

AVIATION FUEL COMPOSITION

Field of the Invention

This invention relates to an aviation fuel composition comprising a renewable cycloparaffinic kerosene. In particular, the present invention relates to an aviation fuel composition comprising a cycloparaffinic kerosene derived from hydroprocessing of solid biomass.

Background of the invention

Conventional jet fuels are prepared in a refinery from a crude mineral oil source. Typically, the crude mineral oil is separated by means of distillation into a distillate kerosene fraction boiling in the aviation fuel range. If required, these fractions are subjected to hydroprocessing to reduce sulfur, oxygen and nitrogen levels.

Increasing demand for jet fuel and the environmental impact of aviation related emissions places the aviation industry at the forefront of today's global energy challenge. The increased demand for petroleum-based fuels has resulted in a higher production of greenhouse gases. In particular, the aviation industry accounts for about 2% of global CO₂ emissions. The aviation transport sector is growing 3-5% year on year, and due to the projected increasing demand for fuel and increasing production of CO₂ emissions, there is a need to explore methods to increase environmentally-friendly fuel sources while meeting jet fuel specifications.

Perhaps more tangible than the global impact of greenhouse gases is the impact of local emissions from aircraft. Emissions near and around airports have a direct impact on the air composition and therefore have been linked with poor local air quality, which can be

further linked to impacts on human health. Particulates and oxides of sulfur and nitrogen are considered to be the main contributors to poor local air quality. Thus, local air quality is seen as an integral element in the pursuit of environment-friendly fuels.

Petroleum-derived jet fuels inherently contain both paraffinic and aromatic hydrocarbons. In general, paraffinic hydrocarbons offer the most desirable combustion cleanliness characteristics for jet fuels. Aromatics generally have the least desirable combustion characteristics for aircraft turbine fuel. In aircraft turbines, certain aromatics, such as naphthalenes, tend to burn with a smokier flames and release a greater proportion of their chemical energy as undesirable thermal radiation than other more saturated hydrocarbons.

The closest current option for reducing aviation emissions is blending synthesized paraffinic kerosene ("SPK") from Fischer-Tropsch or hydrogenated vegetable oil with conventional jet fuel. Up to 50% by volume of SPK is permitted by the alternative jet fuel specification ASTM D7566. If the resulting blend meets the specification, it can be certified and considered equivalent to conventional, petroleum-derived jet fuel. Typically, these synthesized paraffinic kerosenes contain a mixture of normal and branched paraffin according to ASTM D7566.

It is important that novel fuels meet their respective jet fuel specifications without having a detrimental impact on safety or aircraft performance. Because SPK is purely paraffinic and absent of both aromatics and sulfur, it does not exhibit all of the desired properties expected from a jet fuel. For example, a gas to liquids Fischer-Tropsch-derived fuel is not considered an on-spec fuel in its pure state due to its lower density. Further, SPK fuels tend to have low

volumetric energy density, which may require more fuel than can be accommodated in aircraft fuel tanks for long distance flights.

5 It would therefore be desirable to formulate an aviation fuel composition comprising environmentally-friendly fuel components, but which still meet the requirements of the various jet fuel specifications. It would also be desirable to formulate an environmentally-friendly aviation fuel composition which provides
10 improvements in certain fuel properties such as lubricity and low temperature characteristics.

Summary of the Invention

The present invention provides an aviation fuel composition comprising (i) a cycloparaffinic kerosene
15 generated from hydropyrolysis and hydroconversion of a solid biomass containing lignocellulose, wherein the cycloparaffinic kerosene comprises at least 90 vol% cycloparaffins and less than 1 vol% aromatics; (ii) a synthetic paraffinic-based kerosene comprising normal and
20 iso-paraffins in an amount of greater than 95 vol%; and (iii) optionally, a petroleum-derived kerosene.

The present invention further provides a process for producing an aviation fuel composition comprising:

- (a) feeding a solid feedstock and hydrogen to a first
25 stage hydropyrolysis reactor, wherein the first stage hydropyrolysis reactor comprises one or more deoxygenation catalyst, and wherein the solid feedstock comprises biomass containing lignocellulose;
- 30 (b) hydropyrolysing the solid feedstock in the first stage hydropyrolysis reactor to generate a product stream comprising partially deoxygenated hydropyrolysis product, H₂O, H₂, CO₂, CO, C₁ - C₃ gases, char and catalyst fines;

- (c) feeding at least a portion of the product stream to a second stage hydroconversion reactor comprising one or more hydroconversion catalyst;
- (d) hydroconverting the partially deoxygenated hydropyrolysis product in the product stream to generate a vapor phase product comprising substantially fully deoxygenated hydrocarbon product, H₂O, CO, CO₂, and C₁ - C₃ gases;
- (e) condensing the vapor phase product to generate a deoxygenated hydrocarbon liquid comprising the substantially fully deoxygenated hydrocarbon product, wherein the substantially fully deoxygenated hydrocarbon product comprises a cycloparaffinic kerosene wherein the cycloparaffinic kerosene comprises at least 90 vol% cycloparaffins and less than 1 vol% aromatics; and
- (f) mixing the cycloparaffinic kerosene with a paraffinic-based kerosene comprising normal and iso-paraffins in an amount of greater than 95% and a petroleum derived jet fuel to generate the aviation fuel composition.

The present invention further provides a process for producing an aviation fuel composition, comprising:

- mixing a cycloparaffinic kerosene derived from hydropyrolysis and hydroconversion of a biomass containing lignocellulose wherein the cycloparaffinic kerosene comprises at least 90 vol% cycloparaffins and less than 1 vol% aromatics with a synthetic paraffinic-based kerosene comprising normal and iso-paraffins in an amount of greater than 95%, and, optionally, a petroleum-derived jet fuel.

It has been surprisingly found that the aviation fuel composition of the present invention provides an environmentally-friendly jet fuel containing low levels of

aromatics while providing unexpected improvements in certain fuel characteristics such as lubricity, and low temperature viscosity characteristics.

Brief Description of the Drawings

5 Figure 1 is a block diagram of an embodiment of a system **10** that may be used for hydroprocessing solid feedstocks (e.g., biomass and/or waste plastics/oils) to generate one or more hydrocarbon products (e.g., GO/diesel, gasoline, kerosene, etc.) which can be used as
10 the cycloparaffinic kerosene herein.

 Figure 2 is a ternary diagram showing the difference between the measured low temperature viscosity at -20°C and the linear interpolation for Examples 1-18.

 Figure 3 is a ternary diagram showing the difference
15 between the measured low temperature viscosity at -40°C and the linear interpolation for Examples 1-18.

 Figure 4 is a ternary diagram showing the difference between the measured wear scar (lubricity) and the linear interpolation for Examples 1-18.

20 Detailed Description of the Invention

Cycloparaffinic kerosene

 A first essential component of the aviation fuel composition herein is a cycloparaffinic kerosene. The cycloparaffinic kerosene used herein is generated from
25 hydropyrolysis and hydroconversion of a solid biomass containing lignocellulose. The cycloparaffinic kerosene comprises at least 90 vol% cycloparaffins, preferably at least 92 vol% cycloparaffins, more preferably at least 95 vol% cycloparaffins (ASTM D2425). The cycloparaffinic
30 kerosene contains low levels of aromatics, i.e. less than 1 vol% aromatics, preferably less than 0.5 vol% aromatics, more preferably less than 0.2 vol% aromatics (ASTM D6379).

 From the viewpoint of optimising low temperature viscosity characteristics, the cycloparaffinic kerosene is

preferably present in the aviation fuel composition at a level from 10 vol% to 95 vol%, more preferably from 20 vol% to 80 vol%, even more preferably from 40 vol% to 60 vol%, based on the total aviation fuel composition.

5 From the viewpoint of optimising lubricity characteristics, the cycloparaffinic kerosene is preferably present in the aviation fuel composition at a level from 40 vol% to 90 vol%, more preferably from 60 vol% to 80 vol%, based on the total aviation fuel composition.

10 In a preferred embodiment herein, the cycloparaffinic kerosene is generated by a hydroprocess comprising the steps of

- (a) feeding a solid feedstock and hydrogen to a first stage hydropyrolysis reactor, wherein the first stage hydropyrolysis reactor comprises one or more deoxygenation catalyst, and wherein the solid feedstock comprises biomass containing lignocellulose;
- (b) hydropyrolysing the solid feedstock in the first stage hydropyrolysis reactor to generate a product stream comprising a partially deoxygenated hydropyrolysis product, H₂O, H₂, CO₂, CO, C₁-C₃ gases, char and catalyst fines;
- (c) feeding at least a portion of the product stream to a second stage hydroconversion reactor comprising one or more hydroconversion catalyst;
- (d) hydroconverting the partially deoxygenated hydropyrolysis product in the product stream to generate a vapour phase product comprising substantially fully deoxygenated hydrocarbon product, H₂O, CO, CO₂ and C₁-C₃ gases; and
- (e) condensing the vapour phase product to generate a deoxygenated hydrocarbon liquid comprising the substantially fully deoxygenated hydrocarbon product,

wherein the substantially deoxygenated hydrocarbon product comprises the cycloparaffinic kerosene.

With the foregoing in mind, **FIG. 1** is a block diagram of an embodiment of a system **10** that may be used for hydroprocessing solid feedstocks (e.g., biomass and/or waste plastics/oils) to generate one or more hydrocarbon products (e.g., GO/diesel, gasoline, kerosene, etc.) which can be used as the cycloparaffinic kerosene herein. As should be appreciated, the solid feedstock-derived hydrocarbon products disclosed herein may be generated by any suitable hydroprocessing technique such as those disclosed in U.S. Patent No. 9,447,328, which is hereby incorporated by reference in its entirety. In the illustrated embodiment, the system **10** includes a hydropyrolysis reactor **14** and a hydroconversion reactor **16**. As discussed in further detail below, the reactors **14**, **16** are used to convert a solid feedstock into an intermediate hydrocarbon fuel fraction (e.g., a cycloparaffinic kerosene fraction) that may be used in combination with a paraffinic kerosene and optionally, a petroleum-based kerosene base to generate an aviation fuel composition. As illustrated, the reactors **14**, **16** are disposed within one of two stages. For example, the system **10** includes a first stage **18** and a second stage **20**. The first stage **18** includes the hydropyrolysis reactor **14**, and the second stage **20** includes the hydroconversion reactor **16**. The reaction pressure in the first stage **18** and the second stage **20** may be varied to tailor the boiling point distribution and composition of the resultant hydrocarbon product(s) generated by the second stage **18**. The ability to tailor the boiling point distribution and/or composition of the resultant hydrocarbon product by varying the reaction pressure may

provide an efficient process for generating commercially viable hydrocarbon biofuels that meet the different requirements set forth by the location and/or market in which the hydrocarbon biofuel will be used.

