The invention pertains to marine fuel compositions having a sulfur content of less than or equal to 1000 ppm and methods of producing the same. The low sulfur marine fuels are compliant for use in Sulfur Emission Control Areas beginning Jan. 1, 2015. The compositions comprise a blend of a residual fuel oil and a distillate fuel oil. The residual fuel oil can constitute from about 15% to about 50% by volume of the final blend and the distillate fuel oil from about 50% to about 85%. In some embodiments the residual fuel oil contains a vacuum tower bottoms component characterized by a flashpoint of 200°F or higher and the distillate fuel oil an ultra low sulfur diesel component characterized by a flashpoint of 120°F or higher. Methods of producing low sulfur marine fuel comprise blending a residual fuel oil with a distillate fuel oil.
ECA Ships Bunker Fuels

#5
VTB
#4
ULSD
ULSD comp
Low S No 2

Ratio Blended to Meet Sulfur Specification

Finished ECA Fuel

Meets <1000 PPM Sulfur Specification

FIG. 1
FIG. 2

Crude Oil Tower

Atmospheric Distillation

Distillate Fuel Products

Fuel Gas (Methane, Ethane)

LPGs (Propane, Butane, iso-butane)

End Products

Distillation

Naphtha

Catalytic Converter

Gasoline

Kerosene/Jet Fuel

Hydro Crack

Finished Kerosene and Jet Fuel

Home Heating Oil/Diesel

Finished Home Heating Oil and Ultra Low Sulfur Diesel

Vacuum Distillation

Reduced Crude Oil

Light Vacuum Gas Oil

Gasoline

Vacuum Tower Bottoms

Residual Fuel Products

Fluidized Catalytic Cracker

Home Oil Heater Components

Medium/Heavy Gas Oil

Residual Component

Vacuum Tower bottoms

Residual Fuel Asphalt
LOW SULFUR MARINE FUEL
RELATED APPLICATIONS


BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention
[0003] The invention relates to low sulfur marine fuel compositions and methods of producing the same. In particular the invention relates to low sulfur marine fuels with a sulfur content of less than 1000 ppm.

[0004] 2. Background
[0005] Diesel engines have been the workhorses of the marine industry since shortly after the development of the diesel engine by Rudolf Diesel in 1892. In particular, four-stroke diesel engines have been operational in surface ships and submarines since the 1910s. Since that time a series of innovations and improvements have been made to marine diesel engines and to the fuels that can be used in those engines. However, a persistent problem since the introduction of marine diesel engines is the high volume of objectionable emissions produced by these engines and in particular the emission of sulfur oxides. Recently there has been widespread international regulatory efforts designed to reduce the sulfur emissions from marine engines, especially close to land and cities, where air pollution is a never-ending problem.

[0006] In response to the sulfur emission problem, and other emissions, an international ISO standard, ISO 8217, was established in 1987. The stated purpose of ISO 8217 is to define the requirements for petroleum fuels for use in marine diesel engines and boilers, prior to appropriate treatment before use, and is provided for the guidance of interested parties such as marine equipment designers, suppliers and purchasers of marine fuel.

[0007] New regulations and rules adopted by the United Nations specialized agency, the International Maritime Organization (IMO), established stricter controls to minimize air-borne emissions (SOx, NOx, ODS, VOC) from ships. Specifically Annex VI of the 1997 MARPOL Protocol, which came into effect in May 2005, requires that by Jan. 1, 2015 marine fuel used by maritime vessels inside Sulfur Emission Control Areas (SECA) or Emission Control Areas (ECAs) have a sulfur content of less than 0.1% or 1000 ppm. ECAs constitute around 200 miles of coastal radius around the US, Western Europe and Japan. Such stringent emissions rules require that most maritime vessels, tankers and ships, which operate both outside and inside ECAs, use different fuel oils, depending on their area of operation, in order to comply with the distinct limits for each. Therefore, there is a need for a commercially available, low cost marine fuel or blend that offers satisfactory emission profiles for use inside and outside ECAs. Specifically, it has been common for marine engines to be designed to use both high sulfur and low sulfur fuels, with high sulfur fuels being used during open sea travel and low sulfur fuels being used during travel in ECAs. Typically the low sulfur fuels are substantially more expensive than higher sulfur fuels.

