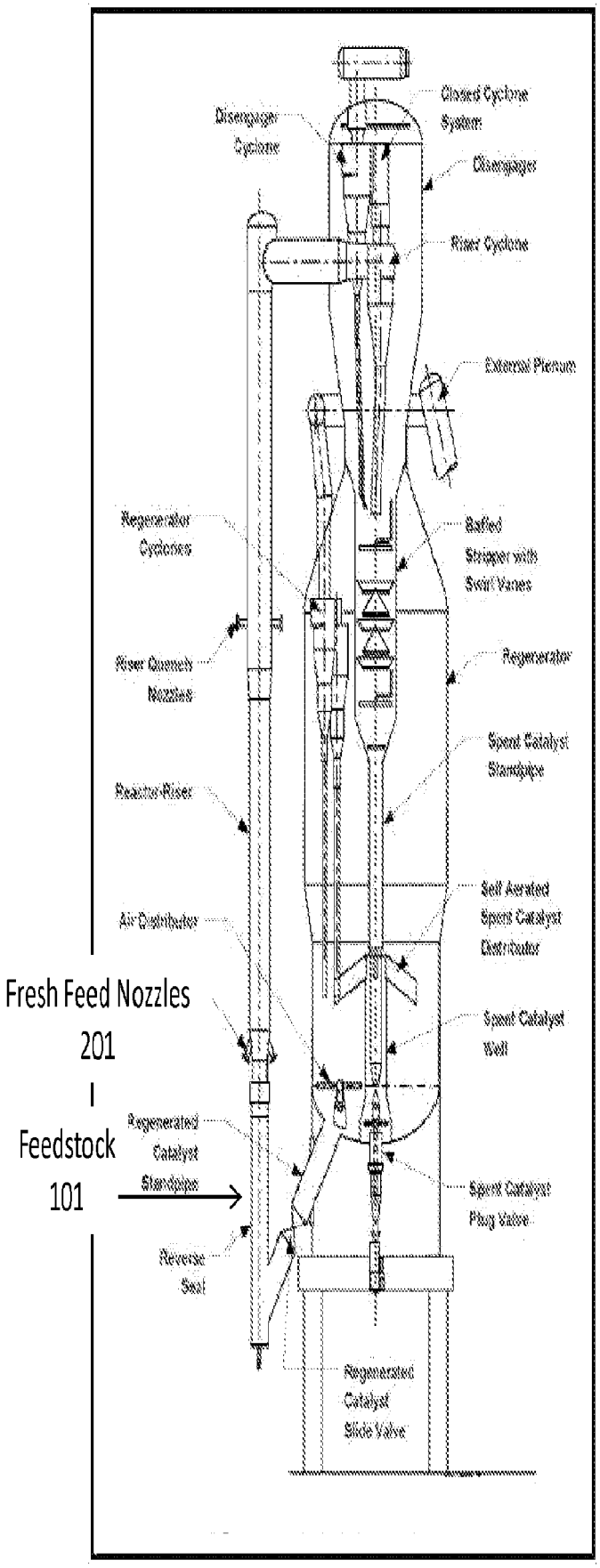
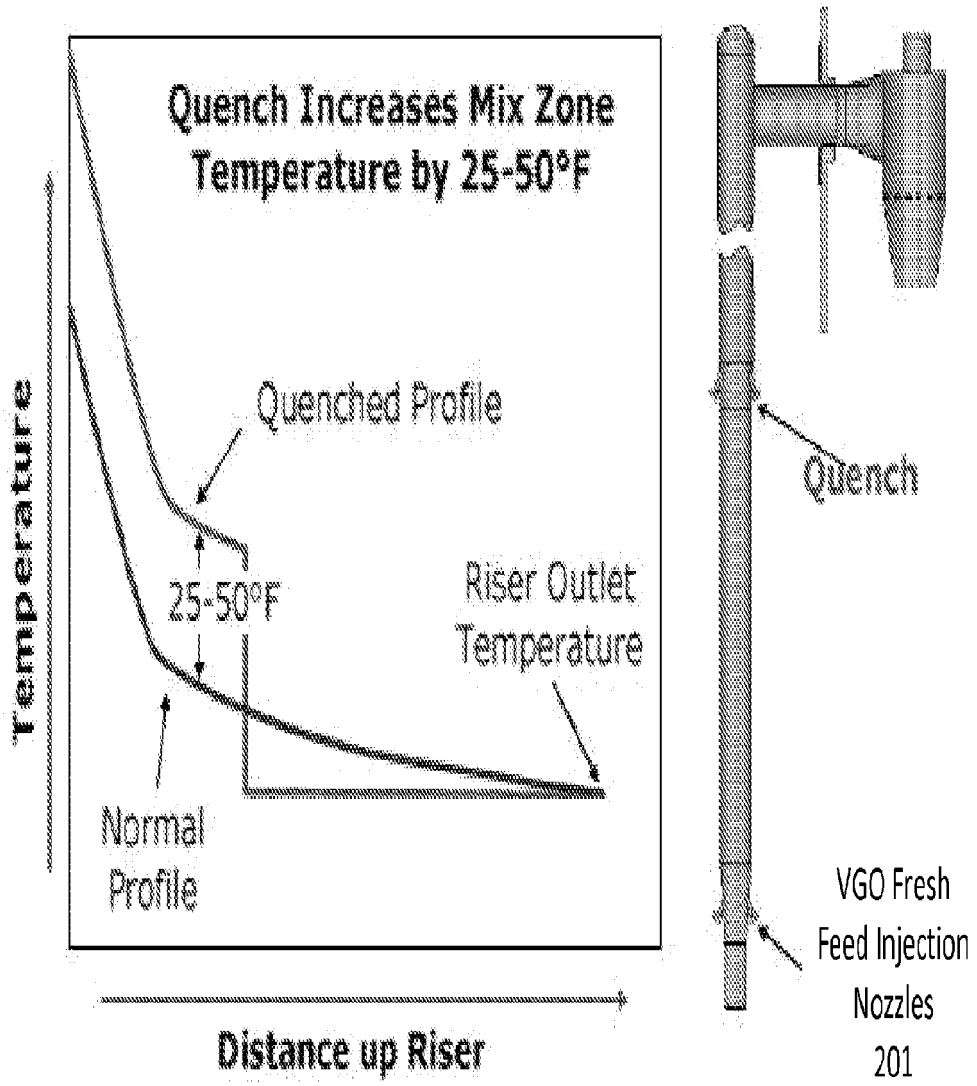

Closed Cyclone System
Disengager Cyclone
Disengager
Riser Cyclone
External Plenum
Regenerator Cyclones
Baffled Stripper with Swirl Vanes
Riser Quench Nozzles
Regenerator
Spent Catalyst Standpipe
Reactor Riser
Self Aerated Spent Catalyst Distributor
Air Distributor
Fresh Feed Nozzles
201
Spent Catalyst Well
Feedstock
101
Regenerated Catalyst Standpipe
Spent Catalyst Plug Valve
Reverse Seal
Regenerated Catalyst Slide Valve