5 First Stage

 In the illustrated embodiment, a solid feedstock **24** having biomass (e.g., lignocellulose) and/or waste plastics and molecular hydrogen (H₂) **28** are introduced into the hydrolysis reactor **14**. The hydrolysis reactor **14** contains a deoxygenation catalyst that facilitates partial deoxygenation of the solid feedstock **24**. For example, in the hydrolysis reactor **14**, the solid feedstock **24** undergoes hydrolysis, producing an output **30** having char, partially deoxygenated products of hydrolysis, light gases (C₁ - C₃ gases, carbon monoxide (CO), carbon dioxide (CO₂), and H₂), water (H₂O) vapor and catalyst fines. The hydrolysis reactor **14** may be a fluidized bed reactor (e.g., a fluidized bubbling bed reactor), fixed-bed reactor, or any other suitable reactor. In embodiments in which the hydrolysis reactor **14** is a fluidized bed reactor, the fluidization velocity, catalyst particle size and bulk density and solid feedstock particle size and bulk density are selected such that the deoxygenation catalyst remains in the bubbling fluidized bed, while the char produced is entrained with the partially deoxygenated products (e.g., the output **30**) exiting the hydrolysis reactor **14**. The hydrolysis step in the first stage **18** employs a rapid heat up of the solid feedstock **24** such that a residence time of the pyrolysis vapors in the hydrolysis reactor **14** is preferably less than approximately 1 minute, more preferably less than approximately 30 seconds and most preferably less than approximately 10 seconds.

The solid feedstock **24** used in the disclosed process may include a residual waste feedstock and/or a biomass feedstock containing lignin, lignocellulosic, cellulosic, hemicellulosic material, or any combination thereof.

5 Lignocellulosic material may include a mixture of lignin, cellulose and hemicelluloses in any proportion and also contains ash and moisture. Such material is more difficult to convert into fungible liquid hydrocarbon products than cellulosic and hemicellulosic material. It is an advantage of the present process that it can be used for lignocellulose-containing biomass. Therefore, the solid feedstock **24** used in the disclosed process preferably contains lignocellulosic material. Suitable lignocellulose-containing biomass includes woody biomass and agricultural and forestry products and residues (whole harvest energy crops, round wood, forest slash, bamboo, sawdust, bagasse, sugarcane tops and trash, cotton stalks, corn stover, corn cobs, castor stalks, Jatropha whole harvest, Jatropha trimmings, de-oiled cakes of palm, castor and Jatropha, coconut shells, residues derived from edible nut production and mixtures thereof), and municipal solid wastes containing lignocellulosic material. The municipal solid waste may include any combination of lignocellulosic material (yard trimmings, pressure-treated wood such as fence posts, plywood), discarded paper and cardboard and waste plastics, along with refractories such as glass, metal. Prior to use in the process disclosed herein, municipal solid waste may be optionally converted into pellet or briquette form. The pellets or briquettes are commonly referred to as Refuse Derived Fuel in the industry. Certain feedstocks (such as algae and lemna) may also contain protein and lipids in addition to lignocellulose. Residual waste feedstocks are those having mainly waste plastics. In a preferred embodiment

of the process disclosed herein, woody biomass, preferably wood, is used as the source of the biomass.

The solid feedstock **24** may be provided to the hydrolysis reactor **14** in the form of loose biomass particles having a majority of particles preferably less than about 3.5 millimeters (mm) in size or in the form of a biomass/liquid slurry. However, as appreciated by those skilled in the art, the solid feedstock **24** may be pre-treated or otherwise processed in a manner such that larger particle sizes may be accommodated. Suitable means for introducing the solid feedstock **24** into the hydrolysis reactor **14** include, but are not limited to, an auger, fast-moving (greater than about 5 minutes (m)/second (sec)) stream of carrier gas (such as inert gases and H₂), and constant-displacement pumps, impellers, turbine pumps or the like. In an embodiment of the present disclosure, a double-screw system having a slow screw for metering the solid feedstock **24** followed by a fast screw to push the solid feedstock **24** into the reactor without causing torrefaction in the screw housing is used for dosing. An inert gas or hydrogen flow is maintained over the fast screw to further reduce the residence time of the solid feedstock **24** in the fast screw housing.

The hydrolysis step is carried out in the hydrolysis reactor **14** at a temperature in the range of from approximately 350 Celsius (°C) to approximately 600 °C and a pressure in the range of from approximately 0.1 megapascal (MPa) to approximately 0.6 MPa (approximately 1-6 bar). The heating rate of the solid feedstock **24** is preferably greater than about 100 watts/meter² (W/m²). The weight hourly space velocity (WHSV) in grams (g) biomass/g catalyst/hour (h) for the hydrolysis step is in the range of from approximately 0.2 h⁻¹ to approximately 10 h⁻¹,

preferably in the range of from approximately 0.3 h^{-1} to 3 h^{-1} .

The hydropyrolysis step may operate at a temperature between approximately $300 \text{ }^{\circ}\text{C}$ and $650 \text{ }^{\circ}\text{C}$. The temperatures used in hydropyrolysis rapidly devolatilize the solid feedstock **24**. Thus, in a preferred embodiment, the hydropyrolysis step includes the use of an active catalyst (e.g., a deoxygenation catalyst) to stabilize the hydropyrolysis vapors. The activity of the catalyst used herein remains high and stable over a long period of time such that it does not rapidly coke. Catalyst particle sizes, for use in the hydropyrolysis reactor **14**, are preferably in the range of from approximately 0.3 mm to approximately 4.0 mm , more preferably in the range of from approximately 0.6 mm to approximately 3.0 mm , and most preferably in the range of from approximately 1 mm to approximately 2.4 mm .

Any deoxygenation catalyst suitable for use in the temperature range of the hydropyrolysis process may be used. Preferably, the deoxygenation catalyst is selected from sulfided catalysts having one or more metals from the group consisting of nickel (Ni), cobalt (Co), molybdenum (Mo) or tungsten (W) supported on a metal oxide. Suitable metal combinations include sulfided NiMo, sulfided CoMo, sulfided NiW, sulfided CoW and sulfided ternary metal systems having any 3 metals from the family consisting of Ni, Co, Mo and W. Monometallic catalysts such as sulfided Mo, sulfided Ni and sulfided W are also suitable for use. Metal combinations for the deoxygenation catalyst used in accordance with certain embodiments of the present disclosure include sulfided NiMo and sulfided CoMo. Supports for the sulfided metal catalysts include metal oxides such as, but not limited to, alumina, silica,

titania, ceria and zirconia. Binary oxides such as silica-alumina, silica-titania and ceria-zirconia may also be used. Preferably, the supports include alumina, silica and titania. In certain embodiments, the support contains recycled, regenerated and revitalized fines of spent hydrotreating catalysts (e.g., fines of CoMo on oxidic supports, NiMo on oxidic supports and fines of hydrocracking catalysts containing NiW on a mixture of oxidic carriers and zeolites). Total metal loadings on the deoxygenation catalyst are preferably in the range of from approximately 1.5 weight percent (wt%) to approximately 50 wt% expressed as a weight percentage of calcined deoxygenation catalyst in oxidic form (e.g., weight percentage of Ni (as NiO) and Mo (as MoO₃) on calcined oxidized NiMo on alumina support). Additional elements such as phosphorous (P) may be incorporated into the deoxygenation catalyst to improve the dispersion of the metal.

The first stage of the process disclosed herein produces the output **30** having a partially deoxygenated hydropyrolysis product. The term "partially deoxygenated" as used herein denotes a material in which at least 30 weight % (wt%), preferably at least 50 wt%, more preferably at least 70 wt% of the oxygen present in the original solid feedstock **24** (e.g., lignocelluloses-containing biomass) has been removed. The extent of oxygen removal refers to the percentage of the oxygen in the solid feedstock **24** (e.g., biomass), excluding that contained in the free moisture in the solid feedstock **24**. This oxygen is removed in the form of water (H₂O), carbon monoxide (CO) and carbon dioxide (CO₂) in the hydropyrolysis step. Although it is possible that nearly 100 wt% of the oxygen present in the solid feedstock **24** is

removed, generally at most 99 wt%, suitably at most 95 wt% will be removed in the hydrolysis step.

Char Removal

As discussed above, the output **30** produced from the hydrolysis step in the hydrolysis reactor **14** includes a mixed solid and vapor product that includes char, ash, catalyst fines, partially deoxygenated hydrolysis product, light gases ($C_1 - C_3$ gases, CO , CO_2 , hydrogen sulfide (H_2S), ammonia (NH_3) and H_2), H_2O vapor, vapors of C_4+ hydrocarbons and oxygenated hydrocarbons. Char, ash and catalyst fines are entrained with the vapor phase product. Therefore, between the hydrolysis and hydroconversion steps, the first stage **18** and the second stage **20**, respectively, char and catalyst fines are removed from the vapor phase product (e.g., the partially deoxygenated hydrolysis product). Any ash present may also be removed at this stage.

