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(54) **FUEL CONSUMING SYSTEM**

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(57) **ABSTRACT**

A method of operating a fuel consuming system in a restricted ventilatioan area is provided. The level of regulated emissions is reduced from a fuel consuming system running on the Fischer-Tropsch derived fuel composition.

FUEL CONSUMING SYSTEM

FIELD OF THE INVENTION

[0001] The present invention relates to a certain method of operating a fuel consuming system.

BACKGROUND OF THE INVENTION

[0002] Where fuel consuming equipment is used in areas of restricted ventilation, for example mines, great care has to be taken to ensure the health and safety of persons operating the equipment. Measures need to be adopted to reduce exposure to potentially toxic emissions from the equipment. Such emissions may be particularly significant in non-coal (e.g. mineral) mines, as in coal mines there may be even greater risks of explosion and fire from the high levels of methane and coal dust present.

[0003] Typical safety measures include the provision of complex and costly ventilation systems, incorporating fans, air ducts, barricades, seals, air heaters, dehumidifiers and/or other mechanical or electrical equipment. They also generally include frequent and stringent analysis of air content and air flow patterns in high risk areas. In most working areas, strict regulatory standards apply, requiring for instance maximum levels of certain emissions (in particular from diesel engines) and minimum oxygen levels, and/or minimum ventilation requirements (typically in terms of air flow rates) in the vicinity of fuel consuming systems.

SUMMARY OF THE INVENTION

[0004] Accordingly there is provided a method of operating a fuel consuming system in an area of restricted ventilation comprising introducing into the system a fuel composition which contains a Fischer-Tropsch derived fuel component in an amount from 20 to 100% v/v.

DETAILED DESCRIPTION OF THE INVENTION

[0005] It may also be possible to improve safety in such situations by altering the properties of the fuel(s) being consumed by the equipment in question. Thus, for example, in WO-A-94/20593 a low emission diesel fuel is proposed for use in underground mining equipment, the fuel being a straight run hydrocarbon distillate fuel having an initial boiling point in the range 170 to 190° C., an end point not higher than 315° C., a cetane number typically in the range of 55 to 60, a specific gravity at 15° C. of not greater than 0.83, a sulphur content not greater than 0.1% w/w and an aromatics content of 18 to 30% w/w. Such a fuel is said to reduce carbon monoxide, nitrogen oxide (NO_x), unburned hydrocarbon and particulate emissions.

[0006] The optimisation of fuels for use in areas of restricted ventilation is not entirely straightforward. It is desirable to reduce as far as possible those emissions which a system running on the fuel will produce in appreciable volumes, in particular sulphur oxides (SO_x, particularly SO₂) and carbon dioxide (CO₂). At the same time, the fuel must have a sufficiently high energy content to run the heavy machinery and vehicles typically used in such contexts. Balancing these two criteria can often prove difficult.

[0007] It has now been found that certain types of fuel may be particularly suitable for use in areas of restricted ventilation, offering a good balance between energy content and emissions.

[0008] The method improves the suitability of the composition for use in an area of restricted ventilation.

[0009] The method provides the use of a Fischer-Tropsch derived fuel component, in a fuel composition, for the purpose of reducing the level of SO_x and/or CO₂ emissions from a fuel consuming system running on the composition, wherein the fuel consuming system is suitable and/or adapted and/or intended for use in an area of restricted ventilation.

[0010] Fischer-Tropsch derived fuels also tend to cause lower levels of so-called regulated emissions than do their more conventional, petroleum derived, counterparts. Thus, according to a fourth aspect of the present invention, there is provided the use of a Fischer-Tropsch derived fuel component, in a fuel composition which is adapted and/or intended for use in an area of restricted ventilation, for the purpose of reducing the level of regulated emissions from a fuel consuming system running on the composition. "Regulated emissions" include nitrogen oxides (NO_x), carbon monoxide, hydrocarbons, particulate matter and mixtures thereof; the fourth aspect of the present invention may be used to reduce any one or more of such emissions, in particular in an area of restricted ventilation. Ideally, it is used to reduce both regulated emissions and SO_x and/or CO₂ emissions.

[0011] In the present context, an area of restricted ventilation is any region where ventilation and/or access to outside air is restricted. Such an area may be an indoor (which includes partially enclosed), underground or underwater location. It may be an at least partially enclosed space such as a building—examples may include warehouses or factories, where diesel powered equipment and vehicles such as fork-lift trucks may need to operate in an area having restricted ventilation; garages and other areas where diesel powered vehicles are housed, used or worked on; and any buildings or enclosed areas where diesel powered generators or other vehicles or equipment (for example indoor go-karts or other recreational vehicles) are operated. The area may in particular be a mine or part thereof, for example a coal mine or mineral mine.

[0012] Another example of such a situation is when an emergency response vehicle such as a fire engine or ambulance needs to have its engine started within the confines of its vehicle station, or needs to be left with its engine running at the scene of an emergency.

[0013] A fuel consuming system which is suitable and/or adapted and/or intended for use in such an area may be or comprise an internal combustion engine, in particular of the compression ignition (diesel) type. 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. The fuel consuming system may comprise a vehicle or part thereof, or other equipment such as for mining, hauling or otherwise moving objects or people.

