METHOD OF FORMULATING A FUEL COMPOSITION

Inventors: Claire Ansell, Chester (GB); Robert Wilfred Matthews Wardle, Chester (GB)

Correspondence Address:
Shell Oil Company
910 Louisiana
Houston, TX 77002

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ABSTRACT

In a fuel composition containing a static dissipator additive, a lubricity enhancing additive is blended for the purpose of increasing the electrical conductivity of the composition, and/or for reducing the concentration of the static dissipator additive in the composition. The fuel composition is preferably an automotive diesel fuel composition and preferably contains a Fischer-Tropsch derived fuel component.
METHOD OF FORMULATING A FUEL COMPOSITION

FIELD OF THE INVENTION

[0001] The present invention relates to a certain method of formulating a fuel composition.

BACKGROUND OF THE INVENTION

[0002] The transport of a fuel often involves pumping, which can generate static electricity in the fuel and hence electric fields in its vapour phase. This is hazardous since subsequent spark discharges can then cause explosion and fire.
[0003] In order to reduce such hazards, static dissipator additives are often included in fuel compositions. These act to increase the electrical conductivity of the fuel, allowing charge generated during pumping to leak away more readily.
[0004] Fuels with an inherently lower conductivity generally require higher levels of static dissipator additives, which can be undesirable for cost reasons. Low conductivity fuels include in particular those which are low in polar fuel components such as aromatics and sulphur- or nitrogen-containing compounds. As pressure to reduce sulphur levels in fuels, in particular automotive fuels, increases, this in turn increases the problems associated with poor conductivity.
[0005] It is an aim of the present invention to provide fuel compositions, and/or additives for use in such compositions, which can overcome or at least mitigate the above described problems.

SUMMARY OF THE INVENTION

[0006] Accordingly, a method of formulating a fuel composition is provided, the method comprising (i) blending together a base fuel and a static dissipator additive, (ii) measuring the electrical conductivity of the resultant blend and (iii) incorporating a lubricity enhancing additive, in an amount effective to increase the electrical conductivity of the blend.

DETAILED DESCRIPTION OF THE INVENTION

[0007] Lubricity enhancing additive has not previously been recognised that such additives could have an effect on electrical conductivity. Surprisingly, it has now been found that a lubricity enhancing additive and a static dissipator additive can interact synergistically to result in an overall conductivity higher than that which would have been expected from the effects of the two components individually.
[0008] In one embodiment of the invention a lubricity enhancing additive is blended into a fuel composition containing a static dissipator additive, for the purpose of reducing the concentration of the static dissipator additive in the composition. Because the static dissipator additive and the lubricity enhancing additive can act together to improve electrical conductivity, incorporation of the lubricity enhancing additive potentially enables lower levels of the static dissipator additive to be used in order to achieve a desired target conductivity in the overall composition.
[0009] A certain level of electrical conductivity may for instance be desirable in order for the fuel composition to meet current fuel specifications, and/or to comply with health and safety regulations, and/or to satisfy consumer demand. According to the present invention, such standards may still be achievable even with reduced levels of static dissipator additive, due to the presence of the lubricity enhancing additive.

[0010] In another embodiment of the present invention, the term “reducing” embraces any degree of reduction, although preferably not reduction to zero. The reduction may for instance be 1% or more of the original concentration of static dissipator additive, preferably 2 or 5 or 10% or more, most preferably 15 or 20 or 25 or even 30% or more. The reduction may be as compared to the concentration of static dissipator additive which would otherwise have been incorporated into the fuel composition in order to achieve the properties and performance required and/or desired of it in the context of its intended use. This may for instance be the concentration of static dissipator additive which was present in the fuel composition prior to the realisation that a lubricity enhancing additive could be used in the way provided by the present invention, and/or which was present in an otherwise analogous fuel composition intended (e.g. marketed) for use in an analogous context, prior to adding a lubricity enhancing additive to it in accordance with the present invention.

[0011] Preferably, the reduction in concentration of static dissipator additive is achieved with less reduction in electrical conductivity than would otherwise be caused by the reduction in concentration of static dissipator additive. The reduction in conductivity may for instance be less than 5%, preferably less than 2 or 1%, more preferably less than 0.5 or 0.1%, compared to the conductivity of the fuel composition before reducing its concentration of static dissipator additive.

[0012] More preferably, the reduction in concentration of static dissipator additive is achieved without any reduction in the electrical conductivity of the fuel composition, relative to the conductivity of the composition before reducing its concentration of static dissipator additive. In some cases the conductivity of the fuel composition may be increased by carrying out the present invention, despite the reduction in concentration of static dissipator additive.

[0013] In certain cases, static dissipator additive levels in a fuel composition need to be “topped up” subsequent to its initial addition, to ensure maintenance of the desired conductivity. This can for instance be necessary after a certain period of time or after an event such as pumping or transportation of the fuel composition.