Figure 2B

Figure 3 Riser Quench Technology



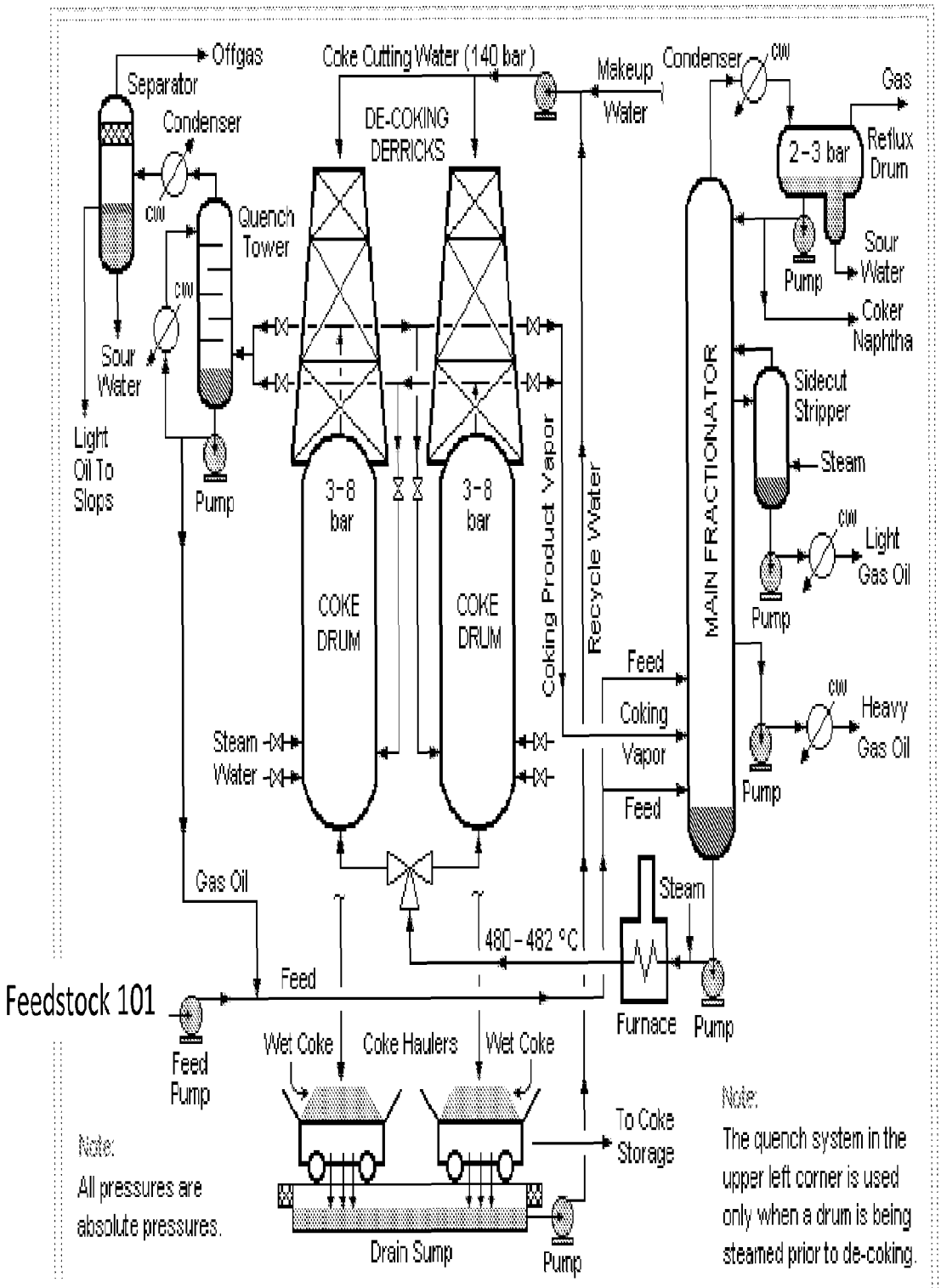


Figure 4 schematic flow diagram of a delayed coking unit

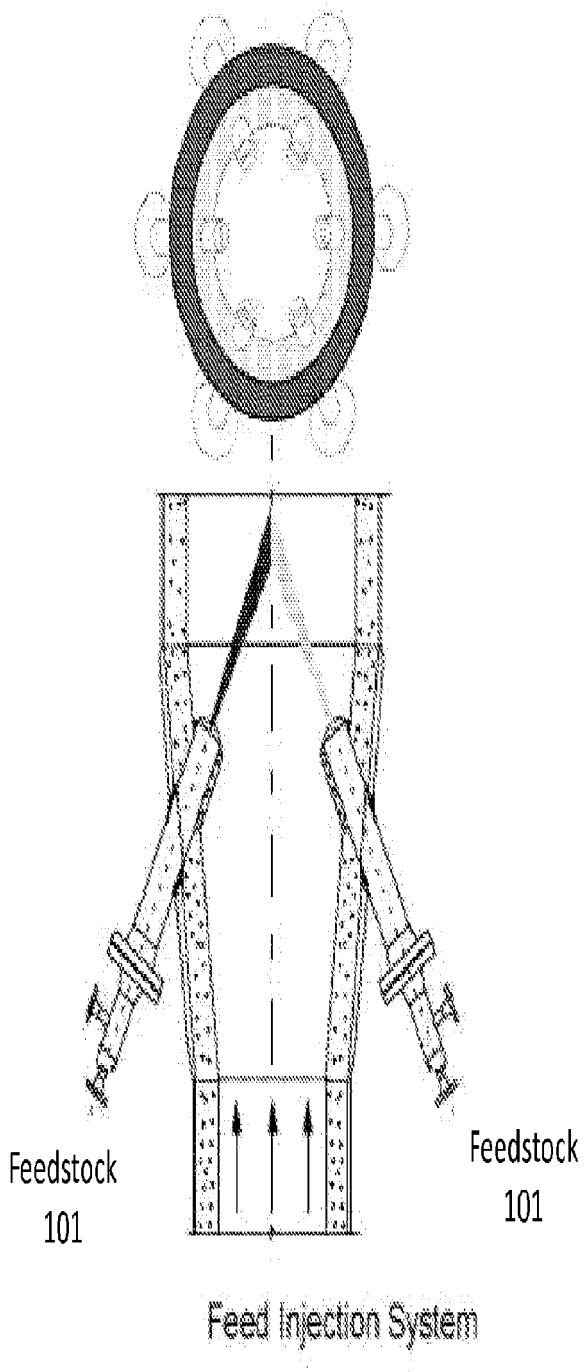


Figure 5

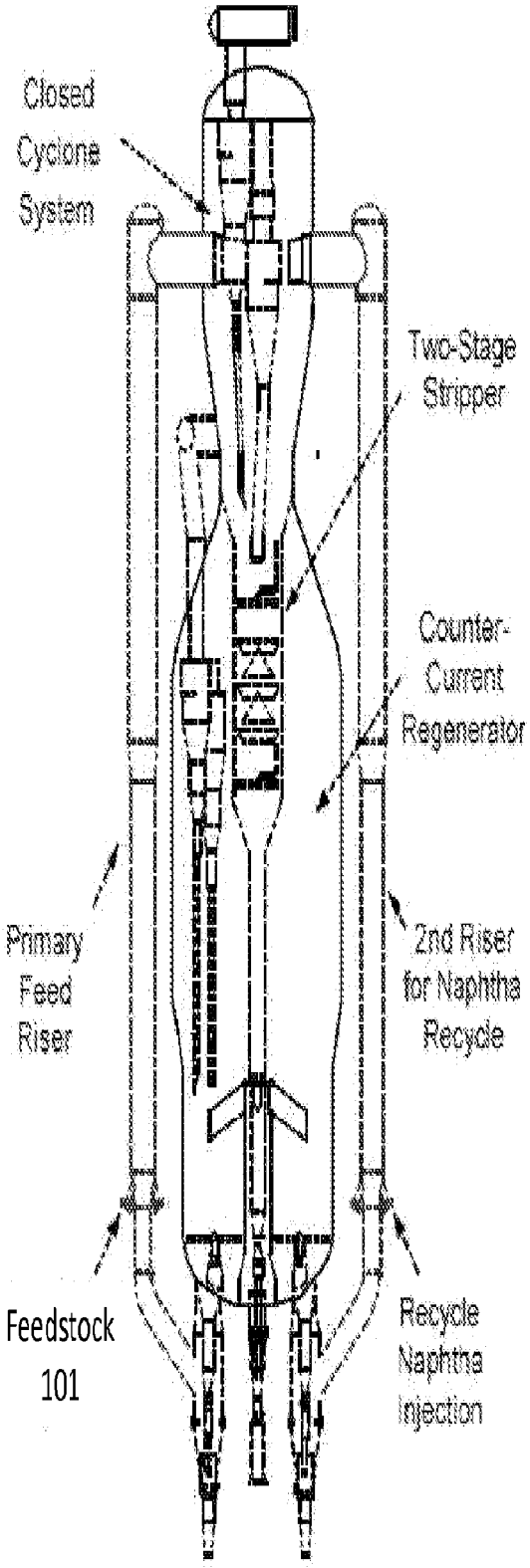

Closed
Cyclone
System
Two-Stage
Stripper
Counter-
Current
Regenerator
Primary
Feed
Riser
2nd Riser