In certain embodiments, the hydrolysis reactor **14** may include solid separation equipment (e.g., cyclones), for example above a dense bed phase, to mitigate the entrainment of solid particles above a certain particle size. In addition, or alternatively, the solid separation equipment may be positioned downstream from the hydrolysis reactor **14** that removes the char and other solids in the output **30** to generate a vapor phase product **34**. For example, as illustrated in **FIG. 1**, the output **30** is fed to a solid separator **36** that separates/removes the solids (e.g., char, ash and catalyst fines **38**) from the output **30**. The char and catalyst fines **38** may be removed from the output **30** by cyclone separation, filtering, electrostatic precipitation, inertial separation, magnetic separation, or any other

suitable solid separation technique and combinations thereof. In one embodiment, the solid separator **36** includes one or more cyclones. For example, char may be removed by filtration from the vapor stream (e.g., the output **30**) or by way of filtering from a wash step-
5 ebullated bed. Back pulsing may be employed in removing char and other solids from the filters as long as hydrogen used in the disclosed process sufficiently reduces the reactivity of the pyrolysis vapors and renders the char
10 free-flowing.

In other embodiments, the solid separator **36** includes one or more filters or a combination of cyclones, filters and other suitable solid separation equipment to remove the entrained solids from the output **30**. For
15 example, the char **38** and other solids may be removed by cyclone separation followed by hot gas filtration. The hot gas filtration removes fines not removed in the cyclones. In this embodiment, the dust cake caught on the filters is more easily cleaned compared to the char
20 removed in the hot filtration of the aerosols produced in conventional fast pyrolysis because the hydrogen from the hydropyrolysis step stabilizes the free radicals and saturated the olefins. In accordance with another embodiment of the present disclosure, cyclone separation
25 followed by trapping the char and catalyst fines **38** in a high-porosity solid adsorbent bed is used to remove the char and catalyst fines **38** from the output **30**. By way of non-limiting example, high-porosity solid adsorbents suitable for trapping the char and catalyst fines **38**
30 include alumina silicate materials. Inert graded bed and/or filter materials may also be used to remove the char and catalyst fines **38** from the output **30** to generate the vapour phase product **34**.

The char and catalyst fines **38** may also be removed by bubbling the first stage product gas (e.g., the output **30**) through a re-circulating liquid. The re-circulated liquid includes a high boiling point portion of a finished oil from this process (e.g., from the second stage **20**) and is thus a fully saturated (hydrogenated), stabilized oil having a boiling point above approximately 370 °C. In certain embodiments, the finished oil may be a heavy oil generated in a separate process. The char or catalyst fines **38** from the first stage **18** are captured in this liquid. A portion of the liquid may be filtered to remove the fines **38** and a portion may be re-circulated back to the hydropyrolysis reactor **14**. By using a re-circulating liquid, the temperature of the char-laden process vapors from the first stage **18** is lowered to a temperature suitable for the hydroconversion step in the second stage **20**, while also removing fine particulates of char and catalyst. Additionally, employing liquid filtration avoids the use of hot gas filtration.

In accordance with another embodiment of the present disclosure, large-size NiMo or CoMo catalysts, deployed in an ebullated bed, are used for char removal to provide further deoxygenation simultaneous with the removal of fine particulates. Particles of this catalyst should be large, preferably in the range of from 15 to 30 mm in size, thereby rendering them easily separable from the fine char carried over from the hydropyrolysis reactor **14**, which is generally less than 200 mesh (smaller than 70 micrometers (µm)).

Second Stage

Following removal of the char and catalyst fines **38**, the vapor phase product **34** (e.g., the partially

deoxygenated hydropyrolysis product) together with the H₂, CO, CO₂, H₂O, and C₁ - C₃ gases from the hydropyrolysis step (e.g., the first stage **18**) are fed into the hydroconversion reactor **16** in the second stage **20** and subjected to a hydroconversion step. The hydroconversion step is carried out at a temperature in the range of from approximately 300 °C to approximately 600 °C and a pressure in the range of from approximately 0.1 MPa to approximately 0.6 MPa. As should be noted, pressures higher than 0.6 MPa may be used to tailor the boiling point distribution and composition of the resultant hydrocarbon product based on the desired specifications of the hydrocarbon fuel produced by the hydroprocessing. The weight hourly space velocity (WHSV) for this step is in the range of approximately 0.1 h⁻¹ to approximately 2 h⁻¹. The hydroconversion reactor **16** is a fixed bed reactor. However, in certain embodiments, the hydroconversion reactor **16** may be a fluidized bed reactor. The vapor phase product **34** undergoes hydroconversion in the presence of a hydroconversion catalyst to generate a fully deoxygenated hydrocarbon product **42**. The term "fully deoxygenated" as used herein denotes a material in which at least 98 wt%, preferably at least 99 wt%, more preferably at least 99.9 wt% of the oxygen present in the original solid feedstock **24** (e.g., lignocelluloses-containing biomass) has been removed. The hydrocarbon product **42** contains light gaseous hydrocarbons, such as methane, ethane, ethylene, propane and propylene, naphtha range hydrocarbons, middle-distillate range hydrocarbons, hydrocarbons boiling above 370 °C (based on ASTM D86), hydrogen and by-products of the hydroconversion reactions such as H₂O, H₂S, NH₃, CO and CO₂.

The solid feedstock **24** used in the disclosed processes may contain metals such as, but not limited to, sodium (Na), potassium (K), calcium (Ca) and phosphorus (P). These metals may poison the hydroconversion catalyst used in the second stage **20**. However, these metals may be removed with the char and ash products (e.g., the char and catalyst fines **38**) in the first stage **18**. Accordingly, the hydroconversion catalyst used in the hydroconversion step is protected from Na, K, Ca, P, and other metals present in the solid feedstock **24** which may otherwise poison the hydroconversion catalyst. Moreover, by hydropyrolysis of the solid feedstock **24** in the first stage **18**, the hydroconversion catalyst is advantageously protected from olefins and free radicals. The conditions under which hydropyrolysis occurs in the first stage **18** stabilize free radicals generated during high temperature devolatilization of the solid feedstock **24** (e.g., biomass) by the presence of hydrogen and catalyst, thereby generating stable hydrocarbon molecules that are less prone to, for example, coke formation reactions which may deactivate the catalyst.

The hydroconversion catalyst used in the hydroconversion step includes any suitable hydroconversion catalyst having a desired activity in the temperature range of the disclosed hydroconversion process. For example, the hydroconversion catalyst is selected from sulfided catalysts having one or more metals from the group consisting of Ni, Co, Mo or W supported on a metal oxide. Suitable metal combinations include sulfided NiMo, sulfided CoMo, sulfided NiW, sulfided CoW and sulfided ternary metal systems having any three metals from the family consisting of Ni, Co, Mo and W. Catalysts such as sulfided Mo, sulfided Ni and sulfided W are also suitable

for use. The metal oxide supports for the sulfided metal catalysts include, but are not limited to, alumina, silica, titania, ceria, zirconia, as well as binary oxides such as silica-alumina, silica-titania and ceria-zirconia. Preferred supports include alumina, silica and titania. The support may optionally contain regenerated and revitalized fines of spent hydrotreating catalysts (e.g., fines of CoMo on oxidic supports, NiMo on oxidic supports and fines of hydrocracking catalysts containing NiW on a mixture of oxidic carriers and zeolites). Total metal loadings on the catalyst are in the range of from approximately 5 wt% to approximately 35 wt% (expressed as a weight percentage of calcined catalyst in oxidic form, e.g., weight percentage of nickel (as NiO) and molybdenum (as MoO₃) on calcined oxidized NiMo on alumina catalyst). Additional elements such as phosphorous (P) may be incorporated into the catalyst to improve the dispersion of the metal. Metals can be introduced on the support by impregnation or co-mulling or a combination of both techniques. The hydroconversion catalyst used in the hydroconversion step may be, in composition, the same as or different to the deoxygenation catalyst used in the hydropyrolysis step (e.g., first stage **18**). In one embodiment of the present disclosure, the hydropyrolysis catalyst includes sulfided CoMo on alumina support and the hydroconversion catalyst includes sulfided NiMo on alumina support.

Following the hydroconversion step, the fully deoxygenated hydrocarbon product **42** is fed to one or more condensers that condenses the hydrocarbon product **42**. The condensed hydrocarbon product **42** is fed to a gas-liquid separator **50** to provide a liquid phase product **52** having substantially fully deoxygenated C₄₊ hydrocarbon liquid and

aqueous material. The term "substantially fully deoxygenated" is used herein to denote a material in which at least 90 wt% to 99 wt% of the oxygen present in the original lignocellulose containing biomass (e.g., the solid feedstock **24**) has been removed. Accordingly, the resulting liquid phase product **52** (e.g., the substantially fully deoxygenated hydrocarbon C₄₊ liquid) contains less than 2 wt%, preferably less than 1 wt%, and most preferably less than 0.1 wt% oxygen. The substantially fully deoxygenated C₄₊ hydrocarbon liquid is compositionally different from bio-oil that is generated using other low pressure hydroprocesses. For example, the oxygen content of bio-oil is greater (e.g., between approximately 5 wt% to 15 wt%) compared to the liquid phase product **52** (e.g., less than 2 wt%). Therefore, due, in part, to the lower oxygen content of the liquid phase product **52**, an amount of acid components (as measured by total acid number) and polar compounds is decreased compared to the bio-oil. By way of non-limiting example, the acid components include carboxylic acids, phenols and mixtures thereof.

The liquid phase product **52** undergoes a separation process in the gas-liquid separator **50** that separates and removes the aqueous material from the substantially fully deoxygenated C₄₊ hydrocarbon liquid. Any suitable phase separation technique may be used to separate and remove the aqueous material from the substantially fully deoxygenated C₄₊ hydrocarbon liquid, thereby generating the liquid phase product **52** having the substantially fully deoxygenated C₄₊ hydrocarbon and non-condensable gases **54**. The non-condensable gases **54** includes mainly H₂, CO, CO₂ and light hydrocarbon gases (typically C₁ to C₃ and may also contain some C₄₊ hydrocarbons).