[0014] The present invention may therefore be carried out for the purpose of reducing the need for such subsequent additions of static dissipator additive, for instance to reduce the number of subsequent additions needed or their frequency. Ideally, as a result of carrying out the present invention, no subsequent addition of static dissipator additive is necessary. The present invention thus preferably results in a fuel composition having an electrical conductivity that does not decrease over time or on transportation of the composition, or at least decreases by no more than 10%, preferably no more than 5 or 2 or 1% of its original value, or decreases by less (over a given time period or following a given event) than it would have done had the lubricity enhancing additive not been added in accordance with the present invention. The relevant time period may for example be 4 weeks, suitably 6 weeks, preferably 10 or 12 weeks; in some cases it may be 6, 12, 18 or even 24 months.

[0015] Accordingly, another embodiment of the present invention provides a method for formulating a fuel composition, the method comprising (i) blending together a base fuel and a static dissipator additive, optionally with other fuel additives, and (ii) incorporating a lubricity enhancing additive, in an amount effective to increase the electrical conductivity of the blend.
components, (ii) measuring the electrical conductivity of the resultant blend and (iii) incorporating a lubricity enhancing additive, in an amount sufficient to increase the electrical conductivity of the blend. Preferably, the static dissipator additive is included in the blend at a lower level than would have been necessary or desirable had the lubricity enhancing additive not been incorporated, as discussed above.

[0016] The methods of the present invention may be used for the purpose of achieving a desired target (typically minimum) electrical conductivity in the fuel composition. This target is suitably 50 pS/m (ASTM D2624) or greater, preferably 100 or 150 pS/m or greater.

[0017] The fuel composition used in the present invention may be, for example, a naphtha, kerosene or diesel fuel composition. It may in particular be a middle distillate fuel composition, such as a heating oil, an industrial gas oil, an automotive diesel fuel, a distillate marine fuel or a kerosene fuel such as an aviation fuel or heating kerosene. Preferably, the fuel composition is for use in an engine such as an automotive engine or an aeroplane engine. More preferably, it is for use in an internal combustion engine; yet more preferably, it is an automotive fuel composition, still more preferably a diesel fuel composition which is suitable for use in an automotive diesel (compression ignition) engine.

[0018] The fuel composition will typically contain a major proportion of, or consist essentially or entirely of, a base fuel such as a distillate hydrocarbon base fuel. A “major proportion” means typically 80% v/v or greater, more suitably 90 or 95% v/v or greater, most preferably 98 or 99 or 99.5% v/v or greater. Such a base fuel may for example be a naphtha, kerosene or diesel fuel, preferably a kerosene or diesel fuel, more preferably a diesel fuel.

[0019] A naphtha base fuel will typically boil in the range from 25 to 175°C. A kerosene base fuel will typically boil in the range from 150 to 275°C. A diesel base fuel will typically boil in the range from 150 to 400°C.

[0020] The base fuel may in particular be a middle distillate base fuel, in particular a diesel base fuel, and in this case it may itself comprise a mixture of middle distillate fuel components (components typically produced by distillation or vacuum distillation of crude oil), or fuel components which together form a middle distillate blend. Middle distillate fuel components or blends will typically have boiling points within the usual middle distillate range of 125 to 550°C. or 150 to 400°C.

[0021] A diesel base fuel may be an automotive gas oil (AGO). Traditional diesel fuel components comprise liquid hydrocarbon middle distillate fuel oils, for instance petroleum derived gas oils. Such base fuel components may be organically or synthetically derived. They will typically have boiling points within the usual diesel range of 125 or 150 to 400 or 550°C., depending on grade and use. They will typically have densities from 0.75 to 1.0 g/cm³, preferably from 0.8 to 0.9 or 0.86 g/cm³, at 15°C. (IP 365) and measured cetane numbers (ASTM D613) of from 35 to 80, more preferably from 40 to 75 or 70. Their initial boiling points will suitably be in the range 150 to 230°C. and their final boiling points in the range 290 to 400°C. Their Kinematic viscosity at 40°C. (ASTM D445) might suitably be from 1.5 to 4.5 mm²/s.

[0022] Such fuels are generally suitable for use in a compression ignition (diesel) internal combustion engine, of either the indirect or direct injection type.

[0023] A diesel fuel composition which results from carrying out the present invention will also preferably fall within these general specifications. Suitably it will comply with applicable current standard specification(s) such as for example EN 590 (for Europe) or ASTM D975 (for the USA). By way of example, the fuel composition may have a density from 0.82 to 0.845 g/cm³ at 15°C.; a T₉₀ boiling temperature (ASTM D86) of 360°C. or less; a cetane number (ASTM D613) of 51 or greater; a kinematic viscosity (ASTM D445) from 2 to 4.5 mm²/s at 40°C.; a sulphur content (ASTM D2622) of 50 mg/kg or less; and/or a polycyclic aromatic hydrocarbons (PAH) content (IP 391) (mod) of less than 11%. Relevant specifications may, however, differ from country to country and from year to year and may depend on the intended use of the fuel composition.