for Naphtha
Recycle
Feedstock
101
Recycle
Naphtha
Injection

Figure 6

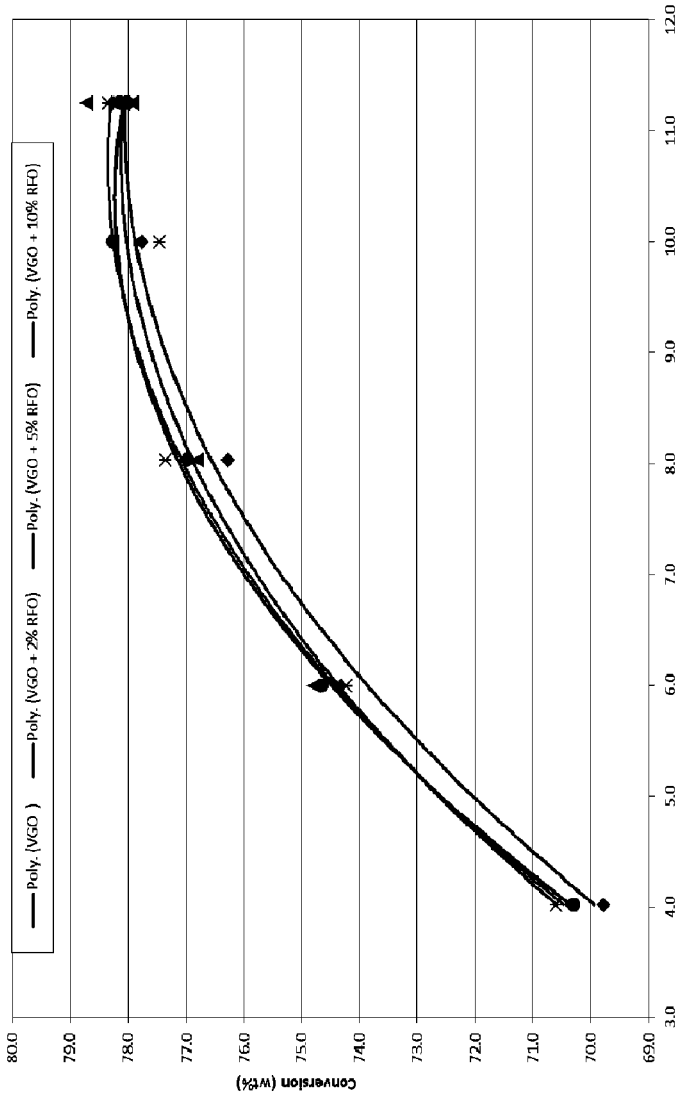

Poly. (VGO)
Poly. (VGO + 2% RFO)
Poly. (VGO + 5% RFO)
Poly. (VGO + 10% RFO)
Conversion (wt%)
Cat:Oil Ratio
80.0
79.0
78.0
77.0
76.0
75.0
74.0
73.0
72.0
71.0
70.0
69.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0

