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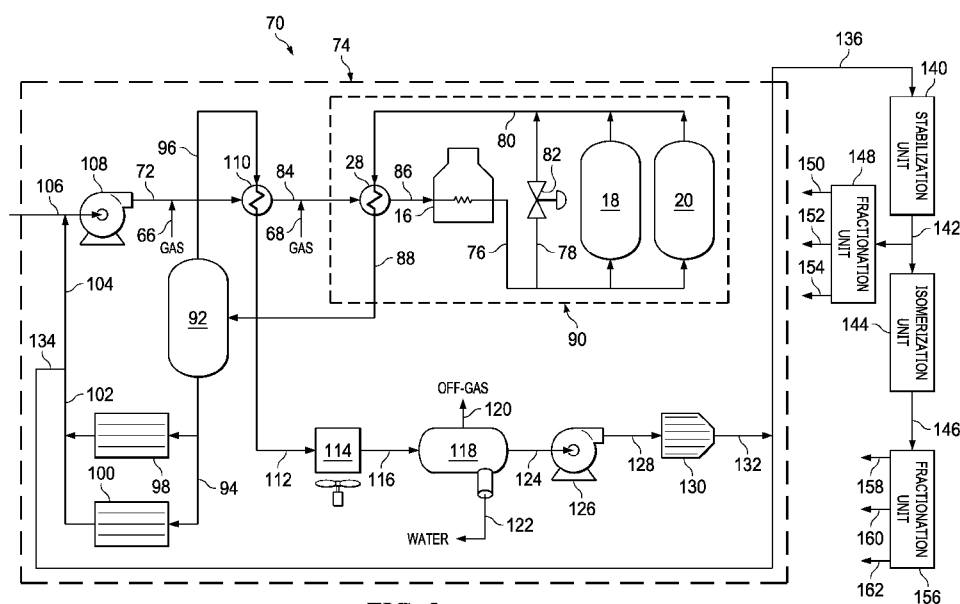


FIG. 2

(57) Abstract: A non-petroleum or renewable feedstock containing oxygen and contaminants of metals, gums, and resins is treated by introducing the feedstock into a reactor at a flow velocity of from 6 m/sec to 35 m/sec. The feedstock is heated within the reactor to a temperature of from 370 C to 595 C to remove and/or reduce the content of the contaminants to form a reactor product. The reactor product is cooled to form a cooled reactor product. Non-condensable gases, metals and water are separated and removed from the cooled reactor product to form a final product. The final product has an oxygen content that is 60% or less of that of the feedstock, and wherein the final product comprises 25 wt% or less any triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols, tocotrienols, or fatty alcohols, from 5 wt% to 30 wt% naphtha, and 50 wt% or more diesel.

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METHOD AND SYSTEM FOR TREATING RENEWABLE FEEDSTOCKS

BACKGROUND

5 [0001] Renewable diesel feedstocks, such as distillers corn oil, fancy bleachable tallow, used cooking oil, etc., which have not been pretreated, contain many components that are detrimental to hydroprocessing reactors or units for producing renewable diesel, as well as other products. These components cause serious plugging problems within the reactors used for forming renewable diesel. As a result, nearly all feedstocks must be pretreated prior to
10 processing into renewable diesel.

[0002] Conventional pretreatment processes for renewable diesel feedstocks typically require two stages of pretreatment. The first stage utilizes centrifuges to remove gums and resins by adding water and then centrifuging out the “hydratable” gums. This is followed by an acid wash and centrifugation to remove the “non-hydratable” gums. In the second stage,
15 “bleaching” is used to remove metals and color bodies by “filtering” through an adsorbent. The “spent” adsorbent must be regenerated or disposed in a land fill. In addition to the solid waste material that must be disposed, the process is both labor and capital intensive. Additionally, such pretreatment processes do not address the high oxygen content typically present in the feedstock.

20 [0003] Once the renewable diesel feedstocks are pretreated, the pretreated feedstock is hydrotreated in a renewable diesel unit. Renewable diesel units are typically built for severe operation, operating at high pressures (e.g., 900 psi or 6200 kPa or more) with a high heat release. This increases the construction costs of the renewable diesel plant, as plants configured for higher operating pressures cost more than those that operate at lower pressures.

25 Conventional renewable diesel units also have a high hydrogen demand. This is due to the high oxygen content (e.g., 10% or more) of conventional renewable diesel feedstocks. The hydrogen reacts with the oxygen of the renewable diesel feedstocks to form water. Water can be especially harmful to the hydroprocessing catalyst of the renewable diesel unit. Water can deactivate the catalyst as well as reduce hydrogen solubility, significantly reducing the overall
30 productivity of the unit.

[0004] Additionally, even with hydrotreating, a large amount of waxes or n-paraffins are contained in the hydrotreated product resulting in the hydrotreated product having a very high pour point (e.g., a pour point of 70 °F or 21 °C). A high pour point may make the renewable diesel unsuitable for use in colder climates. The hydrotreated product is therefore typically

isomerized to reduce the amount of n-paraffins to form iso-paraffins to lower the pour point of the renewable diesel product to the desired level.

[0005] In recent years, much emphasis has been placed on the greenhouse gases produced by burning particular fuels. This not only includes the amount of greenhouse gases that are produced by merely burning the fuels themselves, but also in the amount of greenhouse gases (GHG) that are produced in the fuels production and supply. This evaluation is often referred to as life-cycle assessment (LCA), which is the methodology for assessing the environmental impacts of commercial products or processes. Standards, such as the U.S EPA's revised National Renewable Fuel Standard (RFS2) and California's Low Carbon Fuel Standard (LCFS) have been implemented in an effort to lowering GHG emissions. These standards are expressed in terms of the carbon dioxide emission intensity or carbon intensity (CI) score or value of a particular fuel. The CI is measured in units of grams of CO₂ emissions (CO₂e) per megajoule of fuel (i.e., gCO₂e/MJ or g/MJ). As an example, conventional petroleum diesel may have a CI of 100 g/MJ or more. In contrast, renewable diesel may have a CI of around 20 g/MJ. While the CI value of conventional renewable diesel is much lower than for petroleum diesel, lowering the CI value even further is beneficial. Lowering the CI value of renewable diesel not only lowers the GHG emissions associated with the fuel, but a higher monetary value may also be placed on those fuels with lower CI scores, making their production more profitable.

[0006] Accordingly, improvements in treating renewable diesel feedstocks and in producing renewable diesel fuels are needed to overcome the current shortcomings encountered with respect to these materials and their processing.

BRIEF DESCRIPTION OF THE FIGURES

[0008] For a more complete understanding of particular embodiments of the invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying figures, in which:

5 [0009] FIG. 1 is a schematic flow diagram of a treatment system for treating a feedstock of animal-derived and/or plant-derived fats and/or oils; and

[0010] FIG. 2 is a schematic flow diagram of an alternate embodiment of a treatment system for treating a feedstock of animal-derived and/or plant-derived fats and/or oils.

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DETAILED DESCRIPTION

[0011] In the present invention, a treatment process for treating a feedstock of non-petroleum or renewable feedstocks derived from biological sources containing oxygen and contaminants of one or more of metals, gums, and resins is used to produce higher value products, such as renewable diesel fuel. The feedstocks are typically animal-derived and/or plant-derived fats and oils. Such fats and oils are primarily composed of triglycerides, along with minor amounts of mono- and diglycerides, free fatty acids, phosphatides, sterols, tocopherols and tocotrienols, and fatty alcohols. These fats and oils can be used for renewable diesel feedstocks as well as feedstocks for other products. Sources of such feedstocks may include, but are not limited to, distillers corn oil, fancy bleachable tallow, used cooking oil, animal fat, plant-derived oils, etc. The feedstocks may also include pyrolysis oils, such as those derived from cellulosic materials, which typically have a very high oxygen content, as well as other oils having a high metal and/or oxygen content.

[0012] In certain embodiments, the non-petroleum or renewable feedstocks may have at least one or more of triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols and tocotrienols, and fatty alcohols in an amount of 50 wt%, 55 wt%, 60 wt%, 65 wt%, 70wt%, 80 wt%, 85 wt%, 90 wt%, and 95 wt% or more by total weight of the feedstock. These are all oxygen-containing compounds that may be found in animal-derived and/or plant-derived fats and oils. Most of the feedstock will be triglycerides, which may be as high as 95 wt% or more by total weight of the feedstock. In certain embodiments, the total triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols and tocotrienols, and fatty alcohols may be present in the feedstock from at least, equal to, and/or between any two of 50 wt%, 51 wt%, 52 wt%, 53 wt%, 54 wt%, 55 wt%, 56 wt%, 57 wt%, 58 wt%, 59 wt%, 60 wt%, 61 wt%, 62 wt%, 63 wt%, 64 wt%, 65 wt%, 66 wt%, 67 wt%, 68 wt%, 69 wt%, 70 wt%, 71 wt%, 72 wt%, 73 wt%, 74 wt%, 75 wt%, 76 wt%, 77 wt%, 78 wt%, 79 wt%, 80 wt%, 81 wt%, 82 wt%, 83 wt%, 84 wt%, 85 wt%, 86 wt%, 87 wt%, 88 wt%, 89 wt%, 90 wt%, 92 wt%, 93 wt%, 94 wt%, 95 wt%, 96 wt%, 97 wt%, 98 wt%, and 99 wt% by total weight of the feedstock.

[0013] It should be noted in the description, if a numerical value, concentration or range is presented, each numerical value should be read once as modified by the term "about" (unless already expressly so modified), and then read again as not so modified unless otherwise indicated in context. Also, in the description, it should be understood that an amount range listed or described as being useful, suitable, or the like, is intended that any and every value within the range, including the end points, is to be considered as having been stated. For

example, “a range of from 1 to 10” is to be read as indicating each and every possible number along the continuum between about 1 and about 10. Thus, even if specific points within the range, or even no point within the range, are explicitly identified or referred to, it is to be understood that the inventors appreciate and understand that any and all points within the range
5 are to be considered to have been specified, and that inventors possess the entire range and all points within the range.