[0008] The sulfur content of a marine fuel depends on the crude oil origin and the refining process. Sulfur is an undesirable component in fuels since it causes the release of sulfur oxides into the atmosphere leading to a variety of environmental issues, such as acid rain, creates corrosive combustion by-products and increases deposits on fuel injection and combustion systems. Some sulfur can be removed during the refining process. Hydrodesulfurization (“HDS”) is the industry’s standard method of removing unwanted sulfur compounds in petroleum refining operations and is sometimes referred to as “hydrogating”. The process utilizes a variety of catalysts to add hydrogen to sulfur compounds. Unfortunately, the HDS process typically requires expensive, high-pressure (up to 1,000 psig), high-temperature (400-550° C.) equipment to help produce environmentally compatible fuels.

[0009] Separation of crude oil into its naturally occurring components is performed in a series of distillation towers. The yield from a distillation tower refers to the relative percentage of each of the separated components, known as product streams, which will vary in content based on the chemical composition of the crude oil being processed. Because a liquid’s boiling point decreases at lower pressures, the final distillation steps are performed in a vacuum to maximize liquid recovery. Products from the distillation tower range from gasses at the top to very heavy, viscous liquids at the bottom. Vacuum tower bottoms (VTBs) are the final bottom product of distillation, which is processed in coke to be upgraded into gasoline, diesel and gas oil. Importantly, the VTBs are typically highly viscous, high in sulfur content, and relatively inexpensive. Therefore, it is unlikely that VTB based fuel oils can be used within ECAs once reduced sulfur emission standards are enforced. The hydrocarbon products produced by the distillation process described above can be divided into two broad categories, the first being distillate fuel oil products and the second being residual fuel oil products. Typically, distillate fuel oil products have a low viscosity and low sulfur content, whereas residual fuel oil products are highly viscous and generally high in sulfur content.

[0010] As stated above, various countries have issued regulations for sulfur emissions from marine engines in Emission Control Areas, all designed to decrease the emission of sulfur compounds in the exhaust of marine engines. Although the emission of sulfur on the high seas outside of ECAs remains largely unregulated, the implementation of new regulations for ECAs presents unique problems to large ocean going ships with engines capable of burning low viscosity, high sulfur fuels since those ships will be required to change to a cleaner burning fuel within ECAs. The marine engines of particular concern are referred to as Category 3 marine engines, which have been established as the cause of harm to public health and welfare, and contribute to visibility impairment and other detrimental environmental impact across the United States and elsewhere. These engines also emit air toxins that are associated with adverse health effects.

[0011] In some instances the marine engines can change from a high sulfur fuel to a low sulfur fuel when they enter ECAs, but in many instances this is problematic because the marine engines are designed to burn a certain type of fuel and are not capable of changing back and forth between high sulfur and low sulfur fuels. For instance, many of the high sulfur content fuels are so viscous that they require preheating before they can be used. Such preheating is not necessary, and in fact is undesirable, in the low sulfur content, higher volatility fuels used in ECA areas. Thus the industry has been skeptical of the functional capabilities of blends of
distillate fuel oil products (low viscosity and low sulfur content) with residual fuel oil products (high viscosity and high sulfur content).

[0012] Residual fuel oil refers to a mixture of heavy oils, No. 5 and No. 6 fuel oils, that remain in refinery operations after the distillate fuel oils and lighter hydrocarbons are distilled away. It is often used in large ships, primarily because of its low cost. Residual fuel oil presents some special problems since it is so viscous and therefore has to be heated with a special heating system before use and because it contains relatively high amounts of pollutants, particularly sulfur, which forms sulfur dioxide upon combustion. A very common form of residual fuel oil used in maritime applications is No. 6 fuel oil, which must be stored at around 100° F. and heated to 150-250° F. before it can be easily pumped, and in cooler temperatures it can congeal into a tarry semisolid. Despite these deficiencies No. 6 fuel oil has continued to be used in large ocean going ships because of its cheap price. However, with new regulations regarding sulfur content of marine fuels, the need for an economic, but low cost, marine fuel has increased dramatically.

[0013] By way of example, the sulfur content of different sources of No. 6 fuel can vary from -0.3 to +3.5% by weight. The VTB component of these No. 6 fuels are generally of a similar sulfur level or marginally higher. The VTB is generally blended with lower sulfur distillate or cutter stocks to meet the No. 6 fuel sulfur specification. Similarly, ultra low sulfur diesel (ULSD) has an sulfur level of a maximum of 15 ppm. Other low sulfur components (off test components with S levels >15 ppm) can be blended or reprocessed (hydrotreated) to meet the finished ULSD specification. Against this background of commercial need the inventors have developed methods and fuel blends that satisfy the environmental requirements for marine fuels, specifically the newly enacted sulfur requirements, and that, at the same time, are economic to use.