FIGURE 7

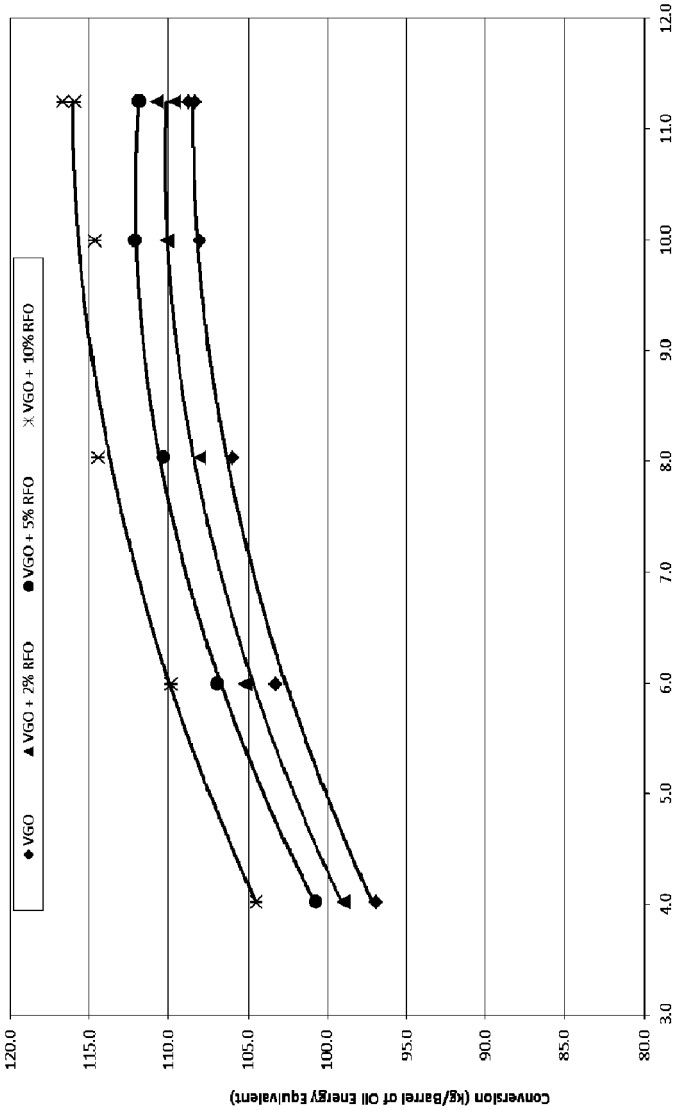

VGO
VGO + 2% RFO
VGO + 5% RFO
VGO + 10% RFO
Conversion (Kg/Barrel of Oil Energy Equivalent)
Cat:Oil Ratio
120.0
115.0
110.0
105.0
100.0
95.0
90.0
85.0
80.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0

FIGURE 8

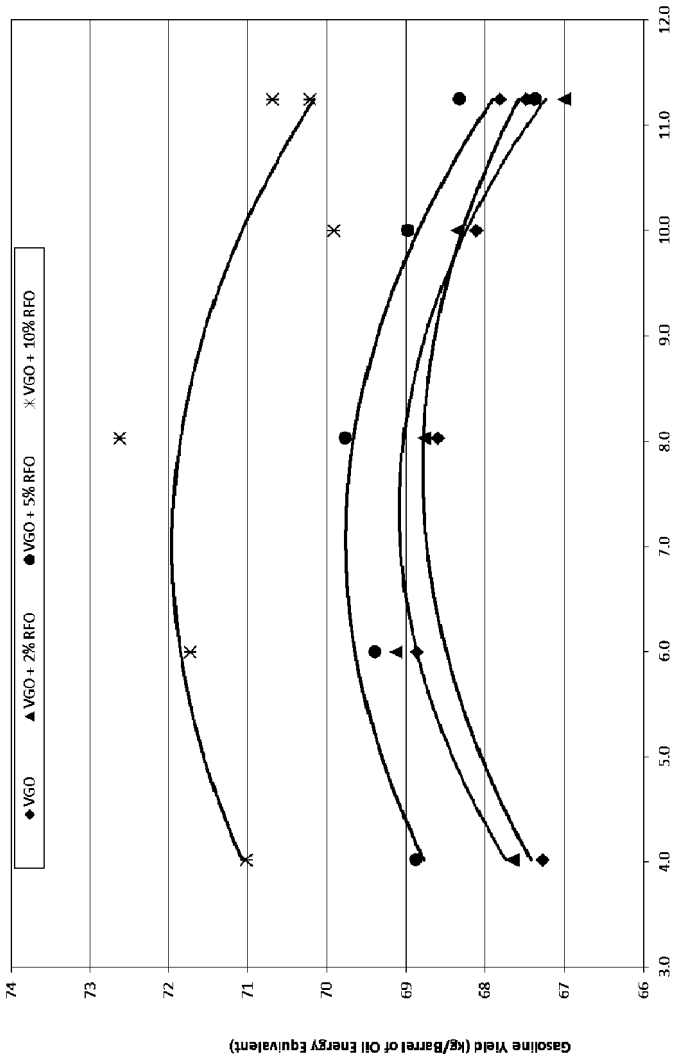

◆ VGO
▲ VGO + 2% RFO
● VGO + 5% RFO
✳ VGO + 10% RFO
Gasoline Yield (kg/Barrel of Oil Energy Equivalent)
Cat:Oil Ratio
74
73
72
71
70
69
68
67
66
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0

FIGURE 9

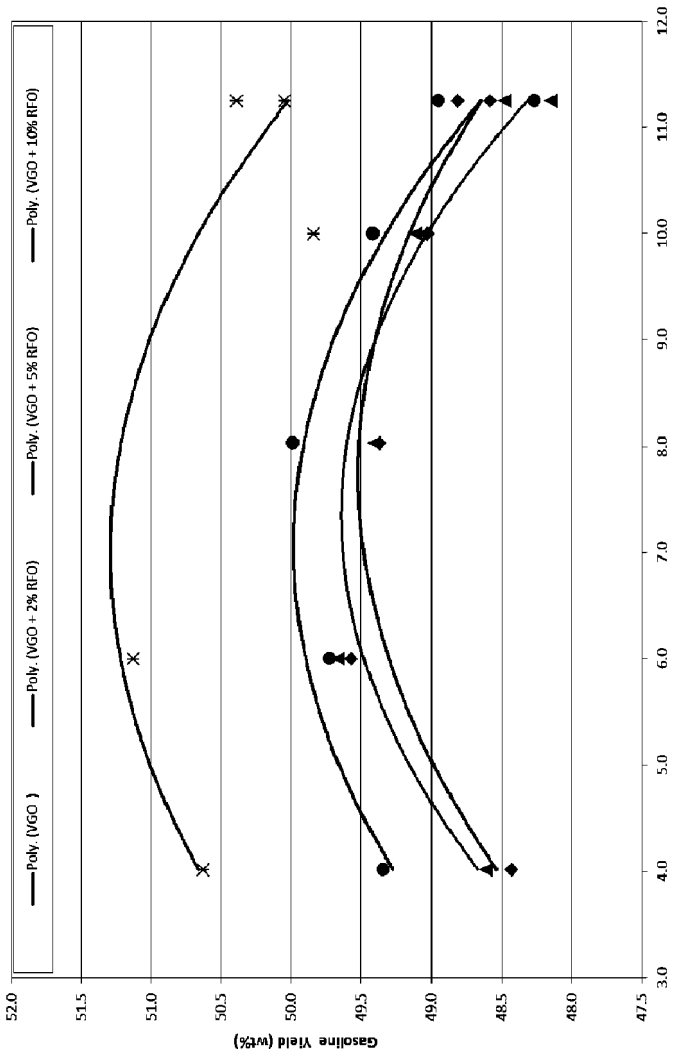

Poly. (VGO)
Poly. (VGO + 2% RFO)
Poly. (VGO + 5% RFO)
Poly. (VGO + 10% RFO)
Gasoline Yield (wt%)
52.0
51.5
51.0
50.5
50.0
49.5
49.0
48.5
48.0
47.5
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
Cat:Oil Ratio