[0024] A petroleum derived gas oil may be obtained from refining and optionally (hydro)processing a crude petroleum source. It may be a single gas oil stream obtained from such a refinery process or a blend of several gas oil fractions obtained in the refinery process via different processing routes. Examples of such gas oil fractions are straight run gas oil, vacuum gas oil, gas oil as obtained in a thermal cracking process, light and heavy cycle oils as obtained in a fluid catalytic cracking unit and gas oil as obtained from a hydrocracker unit. Optionally, a petroleum derived gas oil may comprise some petroleum derived kerosene fraction.

[0025] Such gas oils may be processed in a hydrodesulphurisation (HDS) unit so as to reduce their sulphur content to a level suitable for inclusion in a diesel fuel composition. This also tends to reduce the content of other polar species such as oxygen- or nitrogen-containing species, and leads to a reduction in electrical conductivity.

[0026] In the methods of the present invention, a base fuel may be or contain a so-called “biofuel” component such as a vegetable oil or vegetable oil derivative (e.g. a fatty acid ester, in particular a fatty acid methyl ester) or another oxygenate such as an acid, ketone or ester. Such components need not necessarily be bio-derived.

[0027] In a preferred embodiment of the present invention, a base fuel may be or contain a Fischer-Tropsch derived fuel component, in particular a Fischer-Tropsch derived gas oil. Such fuels are known and in use in diesel fuel compositions, and are described in more detail below. They tend to have low levels of aromatic fuel components and of sulphur and other polar species, and hence low electrical conductivities.

[0028] The fuel composition to which the present invention is applied will typically, prior to incorporation of the static dissipator additive and the lubricity enhancing additive, have a low electrical conductivity. Its conductivity may for instance be less than 100 pS/m, in cases less than 50 or 25 or 20 or even 10 pS/m (ASTM D2624). In other cases its conductivity may be 5 pS/m or lower, or 2 or 1 pS/m or lower.

[0029] Low conductivity can result from low levels of polar species such as aromatic fuel components and sulphur- or nitrogen-containing compounds. Thus the fuel composition may, prior to carrying out the present invention, contain a low concentration of aromatic fuel components, for instance 25% w/w or less, or 20 or 10 or 5 in cases even 1% w/w or less. It may have a low sulphur content, for example at most 1000 mg/kg. More preferably, it will have a low or ultra low sulphur content, for instance at most 500 mg/kg, preferably no more than 350 mg/kg, most preferably no more than 100 or 50 or 10 or even 5 mg/kg, of sulphur.
As described above, the processes used to remove sulphur from a fuel can also often result in a reduction in the levels of other polar materials such as nitrogen- and oxygen-containing species.

Generally speaking, a fuel composition which has been subjected to hydroprocessing (as typically manifested by a relatively low sulphur content, in particular 50 mg/kg or less) is more likely to require a static dissipator additive, and the present invention may thus be of use in treating such compositions.

A fuel composition useable in accordance with the present invention preferably contains a high level of paraffinic fuel components, for example 70% v/v or greater. Normal and iso-paraffins are preferred to cyclic paraffins.

In particular the fuel composition may be or contain a Fischer-Tropsch derived fuel component, preferably a Fischer-Tropsch derived gas oil or kerosene, more preferably a gas oil.

By “Fischer-Tropsch derived” is meant that a fuel is, or derives from, a synthesis product of a Fischer-Tropsch condensation process. A Fischer-Tropsch derived fuel may also be referred to as a GTL (Gas-to-Liquid) fuel.

The Fischer-Tropsch reaction converts carbon monoxide and hydrogen into longer chain, usually paraffinic, hydrocarbons:

\[ n(CO + 2H_2) \rightarrow (\cdots CH_2\cdots)_n + nH_2O + \text{heat} \]

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. The gases which are converted into liquid fuel components using such processes can in general include natural gas (methane), LPG (e.g. propane or butane), “condensates” such as ethane, synthesis gas (CO/ hydrogen) and gaseous products derived from coal, biomass and other hydrocarbons.

Gas oil, naphtha and kerosene 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., GB-B-2077289 and EP-A-0147873) and/or hydroisomerisation which can improve cold flow properties by increasing the proportion of branched paraffins. EP-A-0583836 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. The desired gas oil fraction (s) may subsequently be isolated for instance by distillation.

Other post-synthesis treatments, such as polymerisation, alkylation, distillation, cracking-decarboxylation, isomerisation and hydroreforming, may be employed to modify the properties of Fischer-Tropsch condensation products, as described for instance in U.S. Pat. No. 4,125,566 and U.S. Pat. No. 4,478,955.