[0014] Compared to petroleum, these non-petroleum or renewable feedstocks typically have a high oxygen content. In many instances, the oxygen content of the feedstock can be from 8 wt% or more by total weight of the feedstock. In certain embodiments, the oxygen content
10 may be present in the feedstock in an amount from at least, equal to, and/or between any two of 8 wt%, 9 wt%, 10 wt%, 11 wt%, 12 wt%, 13 wt%, 14 wt%, 15 wt%, 16 wt%, 17 wt%, 18 wt%, 19 wt%, 20 wt%, 21 wt%, 22 wt%, 23 wt%, 24 wt%, 25 wt%, 26 wt%, 27 wt%, 28 wt%, 29 wt%, 30 wt%, 31 wt%, 32 wt%, 33 wt%, 34 wt%, 35 wt%, 36 wt%, 37 wt%, 38 wt%, 39 wt%, and 40 wt%, 41 wt%, 42 wt%, 43 wt%, 44 wt%, 45 wt%, 46 wt%, 47 wt%, 48 wt%, 49
15 wt%, and 50 wt% by total weight of the feedstock. As discussed earlier, during hydroprocessing or hydrotreating, the oxygen of the feedstocks reacts with hydrogen to form water. This water can be detrimental to the renewable diesel or hydroprocessing reactors and catalysts, as well as reduce hydrogen solubility.

[0015] The non-petroleum or renewable feedstocks may also contain undesirable materials or “contaminants,” such as metals, gums and resins, which may cause serious plugging or other
20 problems within the reactors or processing equipment. These materials may be naturally occurring in the initially formed fats and oils or may be formed or added during their later use or processing and prior to their use as a renewable feedstock.

[0016] The metals may include, but are not limited to, phosphorus (P), sodium (Na), potassium (K), copper (Cu), iron (Fe), calcium (Ca) and magnesium (Mg), lead (Pb), cadmium (Cd), nickel (Ni), vanadium (V), manganese (Mn), zinc (Zn), etc. Such metals may be present in the feedstock in an amount of from a few parts (e.g., 0.1 ppm) per million by weight (ppm) of feedstock to several thousand ppm (e.g., 5,000 ppm or more) by total weight of feedstock. In certain embodiments, the total metal contaminants may be present in the feedstock in an
25 amount from at least, equal to, and/or between any two of 0.1 ppm, 0.5 ppm, 1 ppm, 2 ppm, 3 ppm, 4 ppm, 5 ppm, 6 ppm, 7 ppm, 8 ppm, 9 ppm, 10 ppm, 15 ppm, 20 ppm, 30 ppm, 40 ppm, 50 ppm, 60 ppm, 70 ppm, 80 ppm, 90 ppm, 100 ppm, 150 ppm, 200 ppm, 250 ppm, 300 ppm, 350 ppm, 400 ppm, 450 ppm, 500 ppm, 550 ppm, 600 ppm, 650 ppm, 700 ppm, 750 ppm, 800 ppm, 850 ppm, 900 ppm, 950 ppm, 1000 ppm, 1050 ppm, 1100 ppm, 1150 ppm, 1200 ppm,
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1200 ppm, 1250 ppm, 1300 ppm, 1350 ppm, 1400 ppm, 1450 ppm, 1500 ppm, 1550 ppm, 1600 ppm, 1650 ppm, 1700 ppm, 1750 ppm, 1800 ppm, 1850 ppm, 1900 ppm, 1950 ppm, 2000 ppm, 2050 ppm, 2100 ppm, 2150 ppm, 2200 ppm, 2200 ppm, 2250 ppm, 2300 ppm, 2350 ppm, 2400 ppm, 2450 ppm, 2500 ppm, 2550 ppm, 2600 ppm, 2650 ppm, 2700 ppm, 2750 ppm, 2800 ppm, 2850 ppm, 2900 ppm, 2950 ppm, 3000 ppm, 3050 ppm, 3100 ppm, 3150 ppm, 3200 ppm, 3200 ppm, 3250 ppm, 3300 ppm, 3350 ppm, 3400 ppm, 3450 ppm, 3500 ppm, 3550 ppm, 3600 ppm, 3650 ppm, 3700 ppm, 3750 ppm, 3800 ppm, 3850 ppm, 3900 ppm, 3950 ppm, 4000 ppm 4050 ppm, 4100 ppm, 4150 ppm, 4200 ppm, 4200 ppm, 4250 ppm, 4300 ppm, 4350 ppm, 4400 ppm, 4450 ppm, 4500 ppm, 4550 ppm, 4600 ppm, 4650 ppm, 4700 ppm, 4750 ppm, 4800 ppm, 4850 ppm, 4900 ppm, 4950 ppm, and 5000 ppm by total weight of the feedstock.

[0017] Gums and resins, as wells as carbohydrates and proteins, may make up a few percent by weight of the feedstock (e.g., from 1 wt% to 10 wt%). These undesirable components can cause serious plugging and other detrimental problems within the reactors and processing equipment if not removed or converted prior to processing. In certain embodiments, the total gums and resins may be present in the feedstock in an amount from at least, equal to, and/or between any two of 1.0 wt%, 1.1 wt%, 1.2 wt%, 1.3 wt%, 1.4 wt%, 1.5 wt%, 1.6 wt%, 1.7 wt%, 1.8 wt%, 1.9 wt%, 2.0 wt%, 2.1 wt%, 2.2 wt%, 2.3 wt%, 2.4 wt%, 2.5 wt%, 2.6 wt%, 2.7 wt%, 2.8 wt%, 2.9 wt%, 3.0 wt%, 3.1 wt%, 3.2 wt%, 3.3 wt%, 3.4 wt%, 3.5 wt%, 3.6 wt%, 3.7 wt%, 3.8 wt%, 3.9 wt%, and 4.0 wt%, 4.1 wt%, 4.2 wt%, 4.3 wt%, 4.4 wt%, 4.5 wt%, 4.6 wt%, 4.7 wt%, 4.8 wt%, 4.9 wt%, 5.0 wt%, 5.1 wt%, 5.2 wt%, 5.3 wt%, 5.4 wt%, 5.5 wt%, 5.6 wt%, 5.7 wt%, 5.8 wt%, 5.9 wt%, 6.0 wt%, 6.1 wt%, 6.2 wt%, 6.3 wt%, 6.4 wt%, 6.5 wt%, 6.6 wt%, 6.7 wt%, 6.8 wt%, 6.9 wt%, 7.0 wt%, 7.1 wt%, 7.2 wt%, 7.3 wt%, 7.4 wt%, 7.5 wt%, 7.6 wt%, 7.7 wt%, 7.8 wt%, 7.9 wt%, 8.0 wt%, 8.1 wt%, 8.2 wt%, 8.3 wt%, 8.4 wt%, 8.5 wt%, 8.6 wt%, 8.7 wt%, 8.8 wt%, 8.9 wt%, 9.0 wt%, 9.1 wt%, 9.2 wt%, 9.3 wt%, 9.4 wt%, 9.5 wt%, 9.6 wt%, 9.7 wt%, 9.8 wt%, 9.9 wt%, and 10.0 wt% by total weight of the feedstock.

[0018] Referring to FIG. 1, a system 10 for forming products from a fresh or initial non-petroleum or renewable feedstock 12, which may be animal-derived and/or plant-derived fats and/or oils containing oxygen and contaminants of one or more of metals, gums, and resins, is shown. The system 10 includes a treatment system 14 for removing oxygen and undesirable materials including metals, gums, and resins from the feedstock 12 before any hydroprocessing or hydrotreating, such as in a renewable diesel unit.

[0019] The feedstock 12 is ultimately heated to a temperature of from 390 °C to 600 °C in an externally heated tubular reactor 16. The reactor 16 is catalyst free or does not contain or utilize a hydroprocessing catalyst. In certain embodiments, a useful operating or treatment

temperature range for the reactor 16 may be from at least, equal to, and/or between any two of 390 °C, 395 °C, 400 °C, 405 °C, 410 °C, 415 °C, 420 °C, 425 °C, 430 °C, 435 °C, 440 °C, 445 °C, 450 °C, 455 °C, 460 °C, 465 °C, 470 °C, 475 °C, 480 °C, 485 °C, 490 °C, 495 °C, 500 °C, 505 °C, 510 °C, 515 °C, 520 °C, 525 °C, 530 °C, 535 °C, 540 °C, 545 °C, 550 °C, 555 °C, 560 °C, 565 °C, 570 °C, 575 °C, 580 °C, 585 °C, 590 °C, 595 °C, and 600 °C. In the discussion that follows, a temperature of 510 °C for the heating of the feedstock within the reactor 16 may be used for illustrative purposes. The reactor 16 can be a fired heater, electrically heated, steam heated, hot gases, oil heated, etc. The heating can also be that provided as waste heat from other processes.

[0020] In some embodiments, one or more optional secondary reactors 18, 20 may be provided with the treatment system 14 that are located downstream and receive the reactor discharge stream 22 from reactor 16, which may be considered a primary reactor. These secondary reactors 18, 20 may be configured in parallel or series and may be heated or fired reactors, as well, for continued heating of the discharge stream 22 to maintain the elevated reaction temperatures. In other embodiments, the reactors 18, 20 are non-heated, with the reactors 18, 20 merely serving as vessels for increased residence time before cooling, where the reactions can continue to occur from the heated discharge stream 22 from reactor 16. The reactors 16, 18, 20 and their inlets are configured in combination with the fluid flow of the feeds to provide tubular or plug flow through the reactors to eliminate or reduce backflow and back mixing. The primary reactor 16 and secondary reactors 18, 20 may be sized and configured to provide a selected residence time for the introduced feedstock at the selected reactor temperature to ensure that the feedstock is sufficiently reacted before being discharged from the reactors. The residence time within the reactor section of the system 14 is typically on the order of only a few seconds (e.g., 5 seconds or less).