In certain embodiments, the non-condensable gases **54** are fed to a gas clean-up system **58**. The gas clean-up system **58** removes H_2S , NH_3 and trace amounts of organic sulfur-containing compounds, if present, as by-products of the process, thereby generating a hydrocarbon stream **60** having CO , CO_2 , H_2 and the light hydrocarbon gases. The gas clean-up system **58** includes one or more process units that remove H_2S **62** and NH_3 **64** from the non-condensable gases **54** as by-products of the process. The hydrocarbon stream **60** may be sent to a separation, reforming and water-gas shift section **68** where hydrogen **28** is produced from the light hydrocarbon gases in the hydrocarbon stream **60** and renewable CO_2 **70** is discharged as a by-product of the process. A fuel gas stream may be recovered as a by-product of this process. The produced hydrogen **28** may be re-used in the process. For example, the hydrogen **28** may be recycled to the hydropyrolysis reactor **14** in the first stage **18**. Sufficient hydrogen is produced for use in the entire process disclosed herein. That is, the quantity of the hydrogen **28** produced by the separation, reforming and water-gas shift section **68** is equal to or greater than the hydrogen required to maintain fluidization and sustain chemical consumption of hydrogen in the process.

The liquid phase product **52** recovered from the gas-liquid separator **50** is fed to a product recovery section **72**. In the product recovery section **72**, aqueous product **74** is removed from the liquid phase product **52** to generate an intermediate liquid phase product **80**. The intermediate liquid phase product **80** may undergo distillation to separate the substantially fully deoxygenated C_{4+} hydrocarbon liquid into fractions according to ranges of the boiling points of the liquid products contained in the intermediate liquid phase product **80**. For example, the

substantially fully deoxygenated C₄₊ hydrocarbon liquid in the intermediate liquid phase product **80** includes naphtha range hydrocarbons, middle distillate range hydrocarbons (e.g., gasoil, diesel), vacuum gasoil (VGO) range hydrocarbons and kerosene.

For the purpose of clarity, "kerosenes" as used herein are hydrocarbons or oxygenated hydrocarbons recovered by distillation between an atmospheric-equivalent initial boiling point (IBP) and a final boiling point (FBP) measured according to standard ASTM distillation methods. ASTM D86 initial boiling point of kerosenes may vary from between approximately 130 °C to approximately 210 °C. Final boiling point of kerosenes, according to ASTM D86 distillation, may vary from between approximately 240 °C to approximately 315 °C.

The term "middle distillates" as used herein are hydrocarbons or oxygenated hydrocarbons recovered by distillation between an atmospheric-equivalent initial boiling point (IBP) and a final boiling point (FBP) measured according to standard ASTM distillation methods. ASTM D86 initial boiling point of middle distillates may vary from between approximately 150 °C to approximately 220 °C. Final boiling point of middle distillates, according to ASTM D86 distillation, may vary from between approximately 350 °C to approximately 380 °C. "Naphtha" as used herein is one or more hydrocarbons or oxygenated hydrocarbons having four or more carbon atoms and having an atmospheric-equivalent final boiling point that is greater than approximately 90 °C but less than approximately 200 °C. A small amount of hydrocarbons produced in the process (approximately less than 3 wt% of total C₄₊ hydrocarbons, and preferably less than 1 wt% of total C₄₊ hydrocarbons) boil at temperatures higher than

those for the middle distillates as defined above. That is, these hydrocarbons have a boiling range similar to vacuum-gasoil produced by distillation of petroleum.

Gasoline is predominantly naphtha-range hydrocarbons and is used in spark-ignition internal combustion engines. In the United States, ASTM D4814 standard establishes the requirements of gasoline for ground vehicles with spark-ignition internal combustion engines. Gasoil (GO)/diesel is predominantly middle-distillate range hydrocarbons and is used in compression-ignition internal combustion engines. In the United States, ASTM D975 standard covers the requirements of several grades of diesel fuel suitable for various types of diesel engines.

Accordingly, in the illustrated embodiment, the intermediate liquid product **80** is fed to a distillation unit **82** to recover gasoline product **84**, a distillate product **86** (e.g., a middle distillate) and a kerosene/jet fuel **88**.

The kerosene/jet fuel product **88** is substantially fully free from oxygen, sulfur and nitrogen. In certain embodiments, the oxygen content of the distillate product **88** is less than approximately 1.50 wt %. For example, the oxygen content may be approximately 1.40 wt %, 1.25 wt %, 0.50 wt %, 0.25 wt %, or 0.10 wt % or less. In one embodiment, the sulfur content is less than 100 ppmw. For example, the sulfur content may be approximately 75 ppmw, 50 ppmw, 25 ppmw, 10 ppmw, 5 ppmw, 1 ppmw or less. Regarding the nitrogen content, in certain embodiments, the nitrogen content of the substantially fully deoxygenated C₄₊ hydrocarbon liquid is less than 1000 ppmw. For example, the nitrogen content may be approximately 750 ppmw, 500 ppmw, 250 ppmw, 100 ppmw, 75 ppmw, 50 ppmw, 25 ppmw, 10 ppmw, or 1 ppmw or less.

The hydrocarbon liquid products such as the kerosene/jet fuel product **88** generated from hydroprocessing of solid biomass feedstock (e.g., the solid feedstock **24**) may need additional processing to upgrade and improve certain product properties such as density, sulfur and/or nitrogen content, aromatics content, among others, and facilitate tailoring the overall hydrocarbon product to certain location and market specifications, among other benefits. However, the additional processing to upgrade the kerosene product **88** introduces complexity to the process, while also increasing the overall cost of producing commercially viable aviation fuel compositions having the desired specifications set forth by various fuel regulations. However, it has been recognized that by blending the kerosene product **88** with a paraffinic kerosene and/or optionally, a petroleum-derived kerosene base fuel, the product properties of the resulting aviation fuel composition (e.g., low temperature viscosity properties, lubricity and net heat of combustion properties) are improved without requiring additional processing to upgrade the kerosene product **88**. Therefore, in accordance with an embodiment of the present disclosure, the kerosene product **88** is mixed with a paraffinic kerosene and/or a petroleum-derived kerosene **90** to yield a commercially viable aviation fuel composition **92** that does not require further upgrading via complex and costly processing.

Paraffinic-based kerosene

A second essential component of the aviation fuel compositions of the present invention is a paraffinic-based kerosene. The paraffinic-based kerosene used herein comprises normal and iso-paraffins in an amount of greater than 95 vol%.

From the viewpoint of optimising the low temperature viscosity characteristics, the paraffinic-based kerosene is preferably present in the fuel composition in an amount of from 1 vol% to 80 vol%, more preferably from 10 vol% to 5
60 vol%, even more preferably from 15 vol% to 40 vol%, based on the total aviation fuel composition.

From the viewpoint of optimising the lubricity characteristics, the paraffinic-based kerosene is preferably present in the fuel composition in an amount of
10 from 5 vol% to 50 vol%, more preferably from 10 vol% to 30 vol%, even more preferably from 15 vol% to 25 vol%, based on the total aviation fuel composition.

The paraffinic-based kerosene for use in the present invention can be derived from any suitable source as long
15 as it is suitable for use in an aviation fuel composition. In a preferred embodiment of the present invention, the paraffinic-based kerosene is a Fischer-Tropsch derived kerosene.

While Fischer-Tropsch derived kerosene is the preferred paraffinic-based kerosene for use herein, the
20 term "paraffinic-based kerosene" as used herein also includes those paraffinic kerosenes derived from the hydrotreating of vegetable oils (HVO) which may also be called HEFA, hydroprocessed esters and fatty acids.
25 Feedstocks for producing HEFA can include mono-, di- and triglycerides, free fatty acids and fatty acid esters, as well as those paraffinic kerosenes derived from an alcohol to jet process.

The HVO process is based on an oil refining
30 technology. In the process, hydrogen is used to remove oxygen from the triglyceride vegetable oil molecules and to split the triglyceride into three separate chains thus creating paraffinic hydrocarbons.

In accordance with the present invention, the paraffinic kerosene for use herein, (e.g. the Fischer-Tropsch derived kerosene or the hydrogenated vegetable oil derived kerosene) will preferably consist of at least 95% w/w, more preferably at least 98% w/w, even more preferably at least 99.5% w/w, and most preferably up to 100% w/w of paraffinic components, preferably iso- and normal paraffins.

By "Fischer-Tropsch derived" is meant that a fuel or base oil is, or derives from, a synthesis product of a Fischer-Tropsch condensation process. The term "non-Fischer-Tropsch derived" may be interpreted accordingly. GTL (gas-to-liquid) fuels and PTL (power-to-liquid) fuels are examples of Fischer-Tropsch derived fuels.

The Fischer-Tropsch reaction converts carbon monoxide and hydrogen into longer chain, usually paraffinic, hydrocarbons:
$$n(\text{CO} + 2\text{H}_2) = (-\text{CH}_2-)_n + n\text{H}_2\text{O} + \text{heat}$$
in the presence of an appropriate catalyst and typically at elevated temperatures (e.g. 125 to 300°C, preferably 175 to 250°C) and/or pressures (e.g. 5 to 100 bar, preferably 12 to 50 bar). Hydrogen: carbon monoxide ratios other than 2:1 may be employed if desired.

The carbon monoxide and hydrogen may themselves be derived from organic or inorganic, natural or synthetic sources, typically either from natural gas or from organically derived methane.

Gas oil, kerosene fuel and base oil products may be obtained directly from the Fischer-Tropsch reaction, or indirectly for instance by fractionation of Fischer-Tropsch synthesis products or from hydrotreated Fischer-Tropsch synthesis products. Hydrotreatment can involve hydrocracking to adjust the boiling range (see, e. g. GB2077289 and EP0147873) and/or hydroisomerisation which

can improve cold flow properties by increasing the proportion of branched paraffins. EP0583836 describes a two-step hydrotreatment process in which a Fischer-Tropsch synthesis product is firstly subjected to hydroconversion under conditions such that it undergoes substantially no isomerisation or hydrocracking (this hydrogenates the olefinic and oxygen-containing components), and then at least part of the resultant product is hydroconverted under conditions such that hydrocracking and isomerisation occur to yield a substantially paraffinic hydrocarbon fuel or oil. Desired kerosene fuel fraction(s) may subsequently be isolated for instance by distillation.

Other post-synthesis treatments, such as polymerisation, alkylation, distillation, cracking-decarboxylation, isomerisation and hydrotreatment, may be employed to modify the properties of Fischer-Tropsch condensation products, as described for instance in US-A-4125566 and US-A-4478955.