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 rhenium, iron, cobalt or nickel. Suitable such catalysts are described for instance in EP-A-0583836 (pages 3 and 4).

An example of a Fischer-Tropsch based process is the SMDS (Shell Middle Distillate Synthesis) described by van der Burg et al in “The Shell Middle Distillate Synthesis Process”, paper delivered at the 5th Synfuels Worldwide Symposium, Washington D.C., November 1985 (see also the November 1989 publication of the same title from Shell International Petroleum Company Ltd, London, UK). This process (also sometimes referred to as the Shell “Gas-To-Liquids” or “GTL” technology) produces middle distillate 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 the gas oils useable in diesel fuel compositions. A version of the SMDS process, utilising a fixed bed reactor for the catalytic conversion step, is currently in use in Bentulu, Malaysia and its gas oil products have been blended with petroleum derived gas oils in commercially available automotive fuels.


By virtue of the Fischer-Tropsch process, a Fischer-Tropsch derived fuel 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. This can in turn lead to low electrical conductivities, making such fuels particularly suitable for application of the present invention.

Low levels of sulphur and other heteroatomic species can also lead to low lubricity in a Fischer-Tropsch derived fuel. Thus, incorporation of a lubricity enhancing additive in accordance with the present invention may provide the dual benefits of improved electrical conductivity and a highly desirable improvement in lubricity.

Further, the Fischer-Tropsch process as usually operated produces no or virtually no aromatic components, again reducing the electrical conductivity of the resultant fuel. The aromatics content of a Fischer-Tropsch derived fuel, suitably determined by ASTM D4629, will typically be below 1% w/w, preferably below 0.5% w/w and more preferably below 0.2 or 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. 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.

[0046] Where a Fischer-Tropsch derived fuel component is a naphtha fuel, it will be a liquid hydrocarbon distillate fuel with a final boiling point of typically up to 220°C or preferably of 180°C or less. Its initial boiling point is preferably higher than 25°C, more preferably higher than 35°C. Its components (or the majority, for instance 95% w/w or greater, thereof) are typically hydrocarbons having 5 or more carbon atoms; they are usually paraffinic.

[0047] In the context of the present invention, a Fischer-Tropsch derived naphtha fuel preferably has a density of from 0.67 to 0.73 g/cm³ at 15°C, and/or a sulphur content of 5 mg/kg or less, preferably 2 mg/kg or less. It preferably contains 95% w/w or greater of iso- and normal paraffins, preferably from 20 to 98% w/w or greater of normal paraffins. It is preferably the product of a SMDS process, preferred features of which may be as described below in connection with Fischer-Tropsch derived gas oils.

[0048] A Fischer-Tropsch derived kerosene fuel is a liquid hydrocarbon middle distillate fuel with a distillation range suitably from 140 to 260°C, preferably from 145 to 255°C, more preferably from 150 to 250°C, or from 150 to 210°C. It will have a final boiling point of typically up to 210°C or 260°C, preferably from 190 to 210°C. For a typical “narrow-cut” kerosene fraction or from 240 to 260°C, or for a typical “full-cut” fraction, its initial boiling point is preferably from 140 to 160°C, more preferably from 145 to 160°C.

[0049] A Fischer-Tropsch derived kerosene fuel preferably has a density of from 0.730 to 0.760 g/cm³ at 15°C—for instance from 0.730 to 0.745 g/cm³ for a narrow-cut fraction and from 0.735 to 0.760 g/cm³ for a full-cut fraction. It preferably has a sulphur content of 5 mg/kg or less. It may have a cetane number of from 63 to 75, for example from 65 to 69 for a narrow-cut fraction or from 68 to 73 for a full-cut fraction. It is preferably the product of a SMDS process, preferred features of which may be as described below in connection with Fischer-Tropsch derived gas oils.

[0050] A Fischer-Tropsch derived gas oil should be suitable for use as a diesel fuel, ideally as an automotive diesel fuel; its components (or the majority, for instance 95% v/v or greater, thereof) should therefore have boiling points within the typical diesel fuel (“gas oil”) range, i.e. from 150 to 400°C, or from 170 to 370°C. It will preferably have a 90% v/v distillation temperature of from 300 to 370°C.

[0051] A Fischer-Tropsch derived gas oil will typically have a density of 0.76 to 0.79 g/cm³ at 15°C; a cetane number (ASTM D6131) greater than 70, suitably from 74 to 85; a kinematic viscosity (ASTM D445) from 2 to 4.5, preferably from 2.5 to 4.0, more preferably from 2.9 to 3.7, mm²/s at 40°C; and a sulphur content (ASTM D2622) of 5 mg/kg or less, preferably of 2 mg/kg or less.