FIGURE 10

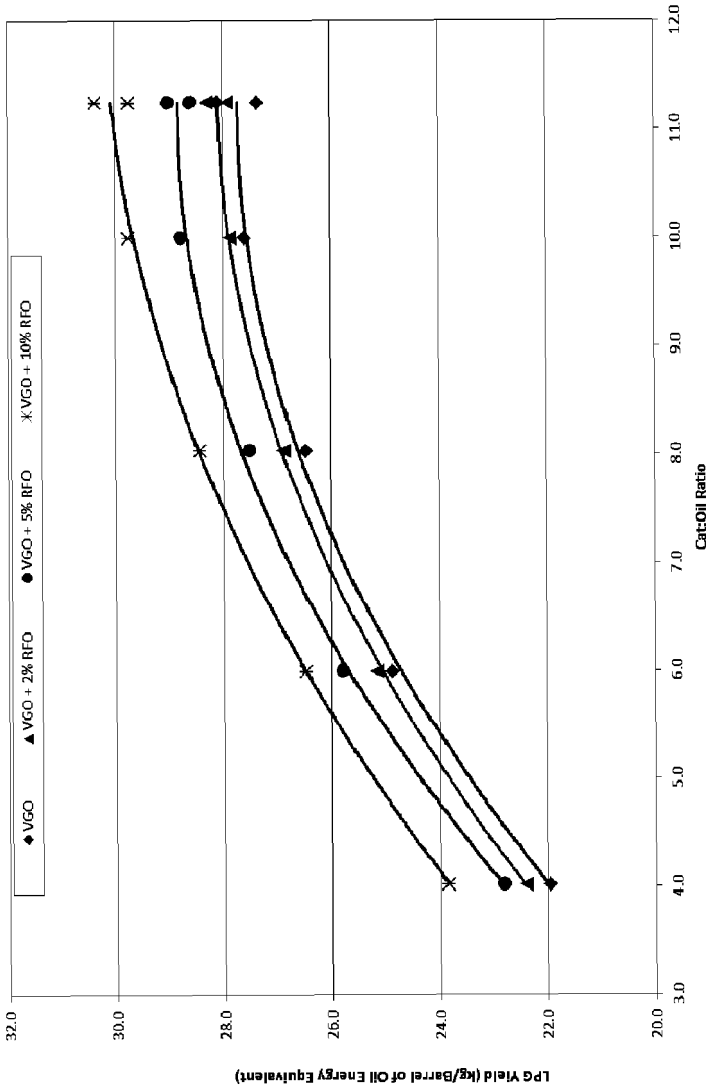

VGO
VGO + 2% RFO
VGO + 5% RFO
VGO + 10% RFO
LPG Yield (Kg/Barrel of Oil Energy Equivalent)
Cat:Oil Ratio
32.0
30.0
28.0
26.0
24.0
22.0
20.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0

FIGURE 11

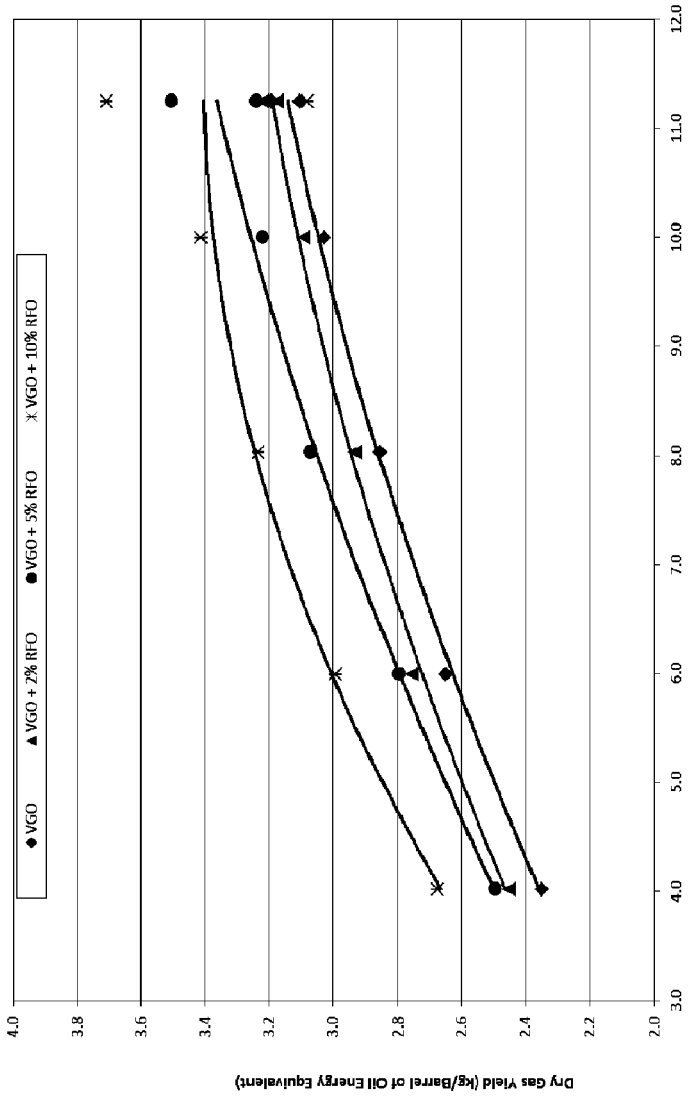

VGO
VGO + 2% RFO
VGO + 5% RFO
VGO + 10% RFO
Dry Gas Yield (kg/Barrel of Oil Energy Equivalent)
Cat:Oil Ratio
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0