[0021] Pressures within the reactors 16, 18, 20 will typically range from 0 kPag to 7000 kPag. In particular applications, the operating pressure of the reactor(s) may be from at least, equal to, and/or between any two of 0 kPag, 50 kPag, 100 kPag, 150 kPag, 200 kPag, 250 kPag, 300 kPag, 350 kPag, 400 kPag, 450 kPag, 500 kPag, 550 kPag, 600 kPag, 650 kPag, 700 kPag, 750 kPag, 760 kPag, 800 kPag, 850 kPag, 900 kPag, 950 kPag, 1000 kPag, 1100 kPag, 1150 kPag, 1200 kPag, 1250 kPag, 1300 kPag, 1350 kPag, 1400 kPag, 1450 kPag, 1500 kPag, 1550 kPag, 1600 kPag, 1650 kPag, 1700 kPag, 1750 kPag, 1760 kPag, 1800 kPag, 1850 kPag, 1900 kPag, 1950 kPag, 2000 kPag, 2100 kPag, 2150 kPag, 2200 kPag, 2250 kPag, 2300 kPag, 2350 kPag, 2400 kPag, 2450 kPag, 2500 kPag, 2550 kPag, 2600 kPag, 2650 kPag, 2700 kPag, 2750 kPag, 2760 kPag, 2800 kPag, 2850 kPag, 2900 kPag, 2950 kPag, 3000 kPag, 3100 kPag, 3150 kPag,

3300 kPag, 3350 kPag, 3300 kPag, 3350 kPag, 3400 kPag, 3450 kPag, 3500 kPag, 3550 kPag, 3600 kPag, 3650 kPag, 3700 kPag, 3750 kPag, 3760 kPag, 3800 kPag, 3850 kPag, 3900 kPag, 3950 kPag, 4000 kPag, 4100 kPag, 4150 kPag, 4200 kPag, 4250 kPag, 4300 kPag, 4350 kPag, 4400 kPag, 4450 kPag, 4500 kPag, 4550 kPag, 4600 kPag, 4650 kPag, 4700 kPag, 4750 kPag, 4760 kPag, 4800 kPag, 4850 kPag, 4900 kPag, 4950 kPag, 5000 kPag, 5100 kPag, 5150 kPag, 5200 kPag, 5250 kPag, 5300 kPag, 5350 kPag, 5400 kPag, 5450 kPag, 5500 kPag, 5550 kPag, 5600 kPag, 5650 kPag, 5700 kPag, 5750 kPag, 5760 kPag, 5800 kPag, 5850 kPag, 5900 kPag, 5950 kPag, 6000 kPag, 6100 kPag, 6150 kPag, 6200 kPag, 6250 kPag, 6300 kPag, 6350 kPag, 6400 kPag, 6450 kPag, 6500 kPag, 6550 kPag, 6600 kPag, 6650 kPag, 6700 kPag, 6750 kPag, 6760 kPag, 6800 kPag, 6850 kPag, 6900 kPag, 6950 kPag, and 7000 kPag.

[0022] Reactions within the reactor 16 and reactors 18, 20 occur very fast at the above temperatures, without significant yield loss. All or a majority of the gums and resins react in a thermal cracking reaction within the reactor 16 to form smaller, lower molecular weight components, such as non-condensable gases, naphtha, jet fuel and diesel compounds, which can removed as off-gases or passed through a renewable diesel hydrotreater or other hydroprocessing equipment to make useful products without causing fouling problems. In particular embodiments, the gum and resin content of the initial feedstock can be reduced to from 10% to 100% by weight of the initial gum and resin content of the feedstock 12. In certain embodiments, the gum and resin content of the feedstock 12 can be reduced by an amount of at least, equal to, and/or between any two of 10%, 11%, 12%, 13%, 14%, 15%, 16%, 17%, 18%, 19%, 20%, 21%, 22%, 23%, 24%, 25%, 26%, 27%, 28%, 29%, 30%, 31%, 32%, 33%, 34%, 35%, 36%, 37%, 38%, 39%, 40%, 41%, 42%, 43%, 44%, 45%, 46%, 47%, 48%, 49%, 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, and 100% by weight of the initial gum and resin content.

[0023] In addition, oxygen-containing compounds in the feedstock (e.g., triglycerides, mono- and diglycerides, free fatty acids, etc.) can also react to form water, CO₂, CO, and other small, oxygenated compounds. Oxygen present in the feedstock delivered to a renewable diesel unit or other hydroprocessing unit will react with hydrogen to form water. The removal of oxygen in the treatment system 14 prior to such hydroprocessing therefore lowers the hydrogen requirement in the renewable diesel unit or other processing unit downstream. From 10% to 100% of oxygen in the initial feedstock can be removed in the treatment. As an example, at a reaction temperature of 510 °C, from 40% to 60% of oxygen can be removed from the

feedstock very rapidly. All of the oxygen can be removed at higher temperatures and/or longer reaction times. The triglycerides and mono- and diglycerides of the feedstock 12 also react or “break apart” to form free fatty acids, paraffins, olefins, and other various compounds.

[0024] The high-temperature reactor product 24 from the primary tubular reactor 16, and any secondary reactors 18, 20, is cooled to form a cooled reactor product. In certain applications, heat from the high-temperature reactor product 24 is recovered and may be used in heating the feed 26 in a first stage cross-heat exchanger. In the first stage of cross-heat exchange, the feed 26 is used to cool the hot reactor product 24 from reactor 16 and any reactors 18, 20 in heat exchanger 28. The temperature of the hot reactor product 24 will typically be from 400 °C to 595 °C and will typically be at a temperature that is from 25 °C to 300 °C above that of the feed 26. This typically results in the feed 26 introduced into reactor 16 being heated (ΔT) from 12.5 °C to 300 °C and the heated product 24 being cooled or dropped in temperature (ΔT) from 12.5 °C to 300 °C. The feed 26 may initially be at a temperature of from 90 °C to 320 °C prior to entering the heat exchanger 28. The heated feedstock 30 discharged from exchanger 28 and introduced into the reactor 16 is typically at a temperature of from 370 °C to 540 °C. Moreover, the reduced-temperature reactor product 32 discharged from the heat exchanger 28 may be at a temperature of from 120 °C to 540 °C. As an example, where the hot reactor product 24 is at 510 °C and the feed 26 is at 345 °C, the feed 26 may be heated to approximately 480 °C to form heated feed 30 and the product 24 cooled to a temperature of about 370 °C to form reduced-temperature reactor product 32.

[0025] At temperatures where the heated feed 30 is heated at or above 370 °C, reactions of the feed 26 begin in the heat exchanger 28 so that it may be considered part of an overall reactor system 34 for treatment of the feedstock. In other embodiments where the feed 30 is not heated at or above 370 °C, only the primary reactor 16 and any secondary reactors 18, 20 may be considered part of the overall reactor system 34.

[0026] In certain embodiments, a second cross-heat exchanger 36 may be provided for further cooling the reduced-temperature reactor product 32 from the heat exchanger 28 at a ΔT of from 12.5 °C to 300 °C. The heat exchanger 36 may use all or portion of the fresh feedstock 12 to further cool the product 32 to a temperature of from 20 °C to 95 °C. This typically results in the initial or fresh feed 12 being heated (ΔT) from 12.5 °C to 300 °C. The temperature of the initial feedstock 12 may vary but can be from room (e.g., 20 °C to 23 °C) or ambient atmospheric temperature (e.g., -18 °C to 38 °C) to 70 °C in some embodiments, which may be heated in the heat exchanger 36 to a temperature of from 90 °C to 345 °C. Where the feedstock 12 contains oils or fats that are solid at room temperature, the fresh feedstock 12 may need to

be pre-heated above room or ambient temperature so that the oils and fats are in a flowable liquid form. In the example where the reduced-temperature reactor product 32 is at 370 °C, the product 32 is cooled further to provide a cooled reactor product 38 having a temperature of about 90 °C to 95 °C, with the initial feed 12 being heated to 345 °C to form the feed 26. At
5 temperatures where the fresh feed 12 is heated at or above 370 °C in heat exchanger 36, reactions of the fresh feed 12 begin in the heat exchanger 36 so that it may be considered part of an overall reactor system 34 for treatment of the feedstock.

[0027] In some instances, further cooling of the cooled reactor product 38 may be carried out in a further heat exchanger 40 that does not utilize the feedstock 12 as a cooling fluid. The heat
10 exchanger 40 may be used in lieu of or in addition to the heat exchanger 36. The final cooled reactor product 42 will typically be at a temperature of from 35 °C to 95 °C.

[0028] The final cooled reactor product 42 is then introduced into one or more separators 44. Non-condensable off-gases 46, such as CO₂, CO and light hydrocarbons (i.e., C₁ to C₅ hydrocarbons), that are produced in the reactor system 34 are separated from the cooled reactor
15 product 42. In one example, at a reaction temperature of 510 °C, the non-condensable gases may be from 75% to 80% CO₂ and some CO, from 1% to 2% methane, from 6% to 8% ethane, from 4% to 6% propane, from 4% to 5% butane, and from 4% to 5% pentane. Carbon dioxide and CO produced in the reaction may reduce the final liquid hydrocarbon product yield. The oxygen lost to these compounds, however, results in lower hydrogen consumption if the
20 product is further hydroprocessed, because it is no longer available to react with the hydrogen to end up as water.

[0029] Liquid water 48 is also separated from the liquid hydrocarbon or oil phase of reactor product 42. Metals that have been stripped from the reactor walls of reactor 16 and reactors
25 18, 20 that are carried in the cooled reactor product 42 are predominantly distributed in the water phase 48 and thus most of the metals are removed with the water 48. Some metals may also be present with the coke formed in the reactors that is carried in the reactor product. The remaining liquid hydrocarbons 50 from separator 44 may then be introduced into a further stripping unit 52 where stripping gases 53 are used to remove additional light off-gases 54 that are separated from the liquid hydrocarbons 56. The non-condensable or off-gas composition,
30 and quantity, is dependent on reaction temperature. Also, the amount of off gas depends on the temperature and pressure of the separator. Higher pressure and lower temperatures in the separators 44, 52 results in less off gas due to the gases remaining in the liquid.

[0030] The separated liquid hydrocarbons 56 are introduced into and pressurized in pump 58. The pressurized liquid hydrocarbons 60 are then filtered in filtering unit 62, such as a cartridge

filter or sand filter, to remove coke and any remaining metals and other solids to form the final treated product 64.

[0031] At the high reaction temperatures, coke formed during the reaction and metals present in the initial feedstock 12 may tend to be deposited on the walls of the reactor 16 and reactors 18, 20. To keep the reactors 16, 18, 20 from coking and plugging from such materials, a high velocity is maintained in the reactor system 34 through a combination of pipe sizing, to keep the velocity high, and the addition of a high velocity oxygen-gas-free gas (i.e., no O₂), such as one or more of steam, nitrogen, CO₂, hydrogen, etc., to increase the velocity even more. In most instances, the gas will be steam or nitrogen. In particular embodiments, the gas is added with the feedstock to provide a flow velocity of the feedstock within the reactors 16, 18, 20 or reactor tubes of from 6 m/sec to 35 m/sec, more particularly from 9 m/sec to 22 m/sec, and still more particularly from 6 m/sec to 16 m/sec. The high velocity gas may be added to the feed stream 12 and/or 26, as shown at 66 and 68. If added to the heated feed stream 26, the gas may be heated to a temperature around (e.g., ≤ 30 °C of the feed temperature) or above the temperature of the feed 26 to prevent a significant drop in temperature of the feed 26. In other embodiments, the high velocity gas 66 and/or 68 is not preheated.