SUMMARY OF THE INVENTION

[0014] The current invention provides methods of producing compositions of fuel oils with a sulfur content of less than 1000 ppm. Specifically the current invention provides marine fuel oils with a sulfur content of less than 1000 ppm that can be burned by maritime vessels inside ECAs as required by MARPOL Annex VI by Jan. 1, 2015. In particular the current invention provides methods of producing and compositions of fuel with a sulfur content of less than 1000 ppm that comprise mixing blends of residual fuel oil from about 15% to about 50% and distillate fuel oils from about 50 to 85% by volume of the final marine fuel blend.

[0015] In particular, the current invention provides a low sulfur marine fuel composition having a sulfur content of less than or equal to 1000 ppm having a blend of a residual fuel oil and a distillate fuel oil. In certain embodiments, the residual fuel oil has a vacuum tower bottoms component and the distillate fuel oil contains an ultra low sulfur diesel oil (ULSD) component or a ultra low sulfur component. In some preferred embodiments, the residual fuel oil constitutes from about 15% to about 50% of the final blend and in other embodiments 28% to about 38% by volume of the final blend. In alternate embodiments of the invention, the low sulfur marine fuel constitutes distillate fuel from about 50% to about 85% by volume of the final marine fuel blend and in other preferred embodiments from about 62% to about 72% by volume of the final marine fuel blend. In further embodiments of the low sulfur marine fuel of the current invention, the residual fuel oil can be grade No. 6 fuel oil and/or the distillate fuel oil can be a grade No. 2 fuel oil. Other embodiments of the invention provide a low sulfur marine fuel having a sulfur content of less than or equal to 1000 ppm such that the low sulfur marine fuel constitutes a blend of grade No. 2 fuel oil and grade No. 4 fuel oil. In some embodiments, the low sulfur marine fuel further contains a grade No. 6 fuel oil component. In partial summary, the low sulfur marine fuel of this invention can comprise a blend of No. 2 fuel oil, No. 4 fuel oil, and No. 6 fuel oil such that the final blended marine fuel product has a sulfur content of less than or equal to 1000 ppm.

[0016] Stated slightly differently, the invention also includes a low sulfur marine fuel having a sulfur content of less than or equal to 1000 ppm that can be adapted for use in Category 3 marine diesel engines operating in emission control areas. Such a low sulfur marine fuel comprises a blend of from 15% to 50% of a residual fuel oil containing a vacuum tower bottoms component, and from about 50% to about 85% of a distillate fuel oil component containing an ultra low sulfur diesel oil component. In one variation of these embodiments the residual fuel oil comprises grade No. 6 fuel oil and the distillate fuel oil comprises grade No. 2 fuel oil.

[0017] The invention also provides for a low sulfur marine fuel having a sulfur content of less than or equal to 1000 ppm adapted for use in Category 3 marine diesel engines operating in emission control areas, such that the low sulfur marine fuel has a blend of vacuum tower bottoms and ultra low sulfur diesel.

[0018] Furthermore, the current invention also provides a low sulfur marine fuel having a sulfur content of less than or equal to 1000 ppm suitable for use in Category 3 marine diesel engines operating in emission control areas, comprising a blend of a first hydrocarbon component which includes a distillate fuel oil having an ultra low sulfur diesel component characterized by a flashpoint of 120° F. or higher and a sulfur content of less than about 50 ppm, such that the first hydrocarbon component has about 5% to about 85% by volume of the final marine fuel blend; and a second hydrocarbon component including a residual fuel oil component having a vacuum tower bottoms component characterized by a flashpoint of 200° F. or higher and a sulfur content of 2000 ppm or higher, such that the second hydrocarbon component comprises from about 15% to about 50% by volume of the final marine fuel blend; and such that the final marine fuel blend of the first and second hydrocarbon components has a sulfur content of less than 1000 ppm. In certain embodiments, the sulfur content of the vacuum tower bottoms is greater than 2300 ppm or may even be greater than 3500 ppm. In further embodiments, the first hydrocarbon component comprises from 62% to 72% by volume of the final marine fuel blend and the second hydrocarbon component comprises from 28% to 38% by volume of the final marine fuel blend. In yet further embodiments, the sulfur content of the final blend is less than 1000 ppm and the flashpoint of the final blend is at least 140° F.