FIGURE 12

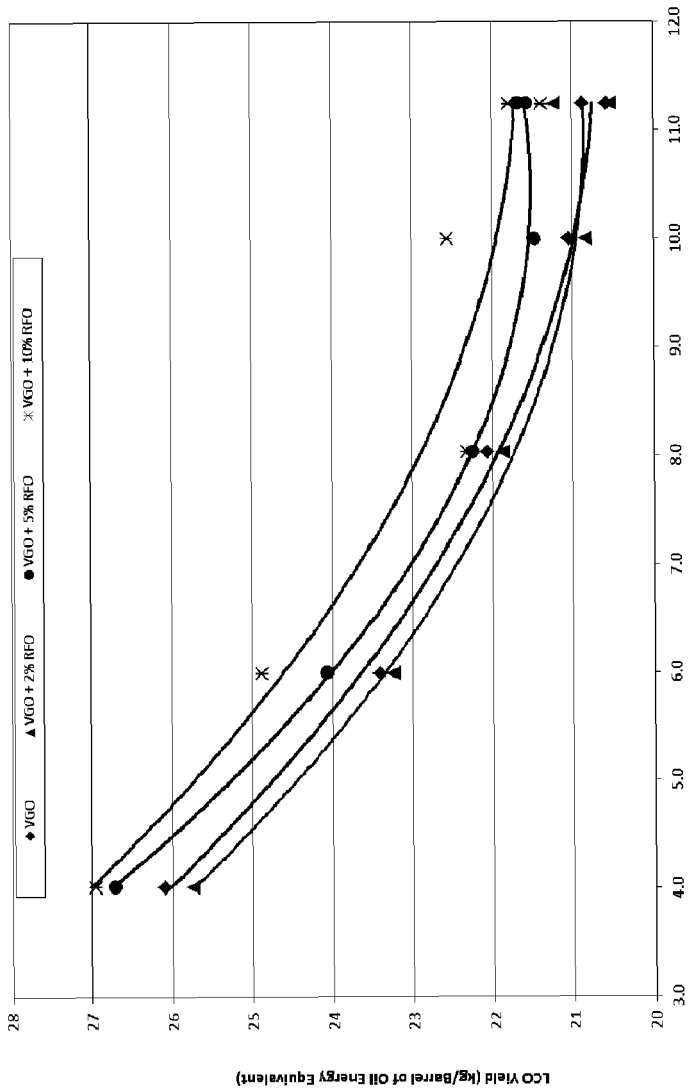

VGO
VGO + 2% RFO
VGO + 5% RFO
VGO + 10% RFO
Cat:Oil Ratio
LCO Yield (kg/Barrel of Oil Energy Equivalent)
28
27
26
25
24
23
22
21
20
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0

FIGURE 13

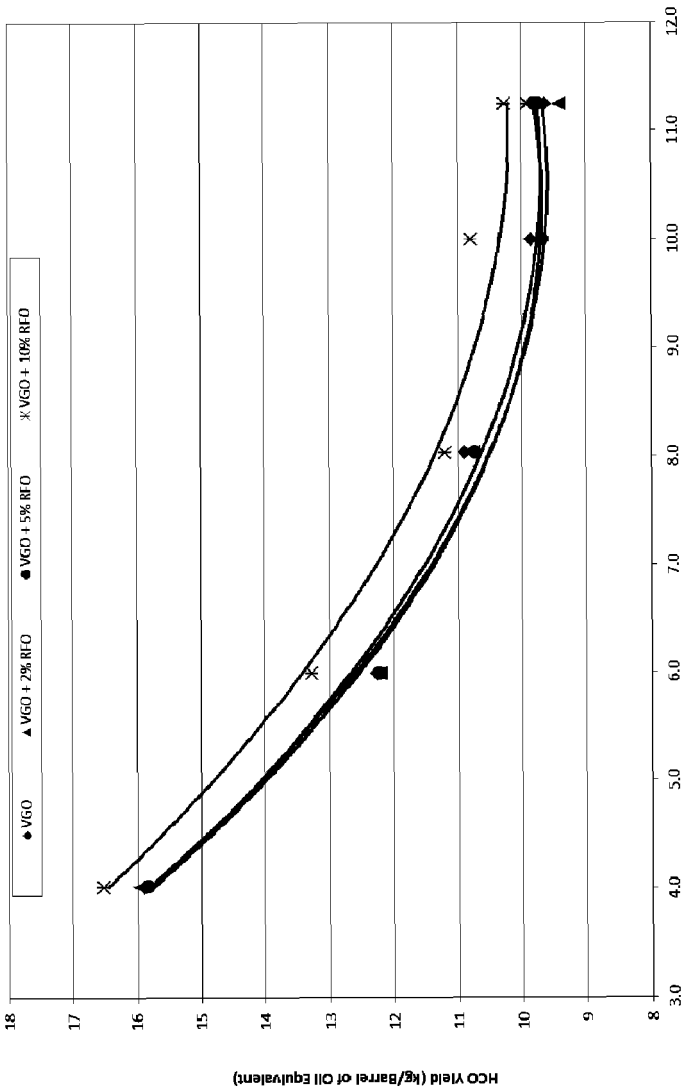

VGO
VGO + 2% RFO
VGO + 5% RFO
VGO + 10% RFO
Cat:Oil Ratio
HCO Yield (kg/Barrel of Oil Equivalent)
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
8
9
10
11
12
13
14
15
16
17
18

FIGURE 14

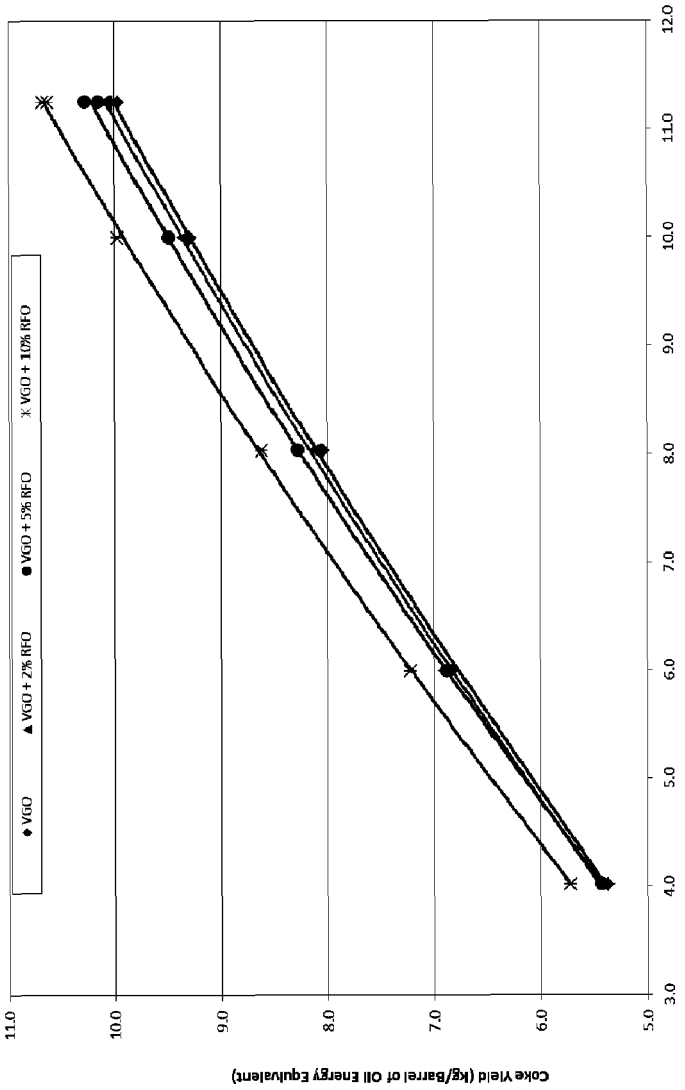

Coke Yield (kg/Barrel of Oil Energy Equivalent)
11.0
10.0
9.0
8.0
7.0
6.0
5.0
Cat:Oil Ratio
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
VGO
VGO + 2% RFO
VGO + 5% RFO
VGO + 10% RFO