[0052] Preferably, a Fischer-Tropsch derived fuel component used in the present invention is a product prepared by a Fischer-Tropsch methane condensation reaction using a hydrogen/carbon monoxide ratio of less than 2.5, preferably less than 1.75, preferably from 0.4 to 1.5, and ideally using a cobalt containing catalyst. Suitably, it will have been obtained from a hydrocracked Fischer-Tropsch synthesis product (for instance as described in GB-2077289 and/or EP-A-0147873), or more preferably a product from a two-stage hydroconversion process such as that described in EP-A-0583836 (see above). In the latter case, preferred features of the hydroconversion process may be as disclosed at pages 4 to 6, and in the examples, of EP-A-0583836.

[0053] Suitably, a Fischer-Tropsch derived fuel component used in the present invention is a product prepared by a low temperature Fischer-Tropsch process, by which is meant a process operated at a temperature of 250°C or lower, such as from 125 to 250°C or from 175 to 250°C, as opposed to a high temperature Fischer-Tropsch process which might typically be operated at a temperature of from 300 to 350°C.

[0054] Suitably, in accordance with the present invention, a Fischer-Tropsch derived fuel component will consist of at least 70% w/w, preferably at least 80% w/w, more preferably at least 90 or 95 or 98% w/w, most preferably at least 99 or 99.5 or even 99.98% w/w, of paraffinic components, preferably iso- and normal paraffins. The weight ratio of iso-paraffins to normal paraffins will suitably be greater than 0.3 and may be up to 12; suitably it is from 2 to 6. The actual value for this ratio will be determined, in part, by the hydroconversion process used to prepare the gas oil from the Fischer-Tropsch synthesis product.

[0055] The olefin content of the Fischer-Tropsch derived fuel component is suitably 0.5% w/w or less. Its aromatics content is suitably 0.5% w/w or lower.

[0056] A fuel composition used according to the present invention may include a mixture of two or more Fischer-Tropsch derived fuel components.

[0057] The proportion of Fischer-Tropsch derived fuel components in the composition, prior to addition of the lubricity enhancing additive, may be from 0 to 100% v/v. It may for example be 0.5% or 1% v/v or greater, preferably 2 or 5 or 10% v/v or greater, more preferably 20 or 25 or 30 or 40 or 50% v/v or greater. It may be up to 100% v/v (i.e. the fuel is entirely Fischer-Tropsch derived), or it may be up to 99 or 98 or 95 or 90 or 80% v/v, in cases up to 75 or 60 or 50% v/v. Most preferably, the proportion of Fischer-Tropsch derived fuel components is up to 30% v/v, or up to 25 or 20 or 15% v/v.

[0058] In accordance with the present invention, the lubricity enhancing additive used in the fuel composition may be any additive capable of improving the lubricity of a fuel composition and/or of imparting anti-wear effects when the composition is in use in an engine or other fuel-consuming system. Although it is known to include such additives in fuel compositions, it has not previously been recognised that they could affect electrical conductivity.

[0059] The lubricity enhancing additive may contain, typically as active constituent(s), one or more carboxylic acids. Suitable carboxylic acids include fatty acids and aromatic acids, in particular fatty acids such as those listed below. A lubricity enhancing additive may alternatively be based on non-acid actives such as esters or amides. Preferably the lubricity enhancing additive is ester- or amide-based, more preferably ester-based.

[0060] Suitable esters for use in such additives are carboxylic acid esters, in particular those derived from fatty acids, and mixtures thereof. Such fatty acids may be saturated or unsaturated (which includes polysaturated). They may for example contain from 1 to 30 carbon atoms, suitably from 10 to 22 carbon atoms, preferably from 12 to 22 or from 14 to 20 carbon atoms, more preferably from 16 to 18 carbon atoms and most preferably 18 carbon atoms. Examples include oleic acid, linoleic acid, linolenic acid, linolic acid, stearic acid, palmitic acid and myristic acid. Of these, oleic, linoleic and linolenic acids may be preferred, more preferably oleic and linoleic acids. In one embodiment of the present invention,
the lubricity enhancing additive is a derivative (in particular an ester) of tall oil fatty acid, which is derived from tall oil and contains mostly fatty acids (such as oleic and linoleic) with a small proportion of rosin acids.

**[0061]** Lubricity enhancing additives based on ester-functionalised oligomers or polymers (e.g. olefin oligomers) may also be of use. Such esters may be mono- or di-functional esters such as methyl esters, or more suitably may be polyol esters such as glycerol esters. Most preferred is a mono-, di- or tri-glycidoxy fatty acid, or preferably a mixture of two or more such species.

**[0062]** Suitable amides for use in such additives are fatty acid amides, wherein preferred fatty acids may be as described above, for example fatty acid amides of mono- or in particular di-alkylamines such as diethanolamine.

**[0063]** Suitable commercially available lubricity enhancing additives include the fatty acid-based R650 (ex. Infinium), the fatty acid ester-based R655 (ex. Infinium), the amide-based Hitite™ 4848A (ex. Alton) and the fatty acid-based Lz 539 series of products (ex. Lubrizol). Of these, fatty acid ester-based additives such as R655 may be preferred.