[0032] This high velocity of the heated feed 30 from heat exchanger 28 that is introduced into reactors 16, 18, 20 results in the walls of the reactors being kept clean due to the erosion of any deposited coke and metals from the walls due to the high velocity fluid flow. The coke and metals thus do not adhere to the reactor walls and are removed and carried in the reactor product streams. The coke and metals carried in the reactor product streams are eventually removed in the water phase 48 and/or through filtration unit 62, as discussed previously.

[0033] From 50 % to 99% or more up to 100% by weight of metals in the fresh or original feedstock can be removed utilizing the disclosed treatment system and method. More particularly, from 90% to 99% or more by weight of metals in the feedstock can be removed utilizing the disclosed process. In certain embodiments, the metal content of the initial feedstock 12 can be reduced by an amount of at least, equal to, and/or between any two of 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, and 100% by weight of the initial metal content.

[0034] Referring to FIG. 2, another treatment system 70 for forming products from a fresh or initial non-petroleum or renewable feedstock, which may be the same or similar to the feedstock 12. This may include animal-derived and/or plant-derived fats and/or oils containing

oxygen and contaminants of one or more of metals, gums, and resins, is shown. The system 70 is similar to the system 10 of FIG. 1, with similar components labeled with the same reference numerals. The system 70 includes a treatment system 74 for removing oxygen and undesirable materials including metals, gums, and resins from a feedstock 72 before any hydroprocessing or hydrotreating, such as in a renewable diesel unit. The system 70 differs from the system 10 in that it utilizes a recycle stream, which may allow better control of the process, as well as facilitate higher removal of oxygen.

[0035] In the treatment system 74, the feedstock 72 is ultimately heated to a temperature of from 400 °C to 595 °C, or similar temperatures to those described previously for the system 10, in the externally heated tubular reactor 16. The reactor pressures may also be the same. The reactor 16 of FIG. 2 is also catalyst free or does not contain or utilize a hydroprocessing catalyst.

[0036] One or more secondary reactors 18, 20, which may be the same or similar to those of FIG. 1, may also be provided with the treatment system 74 that are located downstream and receive all or a portion of the reactor discharge stream 76 from reactor 16. In the treatment system 74 of FIG. 2, a bypass line 78 is provided for bypassing the secondary reactors 18, 20 and directing all or a portion of the reactor discharge stream 76 to reactor product stream 80. A control valve 82 allows selective control of flow of the reactor product through bypass line 76 so that the amount of product through line 76 can be varied, wherein only a portion (e.g., from 10% to 90%) of the product discharge 76 is directed through bypass line 78, with the remaining reactor product discharge 76 being directed through lines 84, 86 to reactors 18, 20. In some embodiments, the valve 82 may remain closed during operation so that all of the discharge product stream 22 is directed through lines 84, 86 to the secondary reactors 18, 20, respectively. In other instances, all of the product stream 22 may be directed through bypass line 78, with none being delivered to the reactors 18, 20. Although not shown, a similar bypass line may be used with the system 10 of FIG. 1.

[0037] In certain applications, heat from the high-temperature reactor product 80 is also recovered and may be used in heating the feed 84 in a first stage cross-heat exchanger. In the first stage of cross-heat exchange, the feed 84 is used to cool the hot reactor product 80 from reactor 16 and any secondary reactors 18, 20 in heat exchanger 28. The temperature of the hot reactor product 24 will typically be from 400 °C to 595 °C and will typically be at a temperature that is from 12.5 °C to 300 °C above that of the feed 84. The heated feedstock 86 discharged from exchanger 28 and introduced into the reactor 16 is typically at a temperature of from 370 °C to 540 °C.

[0038] As with the treatment system 14 of FIG. 1, at temperatures where the heated feed 86 is heated at or above 370 °C, reactions of the feed 84 begin in the heat exchanger 28 so that it may be considered part of an overall reactor system 90 for treatment of the feedstock. In other embodiments where the feed 84 is not heated at or above 370 °C, only the primary reactor 16
5 and any secondary reactors 18, 20 may be considered part of the overall reactor system 90.

[0039] Moreover, the reduced-temperature reactor product 88 discharged from the heat exchanger 28 may be at a temperature of from 150 °C to 320 °C, where some, but not all, of the reactor product is condensed. The reduced temperature product 88 is typically at temperatures and conditions where water remains in a vapor or superheated state. The reduced-
10 temperature reactor product 88 is then introduced into a first “hot” separator where condensed liquid hydrocarbons from product stream 88 are separated as hot liquid stream 94 from other gases, such as lower boiling point hydrocarbons, steam, and other gases, such as CO, CO₂, etc., which are discharged as “hot” gas stream 96.

[0040] The separated liquid stream 94 is passed through one or more filter units 98, 100, which
15 may be the same or similar to the filter unit 62 of FIG. 1. The filter units 98, 100 may be configured in series or parallel. The filter units 98, 100 are used to filter out coke and any entrained metals and other solids present in the liquids of stream 94 to form filtered liquid stream 102.

[0041] A portion (e.g., from 10% to 90%) of the filtered liquid stream 102, is used to form
20 recycle stream 104. The recycle stream 104 is combined with a fresh or initial non-petroleum or renewable feedstock 106, which may be the same or similar to the feedstock 12, previously described. The combined fresh feedstock 106 and recycle stream 104 are delivered to pumping unit 108 where they form feedstock 72, which is a combined feedstock of fresh feedstock and recycled product. Because the recycle stream 104 is at an elevated temperature, this also
25 facilitates heating of the fresh feedstock 106.

[0042] If necessary, the combined feedstock 72 may also be passed through a heat exchanger 110. The heat exchanger 110 may be configured as a cross heat exchanger, where the separated “hot” product gas stream 96 from separator 92 is used to heat the combined feedstock 72 to form feed stream 84. Similarly, the combined feed stream 72, which is at a lower temperature
30 than the product gas stream 96, may be used for further cooling the gas stream 96 to form cooled product stream 112, where some, but not all, reactor products may be condensed.

[0043] High velocity gas, such as that described with the system 10 of FIG. 1, may also be added to the feed stream 72 and/or 84, as shown at 66 and 68, to keep the reactors 16, 18, 20

free from coking and plugging from metals that would otherwise be deposited on the reactor walls.

[0044] Further cooling of the cooled reactor product 112 may be carried out in a further heat exchanger 114 to form cooled reactor product 116. The final cooled reactor product 116 will typically be at a temperature of from 35 °C to 95 °C.

[0045] The final cooled reactor product 116 is then introduced into one or more separators 118. Non-condensable off-gases 120, such as CO₂, CO and light hydrocarbons (i.e., C₁ to C₅ hydrocarbons), which are produced in the reactor system 90 are separated from the cooled reactor product 116. Liquid water 122 is also separated from the liquid hydrocarbon or oil phase of reactor product 116. Metals that have been stripped from the reactor walls of reactor 16 and reactors 18, 20 that are carried in the cooled reactor product 116 are predominantly distributed in the water phase 122 and thus most of the metals are removed with the water 122. The remaining liquid hydrocarbons 124 are introduced into and pressurized in pump 126. Although not shown, a stripping unit, such as the stripping unit 53 of FIG. 1, may also be used with system 70 to remove additional light gases from the stream 124 before the liquid hydrocarbons are introduced into the pump 126. The pressurized liquid hydrocarbons 128 may then be filtered in filtering unit 130, such as a cartridge filter or sand filter, to remove any coke and remaining metals and other solids in the product stream 128 to form filtered liquid product stream 132.

[0046] The portion of the filtered liquid product stream 102 that is not recycled as recycle stream 104 may be combined as liquid product stream 134 with the liquid stream 132 to form the final treated product 136.

[0047] The use of the recycle stream 104 in system 70 facilitates further removal of oxygen from the feedstock. For example, where the system 10 is operated under conditions where the oxygen in the feed is reduced by 50%, recycling a portion of the reaction products, such as with recycle stream 104, can result in a further reduction in oxygen under similar reaction conditions. This may result in a 20% to 70% further reduction of the oxygen content of the feedstock, so that the system 70 can remove from 60% to 85% of the oxygen from the feed under the same reaction conditions.

[0048] The final treated products 64 and 136 from both treatment systems 10 and 70 of FIGS. 1 and 2, respectively, have unique characteristics. As discussed earlier, the gum and resin content of the initial feedstock is significantly reduced or eliminated entirely, with the gum and resins being converted into useful products or other non-detrimental compounds. In most instances, in the final products, virtually no detectable solids indicating the presence of gums

and resins in the final product are found. Moreover, the product can be further processed in the renewable diesel unit without causing problems of plugging.

[0049] Metals are also removed so that from 90% to 99.9% to even 100% of the metals in the initial feedstock are removed. The final product may therefore have very little or no metals. If any metals do remain in the final product, such remaining metal contaminants may be present in the final product in an amount from only 0.00001 ppm to 100 ppm by total weight of the product. In certain embodiments, the total metal contaminants may be present in the final product in an amount from at least, equal to, and/or between any two of 0 ppm, 0.00001 ppm, 0.0001 ppm, 0.001 ppm, 0.01 ppm, 0.1 ppm, 0.5 ppm, 1 ppm, 2 ppm, 3 ppm, 4 ppm, 5 ppm, 6 ppm, 7 ppm, 8 ppm, 9 ppm, 10 ppm, 15 ppm, 20 ppm, 30 ppm, 40 ppm, 50 ppm, 60 ppm, 70 ppm, 80 ppm, 90 ppm, and 100 ppm by total weight of the product.