FIGURE 15

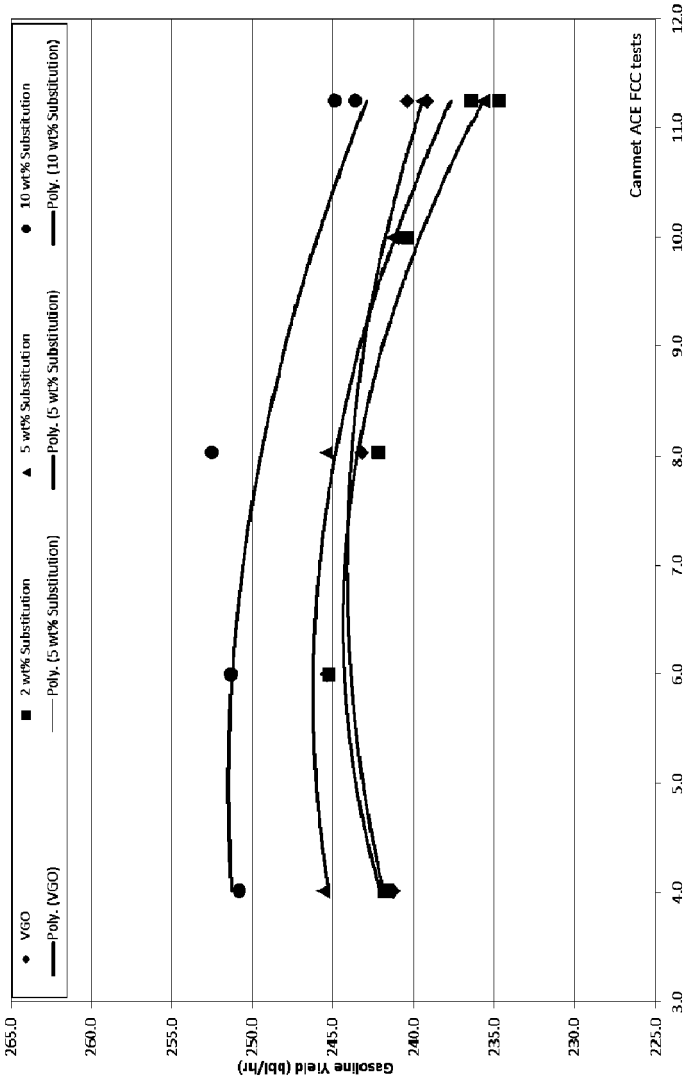

VGO
2 wt% Substitution
5 wt% Substitution
10 wt% Substitution
Poly. (VGO)
Poly. (5 wt% Substitution)
Poly. (5 wt% Substitution)
Poly. (10 wt% Substitution)
Gasoline Yield (bbl/hr)
265.0
260.0
255.0
250.0
245.0
240.0
235.0
230.0
225.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
Cat:Oil Ratio
Canmet ACE FCC tests

FIGURE 16

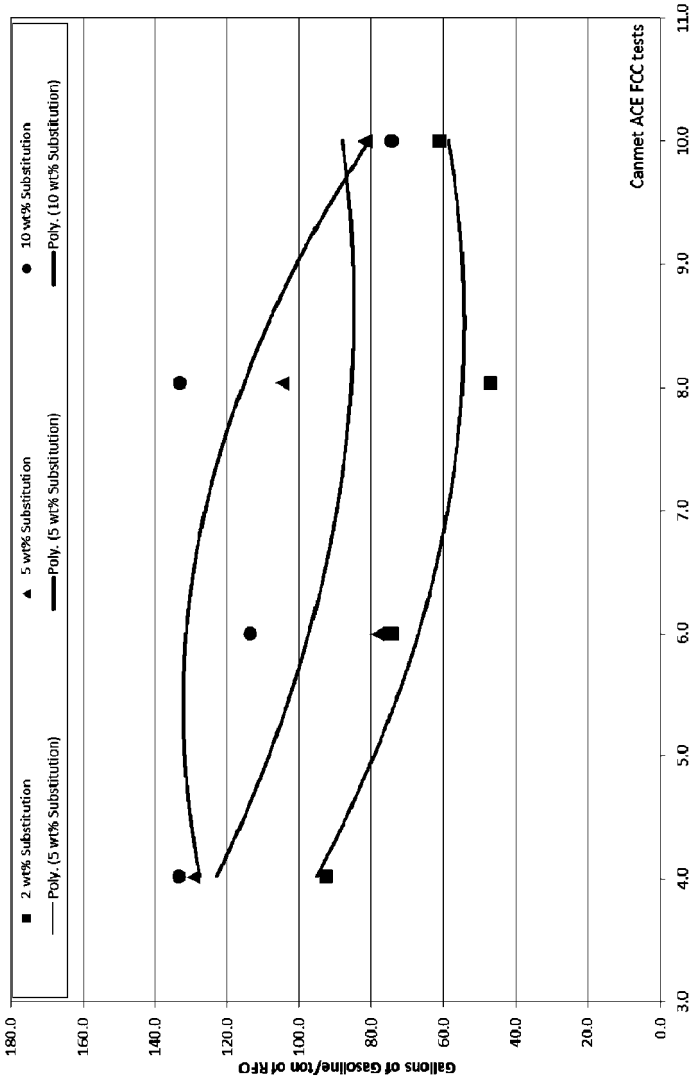

Canmet ACE FCC tests
Gallons of Gasoline/ton of RFO
Cat:Oil Ratio
2 wt% Substitution
5 wt% Substitution
10 wt% Substitution
Poly. (5 wt% Substitution)
Poly. (5 wt% Substitution)
Poly. (10 wt% Substitution)
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0