**[0064]** Other suitable lubricity enhancers are described for example:


**[0066]** WO-A-95/33805—cold flow improvers to enhance lubricity of low sulphur fuels;

**[0067]** WO-A-94/17160—certain esters of a carboxylic acid and an alcohol wherein the acid has from 2 to 50 carbon atoms and the alcohol has 1 or more carbon atoms, particularly glyceral monoooleate and di-isocetyl adipate, as fuel additives for wear reduction in a diesel engine injection system;

**[0068]** U.S. Pat. No. 5,490,864—certain diethoxyphosphoro diester-dialcohols as anti-wear lubricity additives for low sulphur diesel fuels; and

**[0069]** WO-A-98/01516—certain alkyl aromatic compounds having at least one carboxyl group attached to their aromatic nuclei, to confer anti-wear lubricity effects particularly in low sulphur diesel fuels.

**[0070]** A lubricity enhancing additive may contain other ingredients in addition to the key lubricity enhancing active(s), for example a deluizer and/or an anti-rust agent, as well as conventional solvent(s) and/or excipient(s). Alternatively a lubricity enhancing additive may consist essentially or even entirely of a lubricity enhancing active, or mixture thereof, of the type described above.

**[0071]** The (active matter) concentration of the lubricity enhancing additive used in a fuel composition according to the present invention may be up to 1000 mg/kg, preferably up to 500 mg/kg, more preferably up to 400 or 300 mg/kg. Its (active matter) concentration will suitably be at least 20 mg/kg, preferably at least 30 or 50 mg/kg, more preferably at least 100 mg/kg.

**[0072]** In accordance with the present invention, any static dissipator additive may be used in the fuel composition. A static dissipator additive may for example contain one or more active ingredients selected from organic acids, in particular (benzenesulphonic acids; amines, in particular polyamines; sulphones, in particular polysulphones; and other hydrocarbon-soluble (co)polymer such as vinyl (co) polymers, in particular those containing cationic monomer units.

**[0073]** Commercially available static dissipator additives include Stadis™ 450 and Stadis™ 425 (both ex. Innospec) and Tolad™ 3514 (ex. Baker-Petrolite). Stadis™ 450, for example, contains diamonylphenyl sulphonate acid as an active ingredient; it is typically used in certain distillate fuels, solvents, commercial jet fuels and certain military fuels. Stadis™ 425 contains similar active(s) to Stadis™ 450 and is typically used in distillate fuels and solvents. Tolad™ 3514 contains a hydrocarbon-soluble copolymer of an allylvinyl monomer and an anionic vinyl monomer.

**[0074]** The concentration of the static dissipator additive in a fuel composition prepared according to the present invention may be for example from 1 to 3 mg/kg. It may be up to 4 mg/kg. It may be 0.5 mg/kg or more, preferably 1 or 1.5 mg/kg or more, such as about 2 mg/kg.

**[0075]** The static dissipator additive may be present in the fuel composition, in accordance with the present invention, at a concentration which is different (preferably lower) than its standard treat rate, due to the use of the lubricity enhancing additive. Thus, the present invention may embrace use of a static dissipator additive in a fuel composition, together with a lubricity enhancing additive, which involves incorporating the static dissipator additive at a concentration other than that which would have been necessary or desirable or usual—for instance to achieve a desired target conductivity—had the lubricity enhancing additive not been present in the composition. Such use may involve incorporating the static dissipator additive at a concentration lower than that which would be necessary or desirable or usual in order to impart adequate electrical conductivity to the overall fuel composition (e.g. taking account of any other additives present in the composition).

**[0076]** The electrical conductivity of a fuel composition may be measured in any suitable manner, for instance using the standard test method ASTM D2624 (probe method, e.g. as described in the examples below) or ASTM D4308 (conductric rings method).

**[0077]** In the present context, “increasing” the electrical conductivity of the fuel composition embraces any degree of increase compared to the conductivity of the composition before incorporation of the lubricity enhancing additive. The methods of the present invention may, for example, involve adjusting the conductivity of the composition, by means of the lubricity enhancing additive and/or the static dissipator additive, in order to meet a desired target conductivity.

**[0078]** By using the present invention, the conductivity of the fuel composition is preferably increased by at least 5 ps/m (ASTM D2624), more preferably by at least 2 or 20 ps/m, most preferably by at least 25 ps/m, as compared to its value prior to incorporation of the lubricity enhancing additive. The conductivity may be increased by at least 1% of its value prior to incorporation of the lubricity enhancing additive, preferably by at least 2 or 5% of that value, more preferably by at least 10 or 20 or in cases 25% of that value.