[0019] In addition, the current invention provides a method for producing a low sulfur marine fuel having a sulfur content of less than or equal to 1000 ppm, comprising the step blending a residual fuel oil with a distillate fuel oil.

[0020] Furthermore, the current invention provides a method for producing a low sulfur marine fuel having a sulfur content of less than or equal to 1000 ppm, suitable for use in Category 3 marine diesel engines operating in emission con-
trol areas, such that the method includes the step of blending a first hydrocarbon component with a second hydrocarbon component wherein the first hydrocarbon component is a distillate fuel oil having an ultra low sulfur diesel component and is further characterized by a flashpoint of 100°F or higher, a sulfur content of less than about 50 ppm, and comprises from about 50% to about 85% by volume of said final marine fuel blend; and the second hydrocarbon component is a residual fuel oil with a vacuum tower bottoms component characterized by a flashpoint of 200°F or higher, a sulfur content of 2000 ppm or higher and comprises from about 15% to about 50% by volume of the final marine fuel blend, such that the final marine fuel blend has a sulfur content of less than 1000 ppm.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] It being understood that the figures presented herein should not be deemed to limit or define the subject matter claimed herein, the applicants’ invention may be understood by reference to the following description taken in conjunction with the accompanying drawings, in which:

[0022] FIG. 1 is a block diagram depicting blending of various components to yield a finished ECA fuel that has less than 1000 ppm sulfur specification. Components include No. 6 fuel oil, VTB, No. 4 fuel oil and any combinations thereof for the heavy, high sulfur portion of the blend. For the lighter source, low sulfur components including ULSD, ULSD components and low sulfur No. 2 fuel oil.

[0023] FIG. 2 is a block diagram depicting the various unfinished products and end products resulting from the distillation of crude oil.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0024] Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. The following detailed description of exemplary embodiments, read in conjunction with the accompanying drawings, is merely illustrative and is not to be taken as limiting the scope of the invention. Rather, the scope of the invention is defined by the appended claims and equivalents thereof. It will of course be appreciated that in the development of an actual embodiment, numerous implementation-specific decisions must be made to achieve the design-specific goals, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort, while possibly complex and time-consuming, would nevertheless be a routine undertaking for persons of ordinary skill in the art having the benefit of this disclosure. Further aspects and advantages of the various embodiments of the invention will become apparent from consideration of the following description and drawings.

[0025] Embodiments of the present disclosure provide for fuel compositions and mixtures having a sulfur content of less than 0.1 wt. % or 1000 ppm. As a practical matter, the desired final product of this invention is a hydrocarbon based fuel that can be used in marine vessels both inside and outside of established Emission Control Zones, but is functionally effective at a commercially reasonable price. The end product is preferably a blend of a distillate fuel oil and a residual fuel oil. Such a product must be competitive, both functionally and commercially, with current marine fuels, many of which far exceed recently enacted sulfur limitations and other environmental constraints.

[0026] As described briefly hereinabove, the basic hydrocarbon component of the blended fuel final product of this invention is crude oil that has been distilled in a distillation tower to separate the various hydrocarbon components. In most distillation processes the crude oil feedstock is separated into at least six product streams, each of which can be used to formulate a desired end product. At the top of the distillation tower range are typically light ends, naphtha, and kerosene. The light ends are further separated into propane, normal butane, and isobutene and sold as a cooking and heating fuel. Naphtha can be blended into motor gasoline and kerosene is generally treated and used as jet fuel. By comparison to other hydrocarbon components from crude oil, these materials are expensive and volatile.

[0027] The next distillation product streams are identified as diesel distillate, medium gas oil, and heavy gas oil. All of these products are further treated and then blended or used as diesel fuel, gasoline or home heating oil. These hydrocarbon products are less volatile and less expensive than the product streams having a lower boiling point, such as naphtha and kerosene. At the bottom of the distillation tower are the Vacuum Tower Bottoms (VTB), which are processed in Crackers to be upgraded into gasoline, diesel, and gas oil.

[0028] FIG. 2 provides a schematic representation of the typical processing of crude oil into final products. As shown in FIG. 2 crude oil is initially subjected to atmospheric distillation resulting is a variety of products such as fuel gas, LPG, naphtha, kerosene/jet fuel, and home heating oil/diesel fuel. All of these products are considered to be “distillate fuel products” within the meaning of this invention and application. All of the distillate fuel products are potentially subject to additional processing in distillation towers, catalytic reformers, hydro treatment and other well-known hydrocarbon processing methods and apparatus. A dotted line is provided in FIG. 2 to separate the “distillate fuel products” from the “residual fuel products.”