[0050] The final products 64, 136 may have a specific gravity of from 0.73 to 0.85, and a viscosity of from 0.5 cSt (5×10^{-7} m²/s) to 5 cSt (5×10^{-6} m²/s). In certain embodiments, the final product may have a specific gravity of from at least, equal to, and/or between any two of 0.73, 0.74, 0.75, 0.76, 0.77, 0.78, 0.79, 0.80, 0.81, 0.82, 0.83, 0.84, and 0.85. And the final product may have a viscosity of from at least, equal to, and/or between any two of 0.5 cSt (5×10^{-7} m²/s), 0.6 cSt (6×10^{-7} m²/s), 0.7 cSt (7×10^{-7} m²/s), 0.8 cSt (8×10^{-7} m²/s), 0.9 cSt (9×10^{-7} m²/s), 1.0 cSt (1×10^{-6} m²/s), 1.1 cSt (1.1×10^{-6} m²/s), 1.2 cSt (1.2×10^{-6} m²/s), 1.3 cSt (1.3×10^{-6} m²/s), 1.4 cSt (1.4×10^{-6} m²/s), 1.5 cSt (1.5×10^{-6} m²/s), 1.6 cSt (1.6×10^{-6} m²/s), 1.7 cSt (1.7×10^{-6} m²/s), 1.8 cSt (1.8×10^{-6} m²/s), 1.9 cSt (1.9×10^{-6} m²/s), 2.0 cSt (2.0×10^{-6} m²/s), 2.1 cSt (2.1×10^{-6} m²/s), 2.2 cSt (2.2×10^{-6} m²/s), 2.3 cSt (2.3×10^{-6} m²/s), 2.4 cSt (2.4×10^{-6} m²/s), 2.5 cSt (2.5×10^{-6} m²/s), 2.6 cSt (2.6×10^{-6} m²/s), 2.7 cSt (2.7×10^{-6} m²/s), 2.8 cSt (2.8×10^{-6} m²/s), 2.9 cSt (2.9×10^{-6} m²/s), 3.0 cSt (3.0×10^{-6} m²/s), 3.1 cSt (3.1×10^{-6} m²/s), 3.2 cSt (3.2×10^{-6} m²/s), 3.3 cSt (3.3×10^{-6} m²/s), 3.4 cSt (3.4×10^{-6} m²/s), 3.5 cSt (3.5×10^{-6} m²/s), 3.6 cSt (3.6×10^{-6} m²/s), 3.7 cSt (3.7×10^{-6} m²/s), 3.8 cSt (3.8×10^{-6} m²/s), 3.9 cSt (3.9×10^{-6} m²/s), 4.0 cSt (4.0×10^{-6} m²/s), 4.1 cSt (4.1×10^{-6} m²/s), 4.2 cSt (4.2×10^{-6} m²/s), 4.3 cSt (4.3×10^{-6} m²/s), 4.4 cSt (4.4×10^{-6} m²/s), 4.5 cSt (4.5×10^{-6} m²/s), 4.6 cSt (4.6×10^{-6} m²/s), 4.7 cSt (4.7×10^{-6} m²/s), 4.8 cSt (4.8×10^{-6} m²/s), 4.9 cSt (4.9×10^{-6} m²/s), and 5.0 cSt (5.0×10^{-6} m²/s).

[0051] The final oxygen content of the final products 64 and 136 from treatment 10 and 70 of FIGS. 1 and 2, respectively, will typically be from 6%, 5%, 4%, 3%, or 2% or less by total weight of the final product. In certain embodiments, the oxygen content may be present in the final products 64, 134 in an amount from at least, equal to, and/or between any two of 0.1 wt%, 0.2 wt%, 0.3 wt%, 0.4 wt%, 0.5 wt%, 0.6 wt%, 0.7 wt%, 0.8 wt%, 0.9 wt%, 1.0 wt%, 1.1 wt%, 1.2 wt%, 1.3 wt%, 1.4 wt%, 1.5 wt%, 1.6 wt%, 1.7 wt%, 1.8 wt%, 1.9 wt%, 2.0 wt%, 2.1

wt%, 2.2 wt%, 2.3 wt%, 2.4 wt%, 2.5 wt%, 2.6 wt%, 2.7 wt%, 2.8 wt%, 2.9 wt%, 3.0 wt%, 3.1 wt%, 3.2 wt%, 3.3 wt%, 3.4 wt%, 3.5 wt%, 3.6 wt%, 3.7 wt%, 3.8 wt%, 3.9 wt%, and 4.0 wt%, 4.1 wt%, 4.2 wt%, 4.3 wt%, 4.4 wt%, 4.5 wt%, 4.6 wt%, 4.7 wt%, 4.8 wt%, 4.9 wt%, 5.0 wt%, 5.1 wt%, 5.2 wt%, 5.3 wt%, 5.4 wt%, 5.5 wt%, 5.6 wt%, 5.7 wt%, 5.8 wt%, 5.9 wt%, 6.0 wt%, 6.1 wt%, 6.2 wt%, 6.3 wt%, 6.4 wt%, 6.5 wt%, 6.6 wt%, 6.7 wt%, 6.8 wt%, 6.9 wt%, 7.0 wt%, 7.1 wt%, 7.2 wt%, 7.3 wt%, 7.4 wt%, 7.5 wt%, 7.6 wt%, 7.7 wt%, 7.8 wt%, 7.9 wt%, 8.0 wt%, 8.1 wt%, 8.2 wt%, 8.3 wt%, 8.4 wt%, 8.5 wt%, 8.6 wt%, 8.7 wt%, 8.8 wt%, 8.9 wt%, 9.0 wt%, 9.1 wt%, 9.2 wt%, 9.3 wt%, 9.4 wt%, 9.5 wt%, 9.6 wt%, 9.7 wt%, 9.8 wt%, 9.9 wt%, and 10.0 wt% by total weight of the final product.

10 **[0052]** The final products 64 or 136 may also be composed of from 25 wt%, 20 wt%, 15 wt%, 10 wt%, or 5 wt% or less of any triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols, tocotrienols, and fatty alcohols, from 5 wt% to 30 wt% naphtha, 50 wt% or more of diesel, and from 5 wt% or less olefins. In particular embodiments, the total amount of compounds of triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols, tocotrienols, and fatty alcohols may be present in the final product in an amount from at least, equal to, and/or between any two of 1 wt%, 2 wt%, 3 wt%, 4 wt%, 5 wt%, 6 wt%, 7 wt%, 8 wt%, 9 wt%, 10 wt%, 11 wt%, 12 wt%, 13 wt%, 14 wt%, 15 wt%, 16 wt%, 17 wt%, 18 wt%, 19 wt%, 20 wt%, 21 wt%, 22 wt%, 23 wt%, 24 wt%, and 25 wt% by total weight of the final product.

20 **[0053]** Naphtha may be present in the final product in an amount from 5 wt% to 30 wt% by total weight of the final products 64 or 136. As used herein, unless otherwise stated, “naphtha” may be generally defined as that hydrocarbon fraction having Reid vapor pressure of 70 kPa or less and a final boiling point of 166 °C or less at 1 atmosphere. In certain applications, naphtha may be present in the final products 64 or 136 in an amount from at least, equal to, and/or between any two of 5 wt%, 6 wt%, 7 wt%, 8 wt%, 9 wt%, 10 wt%, 11 wt%, 12 wt%, 13 wt%, 14 wt%, 15 wt%, 16 wt%, 17 wt%, 18 wt%, 19 wt%, 20 wt%, 21 wt%, 22 wt%, 23 wt%, 24 wt%, 25 wt%, 26 wt%, 27 wt%, 28 wt%, 29 wt%, and 30 wt% by total weight of the final product.

25 **[0054]** Renewable jet fuel (i.e., sustainable aviation fuel) may be present in the final product 64 or 136 in an amount of from 5 wt% to 50 wt%. In particular instances, the renewable jet fuel fraction may be present in the final product 64 or 136 from at least, equal to, and/or between any two of 5 wt%, 6 wt%, 7 wt%, 8 wt%, 9 wt%, 10 wt%, 11 wt%, 12 wt%, 13 wt%, 14 wt%, 15 wt%, 16 wt%, 17 wt%, 18 wt%, 19 wt%, 20 wt%, 21 wt%, 22 wt%, 23 wt%, 24 wt%, 25 wt%, 26 wt%, 27 wt%, 28 wt%, 29 wt%, 30 wt%, 31 wt%, 32 wt%, 33 wt%, 34 wt%,

35 wt%, 36 wt%, 37 wt%, 38 wt%, 39 wt%, 40 wt%, 41 wt%, 42 wt%, 43 wt%, 44 wt%, 45 wt%, 46 wt%, 47 wt%, 48 wt%, 49 wt%, and 50 wt% by total weight of the final product.

[0055] Diesel may be present in the final product 64 or 136 in an amount from 50 wt% or more by total weight of the final product. As used herein, unless otherwise stated, “diesel” may be generally defined as that hydrocarbon fraction having a flash point of below 52 °C with 90% of the composition having a boiling point of 338 °C or less at 1 atmosphere. In some embodiments, diesel may be present in the final product 64 or 136 from at least, equal to, and/or between any two of 50 wt%, 51 wt%, 52 wt%, 53 wt%, 54 wt%, 55 wt%, 56 wt%, 57 wt%, 58 wt%, 59 wt%, 60 wt%, 61 wt%, 62 wt%, 63 wt%, 64 wt%, 65 wt%, 66 wt%, 67 wt%, 68 wt%, 69 wt%, 70 wt%, 71 wt%, 72 wt%, 73 wt%, 74 wt%, 75 wt%, 76 wt%, 77 wt%, 78 wt%, 79 wt%, 80 wt%, 81 wt%, 82 wt%, 83 wt%, 84 wt%, 85 wt%, 86 wt%, 87 wt%, 88 wt%, 89 wt%, and 90 wt% by total weight of the final product.

[0056] Olefins may be present in the final product 64 or 136 in an amount of from 5 wt% or less. In particular instances, olefins may be present in the final product 64 or 136 from at least, equal to, and/or between any two of 0 wt%, 0.1 wt%, 0.2 wt%, 0.3 wt%, 0.4 wt%, 0.5 wt%, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1 wt%, 1.2 wt%, 1.3 wt%, 1.4 wt%, 1.5 wt%, 1.6 wt%, 1.7 wt%, 1.8 wt%, 1.9 wt%, 2.0 wt%, 2.1 wt%, 2.2 wt%, 2.3 wt%, 2.4 wt%, 2.5 wt%, 2.6 wt%, 2.7 wt%, 2.8 wt%, 2.9 wt%, 3.0 wt%, 3.1 wt%, 3.2 wt%, 3.3 wt%, 3.4 wt%, 3.5 wt%, 3.6 wt%, 3.7 wt%, 3.8 wt%, 3.9 wt%, and 4.0 wt%, 4.1 wt%, 4.2 wt%, 4.3 wt%, 4.4 wt%, 4.5 wt%, 4.6 wt%, 4.7 wt%, 4.8 wt%, 4.9 wt%, and 5.0 wt% by total weight of the final product.