**[0079]** A lubricity enhancing additive may be used in the fuel composition, in accordance with the present invention, at a concentration which is higher than (for example higher than) its standard treat rate. Thus, use of a lubricity enhancing additive in accordance with the present invention may involve incorporating it at a concentration other than that which would have been necessary or desirable or usual if it had been incorporated into the composition purely for its lubricity enhancing properties. The use may involve incorporating the additive at a concentration higher than that which would be
necessary or desirable or usual in order to impart adequate lubricity properties to the overall fuel composition (e.g., taking account of any other additives present in the composition).

In particular, use of a lubricity enhancing additive in accordance with the present invention may involve incorporating it into a fuel composition which already has (typically because one or more lubricity enhancing additives are already present) adequate lubricity.

In the context of the present invention, “use” of a lubricity enhancing additive in a fuel composition means incorporating the additive into the composition, typically as a blend (i.e., a physical mixture) with one or more other fuel components. An additive will conveniently be incorporated before the composition is introduced into an engine or other system which is to be run on the composition. Instead or in addition the use of an additive may involve running a fuel-consuming system, typically a diesel engine, on a fuel composition containing the additive, typically by introducing the composition into a combustion chamber of an engine. “Use” of a lubricity enhancing additive in the ways described above may also embrace supplying such an additive together with instructions, for instance, to achieve a desired target electrical conductivity and/or to reduce the concentration of static dissipator additive in the composition. The lubricity enhancing additive may itself be supplied as part of a formulation suitable for use or intended for use as a fuel additive, in which case the lubricity enhancing additive may be included in such a formulation for the purpose of influencing its effects on the electrical conductivity of a fuel composition.

According to the present invention, the fuel composition may contain other additives in addition to the static dissipator additive and the lubricity enhancing additive. Many such additives are known and readily available.

The total additive content in the fuel composition may suitably be from 50 to 10000 mg/kg, preferably below 5000 mg/kg.

According to another embodiment of the present invention, there is provided a process for the preparation of a fuel composition, which process involves blending a base fuel with a static dissipator additive and a lubricity enhancing additive, in particular with respect to the electrical conductivity of the resultant fuel composition.

The process above may form part of a process for, or be implemented using a system for, controlling the blending of a fuel composition, for example in a refinery. Such a system will typically include means for introducing each of the relevant additives and a suitable base fuel into a blending chamber, flow control means for independently controlling the flow rates of the additives and the base fuel into the chamber, means for calculating the proportions of each of the additives needed to achieve a desired target electrical conductivity input by a user into the system, and means for directing the result of that calculation to the flow control means which is then operable to achieve the desired proportions of additives in the product composition by altering the flow rates of its constituents into the blending chamber.

In order to calculate the required proportions, a process or system of this type will suitably make use of known electrical conductivities for the base fuel concerned, and conveniently also a model predicting, and/or data describing, the conductivity of fuel compositions containing varying proportions of the relevant additives. The process or system may then for example, according to the present invention, select and produce a concentration of static dissipator additive lower than that predicted to be necessary if the lubricity enhancing additive were not present.

The present invention may thus conveniently be used to automate, at least partially, the formulation of a fuel composition, preferably providing real-time control over the relative proportions of the additives and base fuel incorporated into the composition, for instance by controlling the relative flow rates or flow durations for the constituents.

Another embodiment of the invention provides a method of operating a fuel consuming system, which method involves introducing into the system a fuel composition prepared in accordance with any one of the first to the fourth aspects of the present invention. Again the fuel composition is preferably introduced as described above, in particular to improve the conductivity of the fuel composition and/or to improve the safety of the system and/or its users.

In the present context, a “fuel consuming system” includes a system which transports (for example by pumping) or stores a fuel composition, as well as a system which runs on (and hence combusts) a fuel composition.

The system may in particular be an engine, such as an automotive or aeroplane engine, in which case the method involves introducing the relevant fuel composition into a combustion chamber of the engine. It may be an internal combustion engine, and/or a vehicle which is driven by an internal combustion engine. The engine is preferably a compression ignition (diesel) engine. Such a diesel engine may be of the direct injection type, for example of the rotary pump, in-line pump, unit pump, electronic unit injector or common rail type, or of the indirect injection type. It may be a heavy or a light duty diesel engine.

Throughout the description and claims of this specification, the words “comprise” and “contain” and variations of the words, for example “comprising” and “comprises”, mean “including but not limited to”, and are not intended to (and do not) exclude other moieties, additives, components, integers or steps.

Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

Other features of the present invention will become apparent from the following examples. Generally speaking, the present invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims). Thus, features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular embodiment or example of the present invention are to be understood to be applicable to any other embodiment or example described herein unless incompatible therewith.

Moreover, unless stated otherwise, any feature disclosed herein may be replaced by an alternative feature serving the same or a similar purpose.

The following examples illustrate the properties of fuel compositions prepared in accordance with the present
invention, and assess the effects of lubricity enhancing additives on the electrical conductivity of diesel fuel compositions.