FIGURE 17

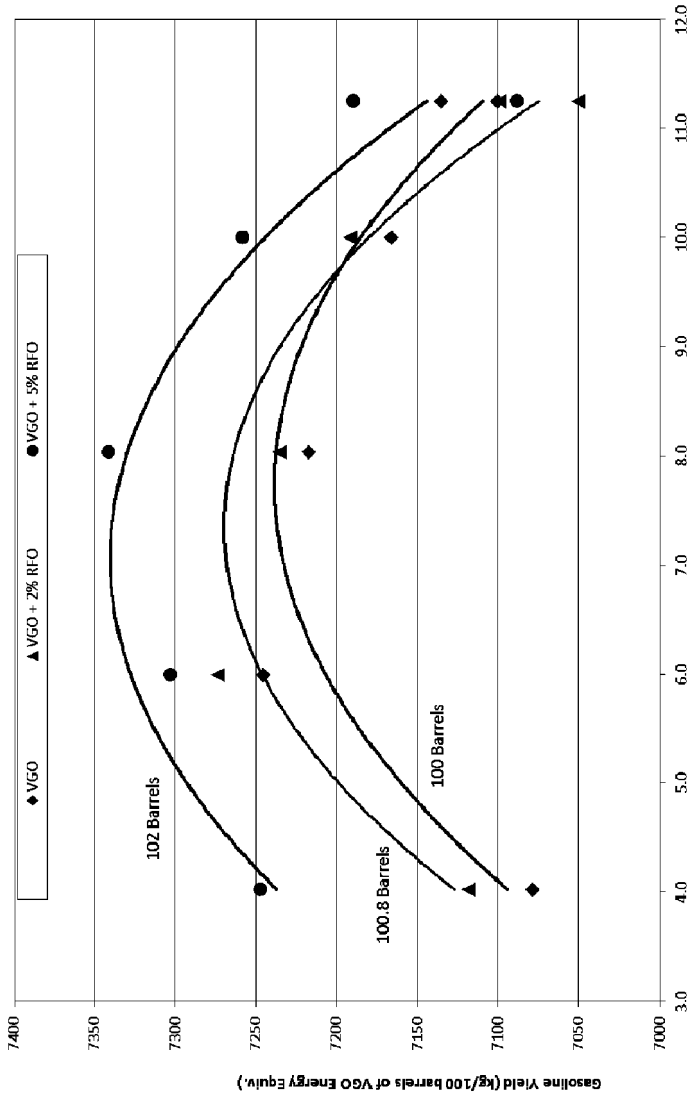

VGO
VGO + 2% RFO
VGO + 5% RFO
102 Barrels
100 Barrels
100.8 Barrels
Gasoline Yield (kg/100 barrels of VGO Energy Equiv.)
Cat:Oil Ratio
7400
7350
7300
7250
7200
7150
7100
7050
7000
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0

FIGURE 18

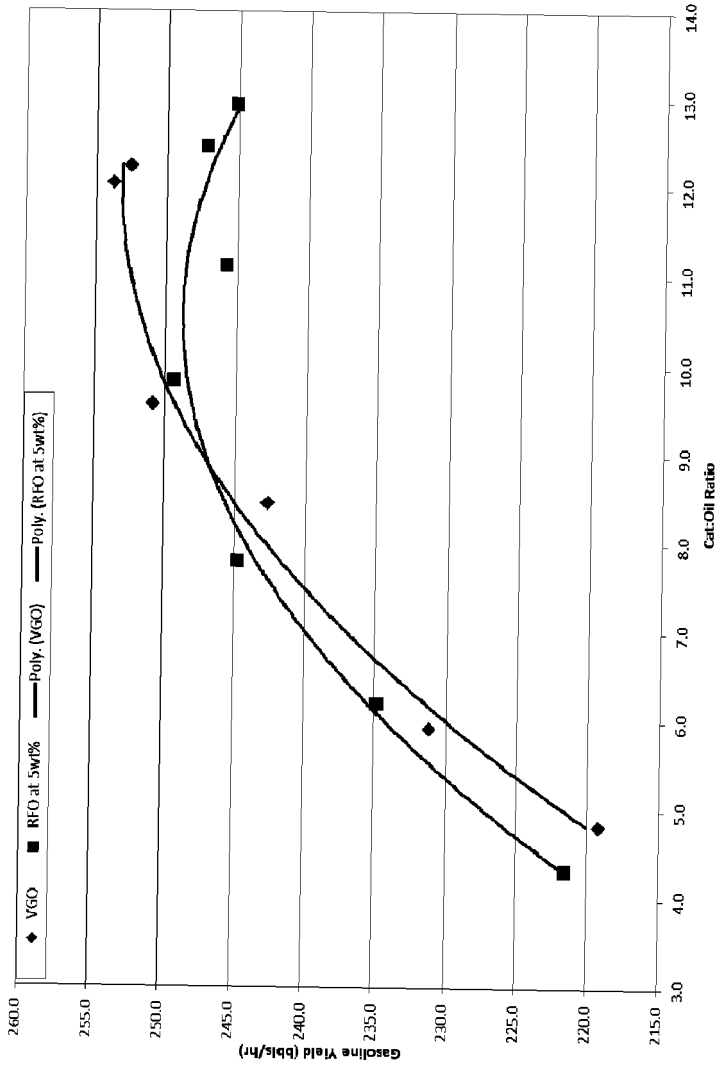

VGO
RFO at 5wt%
Poly. (VGO)
Poly. (RFO at 5wt%)
Gasoline Yield (bbls/hr)
260.0
255.0
250.0
245.0
240.0
235.0
230.0
225.0
220.0
215.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
Cat-Oil Ratio

FIGURE 19

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 5792340 A **[0010] [0036] [0081]**
- US 5961786 A **[0010] [0036] [0081]**
- US 2010222620 A **[0014]**
- US 2011224471 A **[0014]**
- US 7905990 B **[0036] [0081]**

Non-patent literature cited in the description

- **LAPPAS et al.** Biomass Pyrolysis in a Circulating Fluid Bed Reactor for the Production of Fuels and Chemicals. *Fuel,* 2002, vol. 81, 2087-2095 **[0010]**
- **SAMOLADA et al.** Catalyst Evaluation for Catalytic Biomass Pyroloysis. *Fuel & Energy,* 2000, vol. 14, 1161-1167 **[0010]**
- **ADJAYE et al.** Production of Hydrocarbons by Catalytic Upgrading of a Fast Pyrolysis Bio-oil. *Fuel Processing Technology,* 1995, vol. 45, 185-192 **[0011]**
- **ELLIOTT.** Historical Developments in Hydroprocessing Bio-oils. *Energy & Fuels,* 2007, vol. 21, 1792-1815 **[0012]**
- **DE MIGUEL MERCADER.** Pyrolysis Oil Upgrading for Co-Processing in Standard Refinery Units. Ph.D Thesis, University of Twente, 2010 **[0013]**
- **FOGASSY et al.** Biomass Derived Feedstock Co-Processing with VGO for Hybrid Fule Production in FCC Units. Institut de Recherches **[0013]**
- **CATALYSE.** *Environnement de Lyon, UMR5236 CNRS-UCBL* **[0013]**
- **GUTIERREZ et al.** Co-Processing of Upgraded Bio-Liquids in Standard Refinery Units - Fundamentals. *15th European Biomass Conference & Exhibition,* 07 May 2007 **[0013]**