[0057] In many instances, the final products 64 and 136 from each of the treatment systems 10, 70, respectively, may meet the requirements of ASTM D975 for renewable diesel without requiring further processing, such as hydroprocessing or isomerization. In other instances, the final products may undergo hydroprocessing and/or isomerizing, regardless of whether or not it meets the requirements of ASTM D975 for renewable diesel.

[0058] In certain instances, the products 64, 136 from either of the systems 10, 70, may be used as a feedstock for further processes. Each of the systems 10, 70 may thus include a further stabilization unit 140 where the products 64, 136 are stabilized to form a stabilized product 142. This may include hydroprocessing, where the stabilization unit 140 includes a reactor containing a hydroprocessing catalyst that is contacted by the products 64, 136 in the presence of hydrogen under conditions suitable for hydroprocessing. As used herein, the term “hydroprocessing,” unless stated otherwise or is apparent from the context, is meant to include hydrotreating, hydrofinishing, hydrorefining, hydrocracking, hydroisomerization, and

hydrodemetalization. The stabilization unit 140 may be used to remove residual oxygen and/or olefins.

[0059] The stabilized product 142 may have a specific gravity of from .75 to 0.80, a viscosity of from 0.5 cSt (5×10^{-7} m²/s) to 2 cSt (2×10^{-6} m²/s), and an oxygen content of 0.2 wt% or less.

5 The pour point of the stabilized product may be from 35 °F or less. In certain embodiments, the stabilized product 142 may have a specific gravity of from at least, equal to, and/or between any two of 0.75, 0.74, 0.75, 0.76, 0.77, 0.78, 0.79, and 0.80. And the stabilized product 142 may have a viscosity of from at least, equal to, and/or between any two of 0.5 cSt (5×10^{-7} m²/s), 0.6 cSt (6×10^{-7} m²/s), 0.7 cSt (7×10^{-7} m²/s), 0.8 cSt (8×10^{-7} m²/s), 0.9 cSt (9×10^{-7} m²/s), 1.0 cSt
10 (1×10^{-6} m²/s), 1.1 cSt (1.1×10^{-6} m²/s), 1.2 cSt (1.2×10^{-6} m²/s), 1.3 cSt (1.3×10^{-6} m²/s), 1.4 cSt (1.4×10^{-6} m²/s), 1.5 cSt (1.5×10^{-6} m²/s), 1.6 cSt (1.6×10^{-6} m²/s), 1.7 cSt (1.7×10^{-6} m²/s), 1.8 cSt (1.8×10^{-6} m²/s), 1.9 cSt (1.9×10^{-6} m²/s), 2.0 cSt (2.0×10^{-6} m²/s).

[0060] In certain embodiments, all or a portion of the stabilized product 142 may be delivered to a separate isomerization unit 144, which may be provided with the systems 10, 70, under
15 conditions suitable for isomerizing n-paraffins to iso-paraffins to provide an isomerized product 146 with a selected pour point.

[0061] In some embodiments, all or a portion of the stabilized product 142 that has not been isomerized may be directed to a fractionation unit 148 of each of the systems 10, 70, where the product 142 may be fractionated into various products, such as a naphtha fraction 150, a
20 renewable jet fuel fraction 152, and a renewable diesel fraction 154. Similarly, all or a portion of the isomerized product 146 may be sent to a fractionation unit 156 of each of the systems 10, 70, where the isomerized product 146 is fractionated into various products, such as a naphtha fraction 158, a renewable jet fuel fraction 160, and a renewable diesel fraction 162.

[0062] While the products 64, 136 may undergo hydroprocessing (stabilization) and/or
25 separate isomerization, as in a conventional renewable diesel process, it should be distinguished from hydroprocessing and isomerization that are utilized in conventional renewable diesel processing systems.

[0063] Because the product from the treatment systems 10, 70 has a significantly lower oxygen content than conventional renewable diesel feedstocks, the amount of hydrogen necessary for
30 hydroprocessing is significantly lower. For example, in a conventional renewable diesel hydrotreating system, a typical amount of hydrogen gas (H₂) necessary for a given feedstock may be around from 1,500 scf/bbl to 4,000 scf/bbl (675 SCM/m^3 to 1801 SCM/m^3). Utilizing the products 64, 136 derived from the same initial feedstock as a feedstock for hydroprocessing, the amount of hydrogen gas required may be reduced from 30% to 90%. Thus, for example,

while 3000 scf/bbl (1351 SCM/m³) of hydrogen gas may be needed for treating a given feedstock in a conventional renewable diesel unit, the amount of hydrogen gas needed for stabilizing the products 64, 136 derived from the same initial feedstock may be from 300 scf/bbl to 1500 scf/bbl (127 SCM/m³ to 675 SCM/m³) to form a similar or comparable product.

5 Additionally, the operating pressure for hydroprocessing in a conventional renewable diesel unit may be much higher, at around 6200 kPa or more. To form a comparable product utilizing the treated initial feedstock in the stabilization unit 140, the operating pressure may be around 2000 kPa. Because plant costs increase linearly with respect to operating pressure, reducing the operating pressure for a given process can lower the plant construction costs considerably.

10 **[0064]** In some embodiments, the stabilization unit 140 used for hydroprocessing the products 64, 136 may be a liquid-phase hydroprocessing reactor system that utilizes a liquid diluent combined with the feedstock for dissolving the necessary hydrogen for reaction. Such hydroprocessing systems and methods are described in U.S. Patent Nos. 9,096,804; 9,828,552; 10,487,268; 10,961,463 and 10,981,142, each of which is hereby incorporated herein by
15 reference in its entirety for all purposes. Alternatively, the stabilization unit 140 can be configured as a conventional hydroprocessing unit, similar to a conventional renewable diesel unit, where large volumes of hydrogen gas are circulated in the reactor along with the feedstock. In contrast to conventional hydroprocessing or hydrotreating units, the stabilization unit 140 will typically require significantly less hydrogen and significantly lower reactor
20 pressures than conventional processing equipment.

[0065] Additionally, because most of the oxygen is removed from the products 64, 136, less water is produced in the stabilization unit 140 so there is no danger of water damage to the hydroprocessing catalyst or the creation of a separate water phase.

[0066] With respect to isomerization, the products from conventional renewal diesel plants
25 typically contain a significant amount of waxes or n-paraffins and may, for example, have a cloud point of around 21 °C. Given the same initial feedstocks, the products 142 of treatment systems 10 and 70 hydrotreated in the stabilization unit 140 are significantly different from those hydrotreated in a conventional renewable diesel unit. Even after hydrotreating in the stabilization unit 140, there are fewer waxes or n-paraffins in the stabilized product 142. The
30 stabilized product 142 will typically have a cloud point of from 2.0 °C, 1.5 °C, 1.0 °C, 0.5 °C, 0 °C, -0.5 °C, -1.0 °C, -1.5 °C, -2.0 °C, -2.5 °C, -3.0 °C, -3.5 °C, -4.0 °C, -4.5 °C, -5.0 °C, -5.5 °C, -6.0 °C, -6.5 °C, -7.0 °C, -7.5 °C, -8.0 °C, -8.5 °C, -9.0 °C, or -9.5 °C or less without any isomerization treatment. This is considerably lower than the hydrotreated product from a conventional renewable diesel unit.

[0067] One of the advantages of the treatment method and systems 10, 70 is to help in lowering GHG emissions. Not only do the methods and systems utilize a renewable feedstock, which has a lower environmental impact, but assuming the feedstocks received by the systems 10, 70 have a CI score of zero, the stabilized products 142 produced from the systems 10, 70 meet the criteria of renewable diesel but will have a CI score of 10 g/MJ or less, as established by the criteria of California LCFS of 2018. This is based upon natural gas fuel usage for the reactors 16, 18, 20 and power consumption for the various powered equipment utilized to operate the systems 10, 70. Power consumption for calculating the CI value includes the power used to operate pumping units for the initial feedstock (e.g., pump 108), pumping units for the product (e.g., pumping units 58, 126), and forced convection heat exchangers (e.g., heating exchangers 40, 114). The hot reaction product of the system facilitates heating of the renewable feedstock, and the renewable feedstock facilitates cooling of the hot reaction products. And using combustible off-gases as fuel for the systems 10, 70 helps to reduce CI further. In certain embodiments, the stabilized products 142 will have a CI score of 10 g/MJ, 9 g/MJ, 8 g/MJ, 7 g/MJ, 6 g/MJ, 5 g/MJ, 4 g/MJ, or 3 g/MJ or less. This is contrasted with conventional renewable diesel products that, even assuming a feedstock with an initial CI score of zero, will still typically have a CI of around 20 g/MJ.

[0068] The following examples serve to further illustrate various embodiments and applications.

EXAMPLES

EXAMPLE 1

[0069] Tank bottoms from distiller's corn oil having high gums, resins, water and metals content was treated at 600 psig (413g kPa) and 900 °F (483 °C) through a fired heater for a period of a few seconds in a laboratory pilot plant. The treated product was cooled to separate the water and off-gas from the hydrocarbon phase. The final product contained trace amounts of water, 4 wt% off-gas and 96 vol% hydrocarbon liquids. The hydrocarbon liquids contained 19 vol% naphtha and 77 vol% percent diesel relative to the feed.

[0070] While the invention has been shown in only some of its forms, it should be apparent to those skilled in the art that it is not so limited but is susceptible to various changes and modifications without departing from the scope of the invention. Accordingly, it is appropriate that the invention be construed broadly.

CLAIMS:

We claim:

- 5 1. A method of treating a non-petroleum or renewable feedstock containing oxygen and contaminants of one or more of metals, gums, and resins, the method comprising:

 introducing the feedstock having an oxygen content of 8 wt% or more by total weight of the feedstock into a reactor at a flow velocity of from 6 m/sec to 35 m/sec, the feedstock
10 being heated within the reactor to a temperature of from 370 °C to 595 °C to remove and/or reduce the content of one or more of gums and resins in the fats and/or oils of the feedstock to form a reactor product;

 cooling the reactor product to form a cooled reactor product; and
15

 separating and removing non-condensable gases, metals and water from the cooled reactor product to form a final product, the final product having an oxygen content that is 60% or less of that of the feedstock, and wherein the final product comprises 25 wt% or less of any triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols,
20 tocotrienols, and fatty alcohols, from 5 wt% to 30 wt% naphtha, and 50 wt% or more diesel.