EXAMPLE 1

[0096] A Fischer-Tropsch derived gas oil was blended with various amounts of (a) a commercially available static dissipator additive Stadis™ 450 (ex. Innospec) and (b) the commercially available ester-based lubricity enhancing additive R655 (ex. Infineum).

[0097] The Fischer-Tropsch derived gas oil had the properties listed in Table 1 below.

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
</thead>
</table>
| Fuel property | Test method | Density @ 15°C. (kg/m³) | V.K. @ 40°C. (mm²/s) | Distillation (°C.):
| | | IP 365/ASTM D4052 785.0 | IP 71/ASTM D445 3.606 | IP 123/ASTM D86 |
| Initial boiling point | 211.5 | 249.0 |
| 10% recovered | 262.0 | 274.0 |
| 20% | 286.0 | 298.0 |
| 30% | 307.5 | 317.0 |
| 40% | 326.5 | 339.0 |
| 50% | 349.0 | 349.0 |
| 60% | 354.5 | |
| Cetane number | 82.2 | |
| Cloud point (°C.) | 219 | |
| CFFP (°C.) | 309 | |
| Sulphur content (mg/kg) | ASTM D2622 <5 | |
| Aromatics (% m) | IP 391 | |

[0098] The electrical conductivity of each blend was measured using the standard test method ASTM D2624 (probe method). The results are shown in Table 2 below.

<table>
<thead>
<tr>
<th>TABLE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stadis™ 450 concentration (mg/kg)</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>0</td>
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<tr>
<td>2</td>
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<td>2</td>
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<tr>
<td>2</td>
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</tbody>
</table>

[0100] Surprisingly, in view of these data, the incorporation of the lubricity enhancer in addition to the static dissipator additive increases the conductivity above the level provided by the same concentration of static dissipator additive alone. This indicates a synergistic interaction between the two additives, an effect which increases with increasing lubricity enhancer concentration.

EXAMPLE 2

[0101] This example demonstrates how the present invention may be used to reduce levels of the often expensive static dissipator additive, without impairment of electrical conductivity.

[0102] Table 3 below shows the electrical conductivities (in pS/m, measured by ASTM D2624 (probe method)) of various blends of the base fuel, static dissipator additive and lubricity enhancing additive used in Example 1. Figures marked with an asterisk have been empirically derived, from graphs of the measured conductivities of base fuel/Stadis™ 450 blends containing various concentrations of the static dissipator additive—the relevant figures, obtained from an experiment analogous to that of Example 1 but omitting the lubricity enhancer, are shown in Table 4 below.

<table>
<thead>
<tr>
<th>TABLE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel blend</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Base fuel alone</td>
</tr>
<tr>
<td>Base + 150 mg/kg R655</td>
</tr>
<tr>
<td>Base + 300 mg/kg R655</td>
</tr>
</tbody>
</table>

[0103] Table 3 shows that in order to achieve a target conductivity of, say, 178.5 pS/m, a concentration of static dissipator additive of 2.6 mg/kg is needed. However when 150 mg/kg of the lubricity enhancing additive is incorporated in accordance with the present invention, the concentration of static dissipator additive needed in order to achieve the target conductivity is only 2 mg/kg (a 23% reduction). Thus, a lower level of the static dissipator additive can be used, with resultant cost benefits, without impairing the conductivity of the overall fuel blend.

[0104] Similarly in order to achieve a target conductivity of 186 pS/m, a concentration of static dissipator additive of 2.7 mg/kg is needed, but this concentration can be reduced by 26% to 2 mg/kg in the presence of 300 mg/kg of the lubricity enhancer.

[0105] In situations where levels of static dissipator additive have been predetermined, for instance due to additive introduction at the refinery, a lubricity enhancing additive may nevertheless be used, in accordance with the present
invention, to yield an overall improvement in conductivity and hence safer fuel handling properties.

[0106] The present invention is likely to be of particular use for fuel compositions having an inherently low electrical conductivity, for example those containing Fischer-Tropsch derived fuel components.

What is claimed is:

1. A method for formulating a fuel composition, the method comprising (i) blending together a base fuel and a static dissipator additive, (ii) measuring the electrical conductivity of the resultant blend and (iii) incorporating a lubricity enhancing additive, in an amount effective to increase the electrical conductivity of the blend.

2. A method of operating a fuel consuming system, which method comprising introducing into the system a fuel composition prepared by the method of claim 1.

3. The method of claim 1 wherein the fuel composition contains a Fischer-Tropsch derived fuel component.

4. The method of claim 3 wherein the fuel composition is an automotive diesel fuel composition.

5. The method of claim 2 where the fuel composition contains a Fischer-Tropsch derived fuel component.

6. The method of claim 5 wherein the fuel composition is an automotive diesel fuel composition.

* * * * *