Typical catalysts for the Fischer-Tropsch synthesis of paraffinic hydrocarbons comprise, as the catalytically active component, a metal from Group VIII of the periodic table, in particular ruthenium, iron, cobalt or nickel. Suitable such catalysts are described for instance in EP0583836.

An example of a Fischer-Tropsch based process is the SMDS (Shell Middle Distillate Synthesis) described in "The Shell Middle Distillate Synthesis Process", van der Burgt et al (vide supra). This process (also sometimes referred to as the Shell "Gas-to-Liquids" or "GTL" technology) produces diesel range products by conversion of a natural gas (primarily methane) derived synthesis gas into a heavy long-chain hydrocarbon (paraffin) wax which can then be hydroconverted and fractionated to produce liquid transport fuels such as gasoils and kerosene. Versions of

the SMDS process, utilising fixed-bed reactors for the catalytic conversion step, are currently in use in Bintulu, Malaysia, and in Pearl GTL, Ras Laffan, Qatar. Kerosenes and (gas)oils prepared by the SMDS process are commercially available for instance from the Royal Dutch/Shell Group of Companies.

By virtue of the Fischer-Tropsch process, a Fischer-Tropsch derived kerosene has essentially no, or undetectable levels of, sulphur and nitrogen. Compounds containing these heteroatoms tend to act as poisons for Fischer-Tropsch catalysts and are therefore removed from the synthesis gas feed. Further, the process as usually operated produces no or virtually no aromatic components.

For example, the aromatics content of a Fischer-Tropsch kerosene, as determined for instance by ASTM D4629, will typically be below 1% w/w, preferably below 0.5% w/w and more preferably below 0.1% w/w.

Generally speaking, Fischer-Tropsch derived fuels have relatively low levels of polar components, in particular polar surfactants, for instance compared to petroleum derived fuels. It is believed that this can contribute to improved antifoaming and dehazing performance. Such polar components may include for example oxygenates, and sulphur and nitrogen containing compounds. A low level of sulphur in a Fischer-Tropsch derived fuel is generally indicative of low levels of both oxygenates and nitrogen-containing compounds, since all are removed by the same treatment processes.

The Fischer-Tropsch derived kerosene fuel used in the present invention has a distillation range typically within the 160°C to 250°C range (ASTM D86). Again, Fischer-Tropsch derived fuels tend to be low in undesirable fuel components such as sulphur, nitrogen and aromatics.

5 The Fischer-Tropsch derived kerosene used in the present invention will typically have a density (as measured by ASTM D4052) of from 720 to 780, preferably from 730 to 770, more preferably from 750 to 760 kg/m³ at 15°C.

10 The Fischer-Tropsch derived kerosene used in the present invention preferably has a kinematic viscosity at -40°C (as measured according to ASTM D7945) in the range from 7 mm²/s to 12 mm²/s, preferably from 8 mm²/s to 10 mm²/s.

The Fischer-Tropsch derived kerosene used in the present invention preferably has a sulphur content (ASTM D2622) of 5 ppmw (parts per million by weight) or less, preferably of 2 ppmw or less.

15 The Fischer-Tropsch derived kerosene as used in the present invention is that produced as a distinct finished product, that is suitable for sale and used in applications that require the particular characteristics of a kerosene fuel. In particular, it exhibits a
20 distillation range falling within the range normally relating to Fischer-Tropsch derived kerosene fuels, as set out above.

A fuel composition according to the present invention may include a mixture of two or more Fisher-Tropsch derived kerosene fuels.

25 As mentioned above, a Fischer-Tropsch derived kerosene also encompasses PTL (power-to-liquid) kerosene. In a power-to-liquid process, the syngas is derived from renewable or recycled sources such as CO₂ and H₂O, and
30 electricity.

In accordance with the present invention, the Fischer-Tropsch derived components used herein (i.e. the Fischer-Tropsch derived kerosene) will preferably comprise no more than 3% w/w, more preferably no more than 2% w/w,

even more preferably no more than 1% w/w of cycloparaffins (naphthenes), by weight of the Fischer-Tropsch derived component.

The Fischer-Tropsch derived components used herein (i.e. the Fischer-Tropsch derived kerosene) preferably comprise no more than 1% w/w, more preferably no more than 0.5% w/w, of olefins, by weight of the Fischer-Tropsch derived component.

Petroleum-derived kerosene base fuel

A third optional, but preferred, component of the aviation fuel composition herein is a petroleum-derived kerosene base fuel.

A petroleum-derived kerosene base fuel or kerosene range hydrocarbon component is any petroleum-derived kerosene that may be useful as a jet fuel, or a jet fuel blending component having a boiling point in the range of 130°C to 300°C, at atmospheric pressure (as measured by ASTM D86), preferably in the range of 140°C to 300°C, and most preferably in the range of 145°C to 300°C. For a jet fuel blending component, the kerosene base fuel (whether single stream or a mixture) can have a flash point of 38°C or above (measured by ASTM D56), and a density at 15°C of at least 760 kg/m³ (as measured by D4052). The kerosene base fuel may be any petroleum-derived jet fuel known to skilled artisans, including kerosene fuels meeting at least one of Jet A, Jet A-1, F-24, JP-8, Jet B or AN-8 specification. Preferably, the kerosene base fuel is a kerosene that can meet the jet fuel specification properties according to the invention.

For example, petroleum-derived kerosene fuels meeting Jet A or Jet A-1 requirements and a kerosene stream used in Jet A or Jet A-1 production are listed in Table A. It is also contemplated that petroleum-derived kerosene fuels which do not meet Jet A or Jet A-1

specifications may be used as kerosene base fuels that can be upgraded to meet such specifications according to the present invention.

Table A

Jet fuel Produced Using:
Straight run kerosene stream.
Caustic washing of straight run kerosene.
A sweetening process such as Merox®, Merichem®, or Bender process.
Hydroprocessed jet fuel.

5

As another example, the low boiling fraction as separated from a mineral gas oil may be used as such or in combination with petroleum-derived kerosene, suitably made at the same production location. As the low boiling
10 fraction may already comply with a jet fuel specification, it is evident that the blending ratio between said component and the petroleum-derived kerosene may be freely chosen. The petroleum-derived kerosene will typically boil for more than 90 vol.% within the usual kerosene
15 range of 145°C to 300°C (ASTM D86), depending on grade and use. It will typically have an initial boiling point in the range 130°C to 190°C, and a final boiling point in the range 220°C to 300°C. It will typically have a density from 775 to 840 kg/m³ at 15°C (e.g., ASTM D4052 or IP 365).
20 Its kinematic viscosity at -20°C (ASTM D445) might suitably be from 1.2 to 8.0 mm²/s.

The kerosene base fuel or kerosene range hydrocarbon component may be a straight run kerosene fraction as isolated by distillation from a crude oil source or a

kerosene fraction isolated from the effluent of typical refinery conversion processes, preferably hydrocracking. The kerosene fraction may also be the blend of straight run kerosene and kerosene as obtained in a hydrocracking process. Suitably the properties of the mineral derived kerosene are those of the desired jet fuel.

Aromatic content of the kerosene base fuel may vary in the range of 0 to 25 vol.%, preferably 3 to 25 vol.%, more preferably 15 to 20 vol.% based on the fuel (as measured by ASTM 1319). Typical density of the petroleum-derived kerosene at 15°C is in the range of 775 kg/m³ to 840 kg/m³ (as measured by D4052). The kerosene base fuel most useful herein may have a density of at least 760 kg/m³, more preferably at least 775 kg/m³, to preferably at most 840 kg/m³, and more preferably at most 820 kg/m³.

The kerosene base fuel may be a single stream from a refining stream (petroleum-derived kerosene), or a mixture of one or more refining streams, or a mixture of refining streams and one or more synthetic kerosene components, or one or more synthetic kerosene streams (other than the synthetic cyclo-paraffinic blending component and the paraffinic kerosene component) approved by ASTM D7566 or equivalent specifications.

From the viewpoint of optimising low temperature viscosity characteristics the petroleum-derived kerosene, when present, is preferably present at a level from 5 to 90 vol%, more preferably from 20 to 80 vol%, even more preferably from 30 to 60 vol%, based on the total aviation fuel composition.

From the viewpoint of optimising the lubricity characteristics, the petroleum-derived kerosene, when present, is preferably present at a level from 5 to 20

vol%, more preferably from 5 to 15 vol%, even more preferably from 5 to 10 vol%, based on the total aviation fuel composition.

5 The aviation fuel composition of the present invention can be prepared by a process which comprises mixing the cycloparaffinic kerosene derived from hydropyrolysis and hydroconversion of a biomass containing lignocellulose with the paraffinic-based kerosene comprising normal and iso-paraffins in an amount of greater
10 than 95 vol%, and, optionally, a petroleum-derived jet fuel. The mixing is carried out using standard blending techniques known to a person skilled in the art.

The aviation fuel compositions of the present invention preferably meet most or all of the requirements
15 of the D7566 jet fuel specification.

The aviation fuel compositions of the present invention preferably has a boiling point in the range from 130°C to 300°C at atmospheric pressure, a flash point of at least 35°C, more preferably greater than 38°C, a density at
20 15°C from 750 to 840 kg/m³, more preferably from 775 kg/m³ to 840 kg/m³, a freezing point below -40°C, a net heat of combustion greater than 42.8 MJ/kg, a smoke point of at least 18 mm when the naphthalene content is less than 3 vol%, a wear scar diameter less than 0.85 mm, kinematic
25 viscosity less than 8 cSt at -20°C and less than 12 cSt at -40°C, a maximum aromatics content of 25 vol%, and a total sulfur content less than 3000 ppm by weight.

It has surprisingly been found that the aviation fuel composition of the present invention provides improved
30 performance properties, in particular improved low temperature viscosity and improved lubricity.

Hence according to a further aspect of the present

invention there is also provided a use of an aviation fuel composition as described hereinabove for providing improved low temperature viscosity.

5 According to yet a further aspect of the present invention there is provided a use of an aviation fuel composition as described hereinabove for providing improved lubricity.