2. The method of claim 1, wherein:

 the final product meets the requirements of ASTM D975 for renewable diesel.
25

3. The method of claim 1, wherein:

 the final product has a specific gravity of from 0.73 to 0.85, a viscosity of from 0.5 cSt ($5 \times 10^{-7} \text{ m}^2/\text{s}$) to 5 cSt ($5 \times 10^{-6} \text{ m}^2/\text{s}$), and an oxygen content of 6 wt% or less without further
30 treatment.

4. The method of claim 1, further comprising:

at least one of hydroprocessing and isomerizing the final product to form a at least one of a hydroprocessed product and an isomerized product.

5

5. The method of claim 1, wherein:

the final product is hydroprocessed in a stabilization unit to form a stabilized product.

10 6. The method of claim 5, wherein:

the stabilized product has a specific gravity of from .75 to 0.8, a viscosity of from 0.5 cSt ($5 \times 10^{-7} \text{ m}^2/\text{s}$) to 2 cSt ($2 \times 10^{-6} \text{ m}^2/\text{s}$), and an oxygen content of 0.2 wt% or less.

15 7. The method of claim 5, wherein:

the stabilized product has a pour point of 2 °C or less without any isomerization treatment.

20 8. The method of claim 5, wherein:

the stabilized product produced has a fuel carbon intensity score (CI) of 10 gCO₂e/MJ (grams CO₂ emissions per MJ of fuel) or less, based upon California LCFS criteria of 2018, when the feedstock has a CI selected at zero.

25

9. The method of claim 1, wherein:

at least a portion of the reactor product is cooled to a temperature of from 175 °C to 320 °C to form a reduced-temperature reactor product; and further comprising:

5

separating gases and liquids from the reduced-temperature reactor product, the separated liquid from the reduced-temperature reactor product being recycled and introduced into the reactor with the feedstock; and wherein:

10 the separated gas from the reduced-temperature reactor product is further cooled to a temperature of 125 °C or less to form the cooled reactor product.

10. The method of claim 1, wherein:

15 the final product has an oxygen content that is 40% or less of that of the feedstock.

11. The final product according to claim 1.

12. The at least one of a hydroprocessed product and an isomerized product according to
20 claim 4.

13. The stabilized product according to claim 5.

14. A system for treating non-petroleum or renewable feedstocks containing oxygen and contaminants of one or more of metals, gums, and resins, the system comprising:

a reactor having a heat source for heating an interior of the reactor;

a feedstock of a non-petroleum or renewable feedstock containing oxygen in an amount of 8 wt% or more by total weight of the feedstock and contaminants of one or more of metals, gums, and resins that is introduced into the reactor at a flow velocity of from 6 m/sec to 35 m/sec, the feedstock being heated within the reactor to a temperature of from 370 °C to 595 °C to remove and/or reduce the content of one or more of gums and resins in the fats and/or oils of the feedstock;

a reactor product that is formed in the reactor from the feedstock that has the one or more of gums and resins in the fats and/or oils of the feedstock removed and/or reduced;

a heat exchanger to cool the reactor product;

a cooled reactor product that is formed in the heat exchanger by cooling the reactor product;

a separator unit to separate and remove non-condensable gases, metals and water from the cooled reactor product; and

a final product that is separated from the non-condensable gases, metals and water from the cooled reactor product, the final product having an oxygen content that is 60% or less of that of the feedstock, and wherein the final product comprises 25 wt% or less of any triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols, tocotrienols, and fatty alcohols, from 5 wt% to 30 wt% naphtha, and 50 wt% or more diesel.

15. The system of claim 14, wherein:

the final product meets the requirements of ASTM D975 for renewable diesel.

5 16. The system of claim 14, wherein:

the final product has a specific gravity of from 0.73 to 0.85, a viscosity of from 0.5 cSt ($5 \times 10^{-7} \text{ m}^2/\text{s}$) to 5 cSt ($5 \times 10^{-6} \text{ m}^2/\text{s}$), and an oxygen content of 6 wt% or less without further treatment.

10

17. The system of claim 14, further comprising:

a hydroprocessing unit and/or isomerizing unit that receives the final product; and

15 a hydroprocessed product and isomerized product that is formed in the hydroprocessing unit and/or isomerizing unit from the final product.

18. The system of claim 14, further comprising:

an intermediate heat exchanger wherein at least a portion of the reactor product is cooled to a temperature of from 175 °C to 320 °C;

5

an intermediate cooled reactor product that is formed in the intermediate heat exchanger from the cooled reactor product from the intermediate heat exchanger; and

10 a second separator unit for separating gases and liquids from the intermediate cooled reactor product;

a separated liquid formed in the second separator unit from the separated liquids from the intermediate cooled reactor that is introduced into the reactor as a recycle along with the feedstock; and

15

a separated gas formed in the second separator unit from the separated gases from the intermediate cooled reactor wherein the separated gas is further cooled in the heat exchanger to a temperature of 125 °C or less to form the cooled reactor product.

20 19. A composition formed from a treated feedstock of non-petroleum or renewable feedstocks containing 50 wt% or more of at least one of triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols and tocotrienols, and fatty alcohols, 10 wt% or more oxygen and 1 wt% or more contaminants of one or more of metals, gums, and resins, the composition comprising:

25

from 25 wt% or less of any triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols, tocotrienols, and fatty alcohols;

naphtha in an amount from 10 wt% to 30 wt%; and

diesel in an amount of 50 wt% or more; and wherein:

30

the composition has a specific gravity of from 0.73 to 0.85, a viscosity of from 0.5 cSt ($5 \times 10^{-7} \text{ m}^2/\text{s}$) to 5 cSt ($5 \times 10^{-6} \text{ m}^2/\text{s}$), and an oxygen content of 6 wt% or less.

20. The composition of claim 19, wherein the composition comprises:

from 2 wt% or less of any triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols, tocotrienols, and fatty alcohols;

5 naphtha in an amount from 5 wt% to 30 wt%; and

diesel in an amount of 50 wt% or more; and

the composition has a specific gravity of from .75 to 0.8, a viscosity of from 0.5 cSt ($5 \times 10^{-7} \text{ m}^2/\text{s}$) to 2 cSt ($2 \times 10^{-6} \text{ m}^2/\text{s}$), and an oxygen content of 0.2 wt% or less .