[0029] As shown in FIG. 2, the crude oil feedstock for residual fuel products is provided by the “bottoms” of the atmospheric distillation tower and is referred to as “reduced crude oil” in FIG. 2. The reduced crude oil feedstock is further processed in a vacuum distillation tower resulting is products typically identified as light vacuum gas oil, medium or heavy gas oil, and vacuum tower bottoms. These materials are typically viscous and high in sulfur content and are referenced for purposes of this patent application as “residual fuel products.” The residual fuel products may be subject to additional processing steps such as a fluidized catalytic cracker or other well-known hydrocarbon treatment methods and apparatus.

[0030] As shown in Table 1, the residual fuel products of this invention are typically more viscous, higher in sulfur content, and therefore less expensive than distillate fuel products. In the actual commercial practice of this invention the residual fuel product and distillate fuel product are obtained from commercial vendors and can be prepared in any of a number of methods, some of which are well known, as described hereinabove, and some of which are proprietary to the individual vendor. The particular method of distilling or otherwise processing the crude oil feedstock is not considered to be part of this invention.
For purposes of this disclosure it is important to understand the differences in classification and characterization of fuel oils. Guidance for the classification of fuel oils is found in ASTM Designation D396-13c, Standard Specification for Fuel Oils, which is hereby incorporated by reference. The ASTM standard divides fuel oils into grades based upon the types of burners for which they are suitable. Because of the methods employed in their production, fuel oils fall into two broad classifications: distillates and residuals. The distillates consist of overhead or distilled fractions. The residuals are bottoms remaining from the distillation, or blends of these bottoms with distillates. Grade No. 1 and 2 fuel oils in the specification are distillates, whereas Grades No. 4 to No. 6 are usually residual, although some heavy distillates can be sold as Fuel Grade No. 4.

For the sake of convenience, the definitions of the various grades of fuel oil found in ASTM Designation D396-13c are reproduced herein. Fuel Oil Grade No. 1 is a middle distillate intended for use in burners of the vaporizing type in which the oil is converted to a vapor by contact with a heated surface or radiation. High volatility is necessary to ensure that evaporation proceeds with a minimum of residue.

Fuel Oil Grade No. 2 is a middle distillate somewhat heavier than grade 1. Grade 2 fuel oil is intended for use in atomizing type burners which spray the oil into a combustion chamber where the tiny droplets burn while in suspension. Fuel Oil Grades No. 1 and 2 are typically characterized by very low sulfur content and would be considered distillates.

Fuel Oil Grade No. 4 is a heavy distillate fuel oil or distillate/residual fuel blend meeting the ASTM specification viscosity range. It is intended for use both pressure atomizing commercial industrial burners not requiring higher cost distillates and in burners equipped to atomize oils of higher viscosity. Its permissible viscosity range allows it to be pumped and atomized at relatively low storage temperatures. Thus, in all but extremely cold weather it requires no preheating for handling.

Fuel Oil Grade No. 5 is a residual fuel of intermediate viscosity and is intended for use in burners capable of handling fuel more viscous than Fuel Oil Grade No. 4 without preheating. Preheating may be necessary in some types of equipment for burning and in colder climates for handling. Fuel Oil Grade No. 6, sometimes referred to as Bunker C, is a high-viscosity oil used mostly in commercial and industrial heating. It requires preheating in the storage tank to permit pumping, and additional preheating at the burner to permit atomizing.

Fuel Oil Grade No. 6 or Bunker fuel is the type of fuel oil used in ocean going marine vessels, especially those with Category 3 engines. It is well known that residual fuel oils, such of Grade 6 Fuel Oil, have to be heated with a special heating system before use and that such fuels contain high amounts of pollutants, especially sulfur, which forms sulfur dioxide upon combustion. However, these undesirable properties also make Grade 6 Fuel Oil very inexpensive and therefore desirable for the marine industry, where outside of emission control areas, pollution is for the most part unregulated.