10 It has also been surprisingly found that the low temperature viscosity characteristics of an aviation fuel composition can be improved when the aviation fuel composition comprises a combination of cycloparaffinic kerosene derived from hydropyrolysis and hydroconversion of a biomass containing lignocellulose and a petroleum-derived jet fuel. Hence according to another aspect of the present
15 invention there is provided the use of an aviation fuel composition comprising:

a cycloparaffinic kerosene generated from hydropyrolysis and hydroconversion of a solid biomass containing lignocellulose, wherein the cycloparaffinic kerosene
20 comprises at least 90 vol% cycloparaffins and less than 1 vol% aromatics; and

a petroleum-derived kerosene,
for improving low temperature viscosity.

25 The invention will now be further illustrated by reference to the following non-limiting examples.

Examples

Examples 1-18

30 Aviation fuel compositions comprising various ratios of petroleum-derived Jet A1, synthetic GTL kerosene and bio-derived cycloparaffinic kerosene (CPK) were prepared and evaluated against ASTM D7566 semi-synthetic commercial jet fuel specification.

The petroleum-derived Jet A-1 was sourced from the Shell Haven Terminal (Essex, UK). The GTL kerosene was sourced from the Shell Pearl Refinery (Ras Laffan, Qatar). The CPK kerosene was produced from the biodiesel fraction resulting from hydropyrolysis and hydroconversion of pinewood chips according to a process similar to the process discussed above with reference to **FIG. 1**. The GTL-containing fuel compositions prepared are set out in Table 1 below which shows the volumetric blend ratio of CPK, GTL and conventional jet fuel. The fuel compositions were prepared by blending the constituents by hand mixing under ambient conditions.

Table 1

Example:	Type of fuel	Volumetric Blend Ratio		
		CPK	GTL	Conventional jet fuel
1*	Neat Fuel	0	0	1
2*	Neat Fuel	0	1	0
3*	Neat Fuel	1	0	0
4	CPK/Conventional	0.2	0	0.8
5	CPK/Conventional	0.4	0	0.6
6	CPK/Conventional	0.6	0	0.4
7	CPK/Conventional	0.8	0	0.2
8*	GTL/Conventional	0	0.2	0.8
9*	GTL/Conventional	0	0.4	0.6
10*	GTL/Conventional	0	0.6	0.4
11	CPK/GTL	0.4	0.6	0
12	CPK/GTL	0.6	0.4	0
13	CPK/GTL	0.8	0.2	0
14	CPK/GTL/Conventional	0.2	0.4	0.4
15	CPK/GTL/Conventional	0.2	0.2	0.6
16	CPK/GTL/Conventional	0.4	0.2	0.4
17	CPK/GTL/Conventional	0.6	0.2	0.2
18	CPK/GTL/Conventional	0.4	0.4	0.2

*not according to the present invention

Examples 19-34

Aviation fuel compositions comprising various ratios of petroleum-derived Jet A1, HEFA kerosene (also known as Sustainable Aviation Fuel (SAF)) and bio-derived cycloparaffinic kerosene (CPK) were prepared and evaluated

against ASTM D7566 semi-synthetic commercial jet fuel specification. As used herein, the term 'HEFA' means Hydroprocessed Esters and Fatty Acids). The term 'HEFA' can be used interchangeably with the term 'HVO' (Hydrotreated Vegetable Oil).

The petroleum-derived Jet A-1 was sourced from the Shell Haven Terminal (Essex, UK).

The HEFA kerosene designated as 'HEFA 1' in Table 2 below was produced by hydroisomerization of a blend of an already deoxygenated C15-C18 n-paraffinic feedstock obtained from the open market and a C18 n-paraffinic feedstock obtained from Alfa Aesar. The hydroisomerization step can be carried out essentially as disclosed in Example 1 of co-pending European patent application no. EP21212771.6 with any changes in process conditions noted below. In a reactor, a single catalyst bed was used. 30 ML of a hydroisomerization catalyst comprising 0.7 wt% Pt on a carrier comprising 75 wt% silica and 25 wt% zeolite ZSM-12. The catalyst bed was operated at 340°C. The feedstock was supplied to the catalyst bed at a WHSV of 1.0 g fresh combined liquid per mL hydroisomerisation catalyst per hour. A gas stream comprising 100 vol% hydrogen was supplied to the catalyst bed at a gas-to-oil ratio of 500 NL/kg. The total pressure at the reactor outlet was 73 barg (7.3 MPag).

The HEFA kerosene designated as 'HEFA 2' in Table 2 below was produced by deoxygenation of a distillers corn oil feedstock, followed by a hydroisomerization step. The deoxygenation step can be carried out as taught in the Example of WO2022/038265. The hydroisomerization step can be carried out essentially as disclosed in Example 1 of co-pending European patent application no. EP21212771.6 with any changes in process conditions noted below. The feedstock of the hydroisomerization step is the n-

paraffinic effluent of the deoxygenation step. In a reactor, a single catalyst bed was used. 30 ML of a hydroisomerization catalyst comprising 0.7 wt% Pt on a carrier comprising 75 wt% silica and 25 wt% zeolite ZSM-12. The catalyst bed was operated at 340°C. The feedstock was supplied to the catalyst bed at a WHSV of 1.0 g fresh combined liquid per mL hydroisomerisation catalyst per hour. A gas stream comprising 100 vol% hydrogen was supplied to the catalyst bed at a gas-to-oil ratio of 500 NL/kg. The total pressure at the reactor outlet was 73 barg (7.3 MPag).

The CPK kerosene was produced from the biodiesel fraction resulting from hydropyrolysis and hydroconversion of pinewood chips according to a process similar to the process discussed above with reference to **FIG. 1**.

The HEFA-containing fuel compositions prepared are set out in Table 2 below which shows the volumetric blend ratio of CPK, HEFA and conventional jet fuel. The fuel compositions were prepared by blending the constituents by hand mixing under ambient conditions.

Table 2

Example	Type of fuel	Volumetric Blend Ratio			
		CPK	HEFA 1	HEFA 2	Conventional jet fuel
19	Neat HEFA 1	0	1	0	0
20	Neat HEFA 2	0	0	1	0
21	HEFA 1/Conventional	0	0.5	0	0.5
22	CPK/HEFA 1	0.5	0.5	0	0
23	CPK/HEFA 1/Conventional	0.2	0.4	0	0.4
24	CPK/HEFA 1/Conventional	0.2	0.2	0	0.6
25	CPK/HEFA 1/Conventional	0.4	0.2	0	0.4
26	CPK/HEFA 1/Conventional	0.6	0.2	0	0.2
27	CPK/HEFA 1/Conventional	0.4	0.4	0	0.2

28	HEFA 2/Conventional	0	0	0.5	0.5
29	CPK/HEFA 2	0.5	0	0.5	0
30	CPK/HEFA 2/Conventional	0.2	0	0.4	0.4
31	CPK/HEFA 2/Conventional	0.2	0	0.2	0.6
32	CPK/HEFA 2/Conventional	0.4	0	0.2	0.4
33	CPK/HEFA 2/Conventional	0.6	0	0.2	0.2
34	CPK/HEFA 2/Conventional	0.4	0	0.4	0.2

Neat samples of conventional Jet A-1, GTL kerosene and CPK kerosene fuel (Examples 1 to 3), neat samples of HEFA kerosene (Examples 19 and 20), as well as the fuel compositions of Examples 4-18 set out in Table 1 were tested against ASTM D7566 semi-synthetic jet fuel specification test methods. The test methods used in ASTM D7566 are shown in Table 3 below and the results of these tests are shown in Tables 4 - 8 below.

The fuel compositions of Examples 21-34 underwent density and viscosity measurements using the relevant test methods set out in ASTM D7566. The results of these tests are shown in Tables 9-11 below.

Table 3: Test methods used for analysis of samples by property

Test Description	Test Method Used	Limits (if required by ASTM D7566)
Density at 15 °C, kg/m ³	ASTM D4052	775-840
Initial boiling point, °C	ASTM D86	-
5% recovered T, °C		-
10% recovered T, °C		205 max
20% recovered T, °C		-
30% recovered T, °C		-
40% recovered T, °C		-
50% recovered T, °C		Report
60% recovered T, °C		-
70% recovered T, °C		-
80% recovered T, °C		-
90% recovered T, °C		Report

95% recovered T, °C		-
Final boiling point, °C		300 max
Distillation loss, vol%		1.5 max
Distillation residue, vol%		1.5 max
Net heat of combustion, MJ/kg	ASTM D4809	42.8 min
Total aromatics, vol%	ASTM D6379	8.4-26.5
Freezing point, °C	ASTM D5972	-40 min
Viscosity at -20°C, cSt	ASTM D7945	8.0 max
Viscosity at -40°C, cSt	ASTM D7945	12.0 max
Flash point, °C	ASTM D56	38 min
Smoke point, mm	ASTM D1322	18.0 min
Naphthalenes, vol%	ASTM D1840	3.0 max
Lubricity wear scar, mm	ASTM D5001	0.85 max
Total sulfur, ppm	ASTM D2622	3000 max
JFTOT test temperature,	ASTM D3241	260
JFTOT pressure drop, mm Hg	ASTM D3241	25.0 max
JFTOT deposit thickness (MWETR), nm	ASTM D3241	85 max

Table 4

Test	HEFA 1 (Eg. 19)	HEFA 2 (Eg. 20)	CPK (Eg. 3)	GTL (Eg. 2)	Conventional (Eg. 1)
Density at 15 °C, kg/m ³	754.2	763.5	833.3	754.7	798.5
Initial boiling point, °C	166.6	178	144.7	170.5	148.3
5% recovered T, °C	173.5	195.9	156.0	181.7	163.0
10% recovered T, °C	175.5	203.6	160.6	184.4	166.7
20% recovered T, °C	180.2	216.3	166.8	188.4	172.8
30% recovered T, °C	185.4	227.6	173.6	192.7	179.5
40% recovered T, °C	190.6	237.7	181.1	197.5	186.8
50% recovered T, °C	196.6	245	189.7	202.7	195.4
60% recovered T, °C	203.1	250.5	200.5	208.5	205.9
70% recovered T, °C	210.1	254.8	212.8	214.8	217.3
80% recovered T, °C	218.7	258.6	227.9	221.6	229.7
90% recovered T, °C	228.2	262.7	247.2	229.5	245.5