10

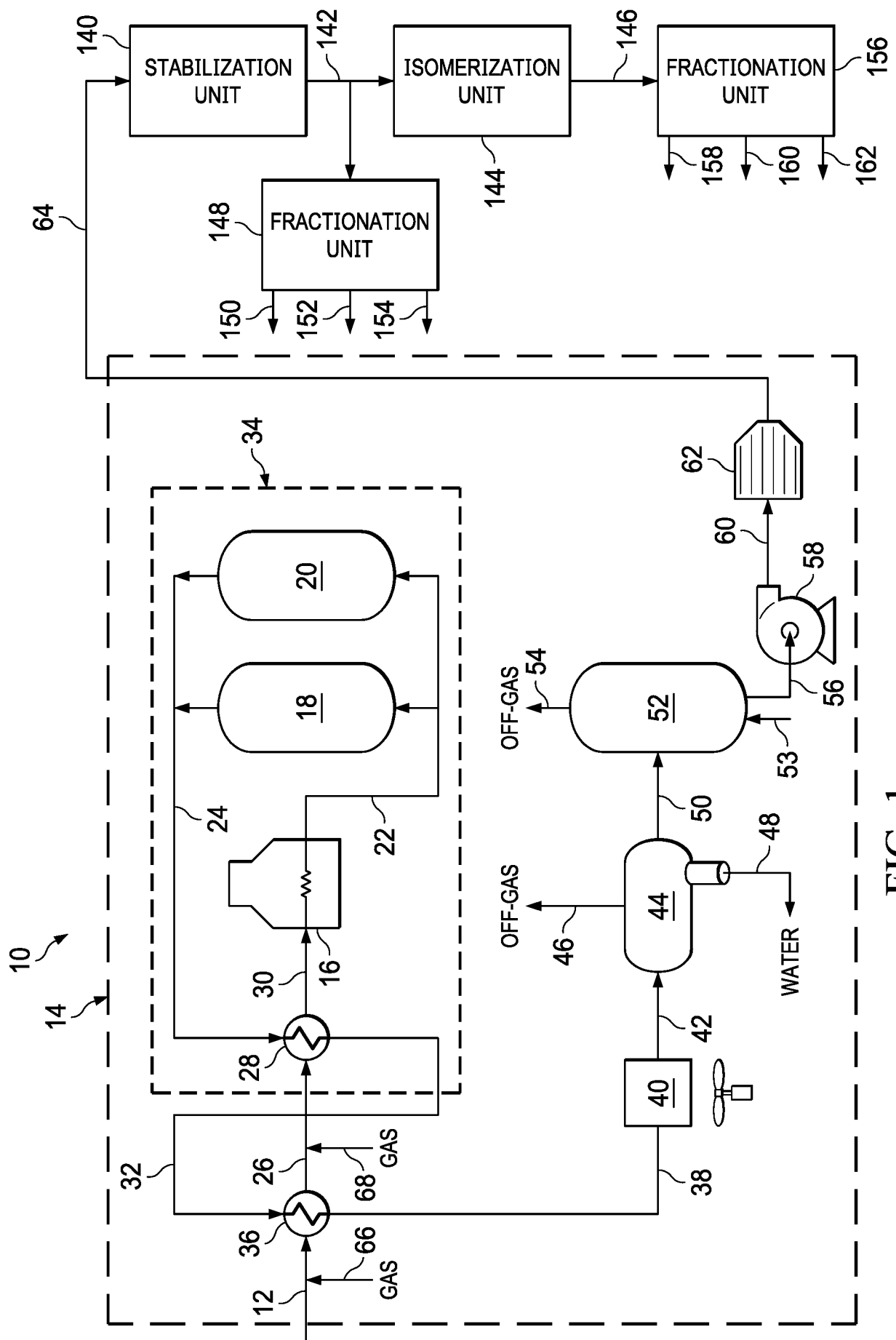
$1/2$ 

FIG. 1

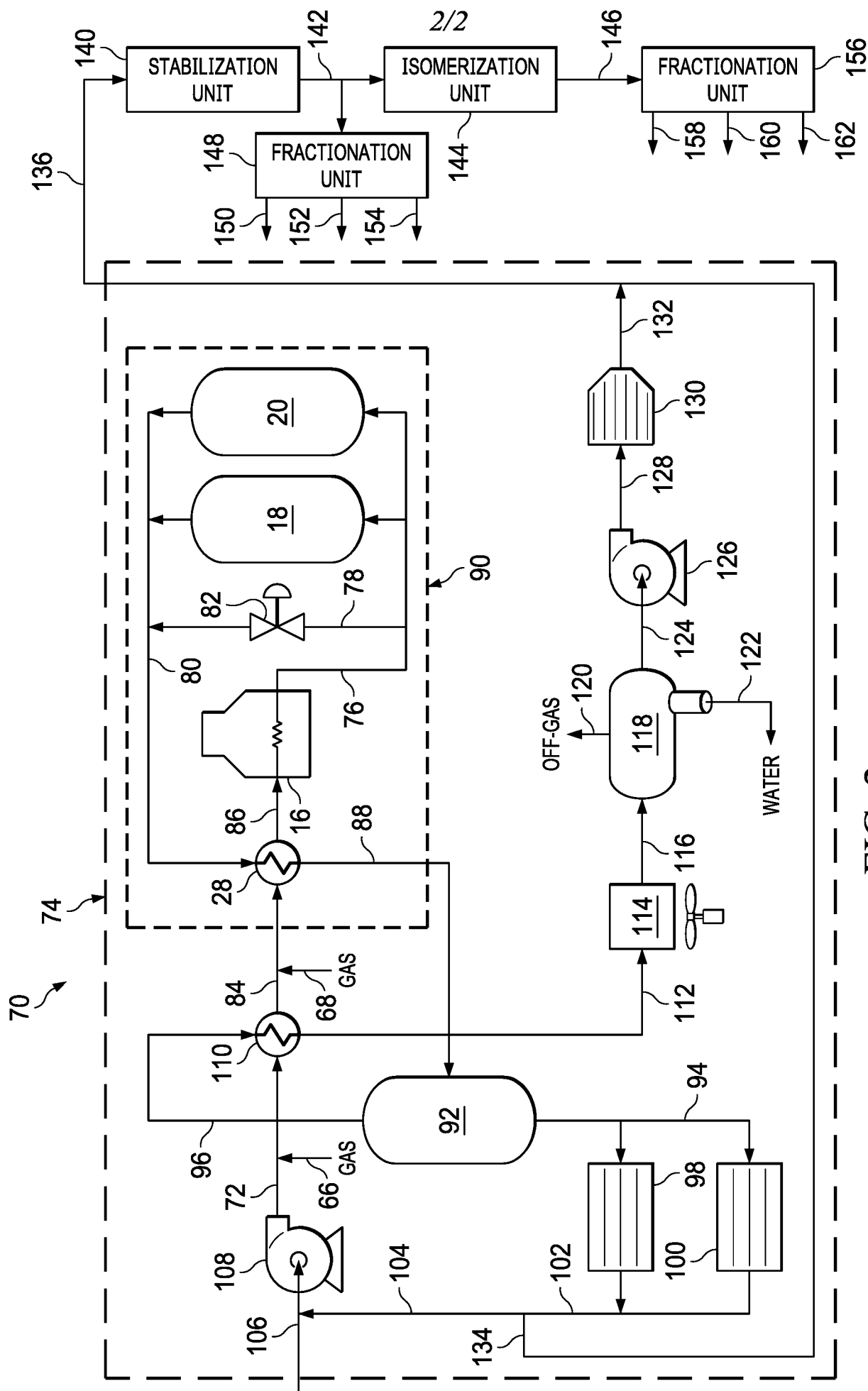


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 21/39767

A. CLASSIFICATION OF SUBJECT MATTER

IPC - B01J 19/00; C07C 5/27; C07C 7/00 (2021.01)

CPC - C10G 3/42; C10G 3/50; C10G 45/58; B01J 2219/00006

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2020/0087577 A1 (Duke Technologies, LLC) 19 March 2020 (19.03.2020) - entire document especially para[0014], [0015], [0016], [0019], [0023], [0065] and [0073]	1-2, 4-5, 9-13 ----- 3, 6-8
Y	WO 2020/007790 A1 (Shell Oil Company) 09 January 2020 (09.01.2020) - entire document especially page 15 line 19-23, page 22 line 18-19 and page 20 line 11-24	3, 6, 8
Y	US 2019/0338205 A1 (Duke Technologies, LLC) 07 November 2019 (07.11.2019) - entire document especially para[0030]	7
P/A	WO 2020/252290 A1 (Duke Technologies, LLC) 17 December 2020 (17.12.2020) - entire document	1-13 1-13
A	US 2015/0126787 A1 (Gevo, Inc) 07 May 2015 (07.05.2015) - entire document	
A	WO 2018/075017 A1 (Mawetal LLC) 26 April 2018 (26.04.2018) - entire document	1-13
A	WO 2019/229037 A1 (Duke Technologies, LLC) 05 December 2019 (05.12.2019) - entire document	1-13



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

"D" document cited by the applicant in the international application

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

10 September 2021

Date of mailing of the international search report

DEC 06 2021

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Kari Rodriguez

Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 21/39767

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

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

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

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

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

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

This International Searching Authority found multiple inventions in this international application, as follows:
---see supplemental box---

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-13

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

---Box No. III Cont.---

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I: Claims 1-13 directed to a method of treating a non-petroleum or renewable feedstock containing oxygen and contaminants of one or more of metals, gums, and resins, the method comprising: introducing the feedstock having an oxygen content of 8 wt% or more by total weight of the feedstock into a reactor at a flow velocity of from 6 m/sec to 35 m/sec, the feedstock being heated within the reactor to a temperature of from 370 °C to 595 °C to remove and/or reduce the content of one or more of gums and resins in the fats and/or oils of the feedstock to form a reactor product; cooling the reactor product to form a cooled reactor product; and separating and removing non-condensable gases, metals and water from the cooled reactor product to form a final product, the final product having an oxygen content that is 60% or less of that of the feedstock, and wherein the final product comprises 25 wt% or less of any triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols, tocotrienols, and fatty alcohols, from 5 wt% to 30 wt% naphtha, and 50 wt% or more diesel.

Group II: Claims 14-18 directed to a system for treating non-petroleum or renewable feedstocks containing oxygen and contaminants of one or more of metals, gums, and resins, the system comprising: a reactor having a heat source for heating an interior of the reactor; a feedstock of a non-petroleum or renewable feedstock containing oxygen in an amount of 8 wt% or more by total weight of the feedstock and contaminants of one or more of metals, gums, and resins that is introduced into the reactor at a flow velocity of from 6 m/sec to 35 m/sec, the feedstock being heated within the reactor to a temperature of from 370 °C to 595 °C to remove and/or reduce the content of one or more of gums and resins in the fats and/or oils of the feedstock; a reactor product that is formed in the reactor from the feedstock that has the one or more of gums and resins in the fats and/or oils of the feedstock removed and/or reduced; a heat exchanger to cool the reactor product; a cooled reactor product that is formed in the heat exchanger by cooling the reactor product; a separator unit to separate and remove non-condensable gases, metals and water from the cooled reactor product; and a final product that is separated from the non-condensable gases, metals and water from the cooled reactor product, the final product having an oxygen content that is 60% or less of that of the feedstock, and wherein the final product comprises 25 wt% or less of any triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols, tocotrienols, and fatty alcohols, from 5 wt% to 30 wt% naphtha, and 50 wt% or more diesel.

Group III: Claims 19-20 directed to a composition formed from a treated feedstock of non-petroleum or renewable feedstocks containing 50 wt% or more of at least one of triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols and tocotrienols, and fatty alcohols, 10 wt% or more oxygen and 1 wt% or more contaminants of one or more of metals, gums, and resins, the composition comprising: from 25 wt% or less of any triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols, tocotrienols, and fatty alcohols; naphtha in an amount from 10 wt% to 30 wt%; and diesel in an amount of 50 wt% or more; and wherein: the composition has a specific gravity of from 0.73 to 0.85, a viscosity of from 0.5 cSt (5x10⁻⁷ m²/s) to 5 cSt (5x10⁻⁶ m²/s), and an oxygen content of 6 wt% or less.

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

Special Technical Features:

Group I requires a method of treating a non-petroleum or renewable feedstock containing oxygen and contaminants of one or more of metals, gums, and resins; not required by Group II or III.

Group II requires a system for treating non-petroleum or renewable feedstocks containing oxygen and contaminants of one or more of metals, gums, and resins; not required by Group I or III.

Group III requires a composition formed from a treated feedstock of non-petroleum or renewable feedstocks containing 50 wt% or more of at least one of triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols and tocotrienols, and fatty alcohols, 10 wt% or more oxygen and 1 wt% or more contaminants of one or more of metals; not required by Group I or II.

Common Technical Features:

Groups I, II and III share the technical feature of a final product that comprises 25 wt% or less of any triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols, tocotrienols, and fatty alcohols, from 5 wt% to 30 wt% naphtha, and 50 wt% or more diesel.

However, these shared technical features do not represent a contribution over prior art, because the shared technical feature is obvious over US 2020/0087577 A1 to Duke Technologies LLC (hereinafter "Duke Technologies"). Duke Technologies teaches the final product comprises 25 wt% or less of any triglycerides, monoglycerides, diglycerides, free fatty acids, phosphatides, sterols, tocopherols, tocotrienols, and fatty alcohols (para[0073] Table 6 shows that the light ends make up 14 wt.% of the product), from 5 wt% to 30 wt% naphtha (para[0073] Table 6 shows that naphtha makes up 30 wt.% of the product), and 16 wt% of diesel (para[0073] Table 6 shows that diesel makes up 16 wt.% of the products), but does not teach 50 wt% or more of diesel. However, Duke Technologies teaches that the reactor feed and composition can be adjusted to obtain a desired product (para[0028] "The reactors may be altered in configuration and in number to accommodate the specifications required of the product, given a specific feed"). Therefore, it would have been obvious to one skilled in the art through routine experimentation to use the method taught by Duke Technologies where feedstock and reactor composition is adjusted to obtain a fuel containing at least 50 wt% diesel.

As the shared technical features were known in the art at the time of the invention, they cannot be considered common technical features that would otherwise unify the groups. Therefore, Groups I-III lack unity under PCT Rule 13.