A chart containing a comparison of characteristics of residual fuel oil and distillate fuel oil is provided:

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>UNIT</th>
<th>MARINE RESIDUAL FUEL OIL</th>
<th>MARINE DISTILLATE FUEL OIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>Kg/m3</td>
<td>960-1010</td>
<td>890-920</td>
</tr>
<tr>
<td>Viscosity</td>
<td>Mm2/s</td>
<td>30-700</td>
<td>5.5-14.0</td>
</tr>
<tr>
<td>Flash Point</td>
<td>°C</td>
<td>60</td>
<td>43-60</td>
</tr>
<tr>
<td>Pour Point</td>
<td>°C</td>
<td>0-30</td>
<td>(-6)-6</td>
</tr>
<tr>
<td>Sulfur</td>
<td>% (m/m)</td>
<td>3.5-4.5</td>
<td>0.10-0.75</td>
</tr>
</tbody>
</table>

The preferred marine fuel of this invention is a blend of a first hydrocarbon component and a second hydrocarbon component wherein the final blend has a sulfur content of 1000 ppm or less. The final blended product is functionally effective in marine diesel engines, especially Category 3 marine diesel engines, and can be used both inside and outside of ECAs. The first hydrocarbon component is a residual fuel oil product having a sulfur content substantially in excess of 1000 ppm. The second hydrocarbon component is a distillate fuel product having a sulfur content of less than 1000 ppm. The ratio in the final blend of the first hydrocarbon component and the second hydrocarbon component is such that the sulfur content of the final blend is 1000 ppm or less.

The first hydrocarbon component is preferably a residual fuel oil product, more particularly a Grade No. 6 fuel oil product, that contains a substantial portion of vacuum tower bottoms. In the preferred embodiments the first hydrocarbon component comprises from about 15% to about 50% by volume of the final blended product, and in a more preferred embodiment from about 35% to about 45% by volume of the final blended product. In one preferred embodiment of the hydrocarbon blend of the invention, the first hydrocarbon component is characterized by a flashpoint of 200°F or higher and a sulfur content of 2000 ppm or higher.

The second hydrocarbon component is preferably a distillate fuel oil product, more particularly a Grade No. 2 fuel oil product, that contains a substantial portion of ultra low sulfur diesel oil. In the preferred embodiments of this invention, the second hydrocarbon component comprises from about 50% to about 85% by volume of the final blended product, and in a more preferred embodiment from about 55% to about 65% by volume of the final blended product. In one preferred embodiment of the hydrocarbon blend of this invention, the second hydrocarbon component is characterized by a flashpoint of 100°F or higher and a sulfur content of less than about 50 ppm.

Any blending process as known by a skilled in the art may be used. For example in-line static mixers, paddle mixers in the tank, etc., or any known process may be used. Adequate mixing is important to ensure reaching a homogeneous state. Specifically, the final blended product must meet the specification requirement of less than 1000 ppm sulfur content as well as other product specifications that may vary from customer to customer or product to product. The method of this invention involves two hydrocarbon supply streams, the first hydrocarbon supply stream comprising a residual fuel product, and the second hydrocarbon fuel stream comprising a distillate fuel oil product, both as defined hereinabove. As the two hydrocarbon streams are blended in conventional mixing equipment it is important that the mixing process and equipment result in a homogeneous blended product. In some instances it will be necessary to preheat the residual fuel product in order to facilitate its mixing with the distillate fuel oil product to form a homogeneous final
blended fuel oil product. However, in most instances preheating of the residual fuel product stream will not be necessary if the mixing equipment is appropriately sized, designed, and powered to permit homogeneous mixing of the two hydrocarbon supply streams.

Example 1

The following paper blending experiment examined how much ULSD is required to meet a maximum of 1000 ppm sulfur content. This represents a scenario based on sulfur levels in vacuum towers bottoms as low as 2300 ppm blended with ULSD at 15 ppm. The resultant product is at <1000 ppm sulfur representing at 42% VTB and 58% ULSD blend.

<table>
<thead>
<tr>
<th>VTB</th>
<th>ULSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfur, ppm</td>
<td>2300</td>
</tr>
<tr>
<td>Flash, F.</td>
<td>230</td>
</tr>
<tr>
<td>Volume</td>
<td>42% Volume</td>
</tr>
</tbody>
</table>

Final Blend Estimate

| Sulfur, ppm | 979 |
| Flash, F.  | 148 |

Example 2

The following paper blending experiment examined how much ULSD is required to meet a maximum of 1000 ppm sulfur content. This represents a scenario based on sulfur levels in vacuum towers bottoms as high as 4500 ppm blended with ULSD at 15 ppm. The resultant product is at <1000 ppm sulfur representing at 42% VTB and 58% ULSD blend.