95% recovered T, °C	234.9	265.6	258.7	234.6	259.4
Final boiling point, °C	240.3	268.4	269.6	239.1	274.4
Distillation recovery, vol%	97.6	97.6	98.4	98.5	98.1
Distillation residue, vol%	1.3	1.6	1.2	1.1	1.2
Total recovery, vol%	98.9	99.2	98.4	99.6	99.3
Net heat of combustion MJ/kg	-	-	43.006	44.148	43.228
Hydrogen content, weight%	-	-	13.88	15.38	13.90
Total aromatics, vol%	<10	<10	<10.0	<10.0	18.9
Freezing point, °C	<-83.1	<-83.1	<-80.0	-50.8	-52.1
Viscosity at -20°C, cSt	4.187	4.524	4.447	4.311	3.740
Viscosity at -40°C, cSt	-	-	8.631	8.946	7.362
Flash point, °C	-	-	44.5	55.0	42.0
Smoke point, mm	-	-	26.8	55.6	23.4
Naphthalenes, mass%	-	-	0	0	0.28
Naphthalenes, vol%	-	-	<0.08	<0.08	0.23
Ignition delay, ms	-	-	5.77	3.37	4.58
Derived cetane number, a.u.	-	-	36.8	59.8	45.2
Lubricity wear scar, mm	-	-	0.73	0.71	0.61
Total sulfur, ppm			<3	<3	151
Mercaptan sulfur, m%			0	0	-
JFTOT Test Temperature, °C			355	355	
JFTOT Test Duration, hr			5	5	
JFTOT pressure drop, mmHg			0.4	0	-

JFTOT deposit thickness (MWETR), nm			79.00	10.25	-
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Table 5

Test	Eg.4	Eg.5	Eg.6	Eg.7
Density 15 °C, kg/m ³	805.4	812.3	819.3	826.5
Initial boiling point, °C	148.0	146.8	146.4	144.9
5% recovered T, °C	161.9	161.1	159.1	158.5
10% recovered T, °C	165.3	161.4	163.4	161.7
20% recovered T, °C	171.7	170.3	169.6	168.3
30% recovered T, °C	178.1	176.8	175.6	175.0
40% recovered T, °C	185.5	184.6	183.5	182.2
50% recovered T, °C	194.6	193.3	192.2	191.3
60% recovered T, °C	204.5	203.8	202.9	201.9
70% recovered T, °C	216.1	215.4	214.8	214.1
80% recovered T, °C	228.7	228.6	228.6	228.4
90% recovered T, °C	245.3	245.5	246.2	246.7
95% recovered T, °C	258.4	258.9	258.5	259.2
Final boiling point, °C	273.5	272.1	271.7	271.2
Distillation recovery, vol%	98.3	98.6	98.5	98.5
Distillation residue, vol%	1.2	1.2	1.2	1.2
Total recovery, vol%	99.5	99.8	99.7	99.7
Net heat of combustion, MJ/kg	43.094	42.960	43.072	42.910
Hydrogen content, weight %	13.92	13.94	13.91	13.93
Monoaromatics, vol%	14.4	11.1	<10.0	<10.0
Diaromatics, vol%	0.9	0.8	0.5	0.3
Total aromatics, vol%	15.4	11.9	<10.0	<10.0
Estimated aromatics, vol% ¹	15.12	11.34	7.56	3.78
Freezing point, °C	-54.7	-57.6	-58.4	-72.5
Viscosity at -20°C, cSt	3.821	3.940	4.084	4.255
Viscosity at -40°C, cSt	7.504	7.727	7.987	8.329
Flash point, °C	40.5	39.5	38.55	37.5
Smoke point, mm	23.9	24.6	25.2	25.8
Naphthalenes, mass%	0.88	0.67	0.45	0.23
Naphthalenes, vol%	0.71	0.55	0.37	0.19
Ignition delay, ms	4.96	5.17	5.41	5.62
Derived cetane number, a.u.	42.1	40.6	38.9	37.7
Lubricity wear scar, mm	0.65	0.67	0.69	0.68
Total sulfur, ppm	164.0	120.0	86.0	38.6

1. Estimated aromatics content was calculated using the measured aromatics content from the neat fuels and the relative ratios of the neat fuels in the blend.

Table 6

Test	Eg.8	Eg.9	Eg.10
Density 15 °C, kg/m ³	789.6	780.9	772.0
Initial boiling point, °C	153.1	156.9	159.5
5% recovered T, °C	166.3	168.8	173.2
10% recovered T, °C	169.6	173.0	176.2
20% recovered T, °C	175.7	178.7	182.0
30% recovered T, °C	182.2	184.9	187.9
40% recovered T, °C	189.2	191.3	193.8
50% recovered T, °C	197.5	199.2	200.6
60% recovered T, °C	206.6	207.2	207.9
70% recovered T, °C	216.4	216.1	215.9
80% recovered T, °C	227.7	226.0	224.6
90% recovered T, °C	241.6	238.3	235.3
95% recovered T, °C	253.9	248.4	244
Final boiling point, °C	269.8	264.6	259.9
Distillation recovery, vol%	98.2	98.3	98.2
Distillation residue, vol%	1.2	1.2	1.2
Total recovery, vol%	99.4	99.5	99.4
Net heat of combustion, MJ/kg	43.344	43.528	43.680
Hydrogen content, weight %	14.22	14.48	14.78
Monoaromatics, vol%	14.7	10.8	<10.0
Diaromatics, vol%	1.0	0.7	0.4
Total aromatics, vol%	15.6	11.5	<10.0
Estimated aromatics, vol% ¹	15.12	11.34	7.56
Freezing point, °C	-52.6	-52.6	-52.6
Viscosity at -20°C, cSt	3.816	3.922	4.039
Viscosity at -40°C, cSt	7.583	7.854	8.179
Flash point, °C	44.0	46.0	48.5
Smoke point, mm	26.9	31.4	37.8
Naphthalenes, mass%	0.93	0.70	0.47
Naphthalenes, vol%	0.74	0.55	0.36
Ignition delay, ms	4.40	4.06	3.83
Derived cetane number, a.u.	46.9	50.4	53.2
Lubricity wear scar, mm	0.68	0.70	0.70
Total sulfur, ppm	162.0	122.0	87.2

1. Estimated aromatics content was calculated using the measured aromatics content from the neat fuels and the relative ratios of the neat fuels in the blend

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Table 7

Test	Eg.11	Eg.12	Eg.13
Density 15 °C, kg/m ³	786.5	802.2	817.9
Initial boiling point, °C	156.1	152.3	145.6
5% recovered T, °C	170.4	165.4	160.9
10% recovered T, °C	173.6	169.7	164.5

20% recovered T, °C	179.7	175.5	170.6
30% recovered T, °C	185.7	181.8	177.6
40% recovered T, °C	191.8	188.5	185.0
50% recovered T, °C	198.8	196.3	193.2
60% recovered T, °C	206.2	204.9	203.3
70% recovered T, °C	214.7	214.5	214.2
80% recovered T, °C	223.7	225.0	227.1
90% recovered T, °C	235.3	239.0	243.3
95% recovered T, °C	244.3	249.6	254.9
Final boiling point, °C	257.0	262.9	266.0
Distillation recovery, vol%	98.4	98.3	98.4
Distillation residue, vol%	1.2	1.2	1.2
Total recovery, vol%	99.6	99.5	99.6
Net heat of combustion, MJ/kg	43.696	43.378	43.318
Hydrogen content, weight %	14.74	14.43	14.14
Monoaromatics, vol%	<10.0	<10.0	<10.0
Diaromatics, vol%	0.0	0.0	0.0
Total aromatics, vol%	<10.0	<10.0	<10.0
Estimated aromatics, vol% ¹	0	0	0
Freezing point, °C	-58.9	-64.1	-68.4
Viscosity at -20°C, cSt	4.301	4.325	4.379
Viscosity at -40°C, cSt	8.664	8.629	8.657
Flash point, °C	45.0	42.0	38.5
Smoke point, mm	40.3	34.5	30.0
Naphthalenes, mass%	0.00	0.00	0.00
Naphthalenes, vol%	<0.08	<0.08	<0.08
Ignition delay, ms	4.30	4.79	5.16
Derived cetane number, a.u.	47.8	43.4	40.6
Lubricity wear scar, mm	0.71	0.68	0.66
Total sulfur, ppm	<3.0	<3.0	<3.0

1. Estimated aromatics content was calculated using the measured aromatics content from the neat fuels and the relative ratios of the neat fuels in the blend.

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Table 8

Test	Eg.14	Eg.15	Eg.16	Eg.17	Eg.18
Density 15 °C, kg/m ³	787.9	796.7	803.5	810.9	804.0
Initial boiling point, °C	155.5	150.8	151.0	148.8	154.2
5% recovered T, °C	168.5	164.8	163.2	162.4	167.0
10% recovered T, °C	172.0	168.6	167.3	165.8	170.3
20% recovered T, °C	177.8	174.6	173.1	172.2	176.2
30% recovered T, °C	183.9	181.1	179.2	177.9	182.4
40% recovered T, °C	190.9	188.1	186.7	185.2	188.9
50% recovered T, °C	198.3	196.2	194.8	193.7	196.5
60% recovered T, °C	206.3	205.8	203.9	203.2	204.8
70% recovered T, °C	215.5	216.0	214.4	213.8	214.3