<table>
<thead>
<tr>
<th>VTB</th>
<th>ULSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfur, ppm</td>
<td>4500</td>
</tr>
<tr>
<td>Flash, F.</td>
<td>230</td>
</tr>
<tr>
<td>Volume</td>
<td>21% Volume</td>
</tr>
</tbody>
</table>

Final Blend Estimate

| Sulfur, ppm | 957 |
| Flash, F.  | 139 |

Example 3

The following is a paper example of a blended product in accordance with the teaching of this invention. Specifically, product information regarding the residual fuel and distillate fuel components were obtained and were calculated to reflect a potential preferred commercial product. The blended product resulted in a final product having less than 0.1 wt % sulfur by weight and satisfied the requirements for an ECA fuel in accordance with the current invention. Similar results may be obtained with a range of blends using from around 58 to 82 percent by volume ULSD with around 18 to 42 percent by volume VTB. A variety of additional criteria were evaluated for the blended products with the results calculated being reflected in the chart below. The tests performed are all well known in the energy industry and would be known to persons of ordinary skill in the relevant art.

<table>
<thead>
<tr>
<th>Method</th>
<th>Test</th>
<th>Result</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 12185</td>
<td>API Gravity</td>
<td>27-33</td>
<td>°F</td>
</tr>
<tr>
<td>ISO 12185</td>
<td>Density @ 15° C.</td>
<td>865-890</td>
<td>Kg/m³</td>
</tr>
<tr>
<td>ISO 3104</td>
<td>Viscosity, @ 40° C.</td>
<td>4-15 cSt</td>
<td></td>
</tr>
<tr>
<td>ISO 3104</td>
<td>Viscosity, @ 50° C.</td>
<td>4-10 cSt</td>
<td></td>
</tr>
<tr>
<td>ISO 8754</td>
<td>Sulfur</td>
<td>&gt;0.3 % Wt</td>
<td></td>
</tr>
<tr>
<td>ISO 2719</td>
<td>Flash Point</td>
<td>&gt;60 ° C.</td>
<td></td>
</tr>
<tr>
<td>ISO 3016</td>
<td>Pour Point</td>
<td>&lt;20 ° C.</td>
<td></td>
</tr>
<tr>
<td>ISO 3733</td>
<td>Water by Dist.</td>
<td>&lt;0.05 Vol %</td>
<td></td>
</tr>
<tr>
<td>ISO 6245</td>
<td>Ash</td>
<td>&lt;0.03 Wt %</td>
<td></td>
</tr>
<tr>
<td>ISO 10307-2</td>
<td>Total Sediment by Hot filtration</td>
<td>0.01 Wt %</td>
<td></td>
</tr>
<tr>
<td>IP 570</td>
<td>Hydrogen Sulfide</td>
<td>&lt;1 mg/kg</td>
<td></td>
</tr>
<tr>
<td>ASTM D664</td>
<td>Acid Number</td>
<td>&lt;1.0 mg KOH/g</td>
<td></td>
</tr>
<tr>
<td>ISO 10370</td>
<td>Micro Carbon</td>
<td>0.04 Wt %</td>
<td></td>
</tr>
<tr>
<td>Residue</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISO 12156-1</td>
<td>Lofnacity</td>
<td>180-260</td>
<td>um</td>
</tr>
<tr>
<td>Calculated</td>
<td>CCAI</td>
<td>800-880</td>
<td></td>
</tr>
<tr>
<td>IP 501 Vanadium</td>
<td>&lt;5 ppm Wt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IP 501 Sodium</td>
<td>&lt;5 ppm Wt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IP 501 Aluminum</td>
<td>&lt;20 ppm Wt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IP 501 Silicon</td>
<td>&lt;35 ppm Wt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IP 501 Calcium</td>
<td>&lt;25 ppm Wt</td>
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<tr>
<td>IP 501 Zinc</td>
<td>&lt;3 ppm Wt</td>
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<tr>
<td>IP 501 Phosphorus</td>
<td>&lt;1 ppm Wt</td>
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<td></td>
</tr>
<tr>
<td>ISO 12950</td>
<td>Oxidation Stability</td>
<td>&lt;25 g/ml</td>
<td></td>
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</tbody>
</table>

Example 4

It will be understood by one of ordinary skill in the art that in general any subset or all of the various embodiments and inventive features described herein may be combined, notwithstanding the fact that the claims set forth only a limited number of such combinations.

1. A low sulfur marine fuel having a sulfur content of less than or equal to 1000 ppm, said low sulfur marine fuel comprising a blend of a residual fuel oil and a distillate fuel oil, wherein said residual fuel oil comprises grade No. 6 fuel oil and wherein said distillate fuel oil comprises grade No. 2 fuel oil.

2. (canceled)

3. (canceled)

4. The low sulfur marine fuel of claim 1 wherein said residual fuel oil comprises from about 15% to about 50% by volume of the final marine fuel blend.

5. The low sulfur marine fuel of claim 1, wherein said residual fuel oil comprises from about 28% to about 38% by volume of the final marine fuel blend.

6. The low sulfur marine fuel of claim 1 wherein said distillate fuel oil comprises from about 50% to about 85% by volume of the final marine fuel blend.

7. The low sulfur marine fuel of claim 1 wherein said distillate fuel oil comprises from about 62% to about 72% by volume of the final marine fuel blend.

8. (canceled)

9. (canceled)

10. The low sulfur marine fuel of claim 1, further comprising grade No. 4 fuel oil.

11. (canceled)

12. A low sulfur marine fuel having a sulfur content of less than or equal to 1000 ppm, said low sulfur marine fuel being adapted for use in Category 3 marine diesel engines operating in emission control areas, said low sulfur marine fuel comprising a blend of from 15% to 50% of a residual fuel oil, said residual fuel oil comprises grade No. 6 fuel oil, and from about 50% to about 85% of a distillate fuel oil component, said distillate fuel oil comprises grade No. 2 fuel oil, wherein said low sulfur marine fuel has a Pour Point of less than −20° C. an API gravity value of about 27-33°.
13. (canceled)
14. (canceled)
15. (canceled)
16. A low sulfur marine fuel having a sulfur content of less than or equal to 1000 ppm, said low sulfur marine fuel being suitable for use in Category 3 marine diesel engines operating in emission control areas, said low sulfur marine fuel comprising a blend of:
(a) a first hydrocarbon component comprising a distillate fuel oil having an ultra low sulfur diesel component, said ultra low sulfur diesel being characterized by a flashpoint of 120°F or higher and a sulfur content of less than about 50 ppm, wherein said first hydrocarbon component comprises from about 50% to about 85% by volume of said final marine fuel blend; and
(b) a second hydrocarbon component comprising a residual fuel oil having a vacuum tower bottoms component, said vacuum tower bottoms being characterized by a flashpoint of 200°F or higher and a sulfur content of 2000 ppm or higher, wherein said second hydrocarbon component comprises from about 15% to about 50% by volume of the final marine fuel blend; and
wherein the first marine fuel blend of said first and second hydrocarbon components has a sulfur content of less than 1000 ppm.
17. The low sulfur marine fuel of claim 16 wherein the sulfur content of said vacuum tower bottoms of said second hydrocarbon component is greater than 2300 ppm.
18. The low sulfur marine fuel of claim 16 wherein the sulfur content of said vacuum tower bottoms of said second hydrocarbon component is greater than 3500 ppm.
19. The low sulfur marine fuel of claim 16 wherein the first hydrocarbon component comprises from 62% to 72% by volume of said final marine fuel blend and wherein said second hydrocarbon component comprises from 28% to 38% by volume of said final marine fuel blend.
20. The low sulfur marine fuel of claim 16 wherein the sulfur content of the final marine fuel blend is less than 1000 ppm and the flashpoint of the final blend is at least 140°F.
21. A method for producing a low sulfur marine fuel having a sulfur content of less than or equal to 1000 ppm, said low sulfur marine fuel being suitable for use in Category 3 marine diesel engines operating in emission control areas, said method comprising the step of blending a first hydrocarbon component with a second hydrocarbon component wherein said first hydrocarbon component comprises a distillate fuel oil having an ultra low sulfur diesel component, said ultra low sulfur diesel being characterized by a flashpoint of 120°F or higher and a sulfur content of less than about 50 ppm, wherein said first hydrocarbon component comprises from about 50% to about 85% by volume of said final blend; and
said second hydrocarbon component comprises a residual fuel oil having a vacuum tower bottoms component, said vacuum tower bottoms being characterized by a flashpoint of 200°F or higher and a sulfur content of 2000 ppm or higher, wherein said second hydrocarbon component comprises from about 15% to about 50% by volume of the final marine fuel blend; and
wherein the final marine fuel blend of said first and second hydrocarbon components has a sulfur content of less than 1000 ppm.
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