80% recovered T, °C	225.6	227.5	226.3	226.1	224.7
90% recovered T, °C	238.2	241.8	241.2	241.8	237.6
95% recovered T, °C	248.9	253.9	252.9	253.3	247.7
Final boiling point, °C	265.3	269.6	268.8	267.2	263.6
Distillation recovery, vol%	98.2	98.2	98.6	98.4	98.6
Distillation residue, vol%	1.2	1.2	1.2	1.2	1.2
Total recovery, vol%	99.4	99.4	99.8	99.6	99.8
Net heat of combustion, MJ/kg	43.70 6	43.45 6	43.27 6	43.27 8	43.47 4
Hydrogen content, weight %	14.53	14.22	14.16	14.28	14.42
Monoaromatics, vol%	<10.0	10.7	<10.0	<10.0	<10.0
Diaromatics, vol%	0.4	0.6	0.4	0.2	0.2
Total aromatics, vol%	<10.0	11.4	<10.0	<10.0	<10.0
Estimated aromatics, vol% ¹	7.56	11.34	7.56	3.78	3.78
Freezing point, °C	-55.8	-55.7	-59.2	-63.9	-59.5
Viscosity at -20°C, cSt	4.035	3.927	4.051	4.209	4.176
Viscosity at -40°C, cSt	8.075	7.768	8.003	8.298	8.333
Flash point, °C	44.5	42.5	44.5	40.5	43.0
Smoke point, mm	32.7	27.6	28.6	29.4	33.6
Naphthalenes, mass%	0.56	0.72	0.43	0.20	0.23
Naphthalenes, vol%	0.44	0.58	0.34	0.17	0.18
Ignition delay, ms	4.33	4.54	4.82	5.06	4.49
Derived cetane number, a.u.	47.5	45.5	43.2	41.4	46.0
Lubricity wear scar, mm	0.68	0.68	0.69	0.70	0.69
Total sulfur, ppm	83.1	116.0	81.0	40.2	42.0

1. Estimated aromatics content was calculated using the measured aromatics content from the neat fuels and the relative ratios of the neat fuels in the blend

Table 9

Test	Eg. 21	Eg. 22	Eg. 23	Eg. 24	Eg. 25
Density 15 °C, kg/m ³	775.8	793.8	787.5	796.2	803.3
Viscosity at -20°C, cSt	3.974	4.307	4.049	3.974	4.106
Linear Interpolation of Viscosity at -20°C, cSt	3.998	4.35	4.1032	4.0276	4.1706

Delta (Measured - Interpolation)	-0.024	-0.0485	-0.0542	-0.0536	-0.0646
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Table 10

Test	Eg. 26	Eg. 27	Eg. 28	Eg. 29	Eg. 30
Density 15 °C, kg/m ³	810.2	786.8	780.6	798.4	791.1
Viscosity at -20°C, cSt	4.258	4.165	4.897	5.305	4.78
Linear Interpolation of Viscosity at -20°C, cSt	4.3136	4.2462	5.18	5.5375	5.0488
Delta (Measured - Interpolation)	-0.0556	-0.0812	-0.283	-0.2325	-0.2688

Table 11

Test	Eg. 31	Eg. 32	Eg. 33	Eg. 34
Density 15 °C, kg/m ³	798	805	812	798.4
Viscosity at -20°C, cSt	4.307	4.448	4.599	4.937
Linear Interpolation of Viscosity at - 20°C, cSt	4.5004	4.6434	4.7864	5.1918
Delta (Measured - Interpolation)	-0.1934	-0.1954	-0.1874	-0.2548

5

Examples 1-18 were subjected to experiments to measure their low temperature viscosity and wear scar, via D7945 and D5001, respectively. The results of these experiments are set out in Tables 4-8 above.

10

Figure 2 is a ternary diagram showing the difference between the measured low temperature viscosity at -20°C and the linear interpolation for Examples 1-18.

Figure 3 is a ternary diagram showing the difference between the measured low temperature viscosity at -40°C and the linear interpolation for Examples 1-18.

Figure 4 is a ternary diagram showing the difference between the measured wear scar (lubricity) and the linear interpolation for Examples 1-18.

In the ternary diagrams of Figures 2 to 4, the darker areas represent a larger deviation from linear interpolation based on base blend components.

Discussion

It was found that mixing Jet A-1 with both CPK and GTL afforded improved low temperature viscosity beyond that predicted by linear interpolation (Figures 2 and 3). Benefits in lubricity (wear scar) characteristics were also observed when Jet A-1 was mixed with both CPK and GTL (Figure 4). These results could not have been predicted based on simple analysis of the neat fuels.

Further, it was found that mixing Jet A-1 with CPK alone afforded improved low temperature viscosity beyond that predicted by linear interpolation (Figures 2 and 3). These results could not have been predicted based on simple analysis of the neat fuels.

Further, it was found that mixing Jet A-1 with both CPK and HEFA afforded improved low temperature viscosity beyond that predicted by linear interpolation (see Tables 9-11). These results could not have been predicted based on simple analysis of the neat fuels.

C L A I M S

1. An aviation fuel composition comprising:
a cycloparaffinic kerosene generated from hydropyrolysis
and hydroconversion of a solid biomass containing
lignocellulose, wherein the cycloparaffinic kerosene
5 comprises at least 90 vol% cycloparaffins and less than 1
vol% aromatics;

a paraffinic-based kerosene comprising normal and iso-
paraffins in an amount of greater than 95 vol%; and

optionally, a petroleum-derived kerosene.
- 10 2. An aviation fuel composition according to Claim 1
wherein the paraffinic-based kerosene is a Fischer-Tropsch
derived kerosene.
3. An aviation fuel composition according to Claim 1 or 2
wherein the cycloparaffinic kerosene is generated by a
15 hydroprocess comprising:
feeding a solid feedstock and hydrogen to a first stage
hydropyrolysis reactor, wherein the first stage
hydropyrolysis reactor comprises one or more deoxygenation
catalyst, and wherein the solid feedstock comprises
20 biomass containing lignocellulose;
hydropyrolysing a solid feedstock in a first stage
hydropyrolysis reactor to generate a product stream
comprising partially deoxygenated hydropyrolysis product,
H₂O, H₂, CO₂, CO, C₁ - C₃ gases, char and catalyst fines;
25 feeding at least a portion of the product stream to a
second stage hydroconversion reactor comprising one or
more hydroconversion catalyst; and
hydroconverting the partially deoxygenated hydropyrolysis
product in the product stream to generate a vapor phase

product comprising substantially fully deoxygenated hydrocarbon product, H₂O, CO, CO₂, and C₁ - C₃ gases; condensing the vapor phase product to generate a deoxygenated hydrocarbon liquid comprising the substantially fully deoxygenated hydrocarbon product, wherein the substantially fully deoxygenated hydrocarbon product comprises the cycloparaffinic kerosene.

4. An aviation fuel composition according to any of Claims 1 to 3 wherein the aviation fuel composition comprises from 40 vol% to 90 vol% of cycloparaffinic kerosene and from 2 vol% to 50 vol% of paraffinic kerosene, based on the total aviation fuel composition.

5. An aviation fuel composition according to Claim 4 wherein the aviation fuel composition comprises from 5 vol% to 20 vol% of petroleum-derived kerosene, based on the total aviation fuel composition.

6. An aviation fuel composition according to any of Claims 1 to 3 wherein the aviation fuel composition comprises from 10 vol% to 95 vol% of cycloparaffinic kerosene and from 1 vol% to 80 vol% of paraffinic kerosene, based on the total aviation fuel composition.

7. An aviation fuel composition according to Claim 6 wherein the aviation fuel composition comprises from 5 vol% to 90 vol% of petroleum-derived kerosene, based on the total aviation fuel composition.

8. A process for producing an aviation fuel composition comprising:

feeding a solid feedstock and hydrogen to a first stage hydrolysis reactor, wherein the first stage hydrolysis reactor comprises one or more deoxygenation catalyst, and wherein the solid feedstock comprises biomass containing lignocellulose; hydrolysis the solid feedstock in the first stage hydrolysis reactor to generate a product stream

comprising partially deoxygenated hydropyrolysis product,
H₂O, H₂, CO₂, CO, C₁ - C₃ gases, char and catalyst fines;
feeding at least a portion of the product stream to a
second stage hydroconversion reactor comprising one or
5 more hydroconversion catalyst;
hydroconverting the partially deoxygenated hydropyrolysis
product in the product stream to generate a vapor phase
product comprising substantially fully deoxygenated
hydrocarbon product, H₂O, CO, CO₂, and C₁ - C₃ gases;
10 condensing the vapor phase product to generate a
deoxygenated hydrocarbon liquid comprising the
substantially fully deoxygenated hydrocarbon product,
wherein the substantially fully deoxygenated hydrocarbon
product comprises a cycloparaffinic kerosene wherein the
15 cycloparaffinic kerosene comprises at least 90 vol%
cycloparaffins and less than 1 vol% aromatics; and
mixing the cycloparaffinic kerosene with a paraffinic-
based kerosene comprising normal and iso-paraffins in an
amount of greater than 95 vol% and a petroleum derived jet
20 fuel to generate the aviation fuel composition.

9. A process for producing an aviation fuel composition,
comprising:

mixing a cycloparaffinic kerosene derived from
hydropyrolysis and hydroconversion of a biomass containing
25 lignocellulose wherein the cycloparaffinic kerosene
comprises at least 90 vol% cycloparaffins and less than 1
vol% aromatics with a paraffinic-based kerosene comprising
normal and iso-paraffins in an amount of greater than 95
vol%, and optionally, a petroleum-derived jet fuel.

30 10. The process of claim 9, wherein the hydroprocessing is
a two stage process comprising a first stage for
hydropyrolysing the biomass to generate a product stream
comprising partially deoxygenated hydropyrolysis product,
H₂O, H₂, CO₂, CO, C₁ - C₃ gases, char and catalyst fines,

and a second stage for hydroconverting the partially deoxygenated hydropyrolysis product in the product stream to generate a vapor phase product comprising substantially fully deoxygenated hydrocarbon product, H₂O, CO, CO₂, and C₁ - C₃ gases, wherein the substantially fully deoxygenated product comprises the cycloparaffinic kerosene.

11. Use of an aviation fuel composition according to any of Claims 1 to 5, or as produced according to any of Claims 8 to 10 for improving lubricity.

12. Use of an aviation fuel composition according to any of Claims 1 to 3, 6 or 7, or as produced according to any of Claims 8 to 10, for improving low temperature viscosity.

13. Use of an aviation fuel composition comprising:

a cycloparaffinic kerosene generated from hydropyrolysis and hydroconversion of a solid biomass containing lignocellulose, wherein the cycloparaffinic kerosene comprises at least 90 vol% cycloparaffins and less than 1 vol% aromatics; and

a petroleum-derived kerosene,
for improving low temperature viscosity.