[0014] It is known to use Fischer-Tropsch derived fuel components in for example automotive diesel fuels. They are recognised to give relatively low levels of regulated emissions (particulate matter, nitrogen oxides, carbon monoxide and unburnt hydrocarbons). They have not, however, to our knowledge, been proposed for use in areas of restricted ventilation, for example as fuels for mining equipment, for the purpose of reducing sulphur oxide (SO_x) and/or CO₂ emissions.

[0015] However, it has now been found that such fuels may be particularly suitable for use in areas of restricted ventila-

tion, since on combustion they can generate relatively low levels of SO_x and CO_2 emissions whilst also providing a reasonable energy content such as would be important for use in the heavy machinery typically used in mines and other areas of restricted ventilation.

[0016] Fischer-Tropsch derived fuels contain relatively low levels of sulphur. This can help to reduce the level of SO_x emissions they generate on combustion. They also tend to have relatively high hydrogen:carbon (H/C) molar ratios, being typically paraffinic in content, with low levels of unsaturated (including aromatic) hydrocarbons and cyclic paraffins and relatively low ratios of iso- to normal paraffins. This has been found, as explained in the examples below, to make them likely to provide a better balance between CO_2 emissions and energy content. Their typically high cetane numbers (in particular for Fischer-Tropsch derived gas oils) can also be of value, in certain fuel consuming systems, in reducing CO_2 emissions by improving engine efficiency.

[0017] Thus, in accordance with the present invention, a Fischer-Tropsch derived fuel component may be used in a fuel composition to reduce, and in cases to minimise, the SO_x or CO_2 emissions (or typically both SO_x and CO_2 emissions) produced per unit of energy or power provided, on combustion, by the composition.

[0018] In this way, emissions from a fuel consuming system being used in an area of restricted ventilation can be reduced, yielding a higher level of safety in the area without the need to alter the existing ventilation system(s). Instead or in addition, the present invention can allow the use of a lower specification ventilation system without compromising safety.

[0019] Thus, according to a fifth aspect of the present invention, there is provided the use of a Fischer-Tropsch derived fuel component in a fuel composition, for the purpose of improving the safety of a fuel consuming system running on the composition, and/or of a person operating or working in the same area as the system.

[0020] According to a sixth aspect, the present invention provides a method of operating a fuel consuming system in an area of restricted ventilation, which method involves introducing into the system, and typically running the system on, a fuel composition which contains a Fischer-Tropsch derived fuel component. The fuel composition may be introduced for one or more of the purposes described above in connection with the first to the fifth aspects of the present invention, in particular to reduce the CO_2 and/or SO_x emissions it produces per unit of energy provided on combustion.

[0021] In the context of the present invention, “use” of a Fischer-Tropsch derived component in a fuel composition means incorporating the component into the composition, optionally as a blend (i.e. a physical mixture) with one or more other fuel components. In one embodiment of the present invention, the Fischer-Tropsch derived fuel component may be the only fuel component present in the composition, optionally with one or more fuel additives. The Fischer-Tropsch derived component will conveniently be incorporated before the fuel composition is introduced into an engine or other fuel consuming system. Instead or in addition the use of the Fischer-Tropsch derived fuel component may involve running a fuel consuming system, typically a diesel engine, on a fuel composition containing or consisting of the Fischer-Tropsch component, typically by introducing the composition into a combustion chamber of an engine.

[0022] “Use” of a Fischer-Tropsch derived fuel component in the ways described above may also embrace supplying such a component together with instructions for its use in a fuel composition to achieve any of the purposes described above, for instance to reduce the CO_2 and/or SO_x emissions produced per unit of energy provided, on combustion, by the fuel composition.

[0023] In the present context, a reduction in CO_2 and/or SO_x emissions embraces any degree of reduction. A reduction in the CO_2 and/or SO_x emissions produced per unit of energy provided, on combustion, by the fuel composition similarly embraces any degree of reduction.

[0024] Such a reduction may be as compared to the relevant property for the fuel composition prior to incorporation of the Fischer-Tropsch derived fuel component, and/or prior to the realisation that a Fischer-Tropsch derived fuel component could be used in the way provided by the present invention, and/or for an otherwise analogous fuel composition intended (e.g. marketed) for use in an analogous context, prior to adding a Fischer-Tropsch derived fuel component to it in accordance with the present invention.

[0025] CO_2 and/or SO_x emissions may be measured in conventional manner, for instance using infrared analysis. Conventional protocols for measuring so-called “regulated emissions” such as NO_x and CO may be adapted for use in determining CO_2 and/or SO_x levels in the gases emitted from a fuel consuming system.

[0026] The reduction in CO_2 emissions from a fuel composition, as a result of carrying out the present invention, may be 0.5% or greater, or it may be 1 or 2 or 3 or 4% or greater.

[0027] The reduction in SO_x (typically SO_2) emissions from a fuel composition, as a result of carrying out the present invention, may be 20% or greater, or it may be 30 or 50 or 70 or 80 or 90 or even 95% or greater.

[0028] In accordance with the present invention, a Fischer-Tropsch derived fuel component may itself be used as a fuel composition, optionally with one or more suitable fuel additives. In other words, a fuel composition prepared according to the present invention may consist entirely or essentially of the Fischer-Tropsch derived fuel component. Alternatively, such a fuel composition may contain a proportion of the Fischer-Tropsch derived fuel component, for instance together with one or more non-Fischer-Tropsch derived fuel components such as non-Fischer-Tropsch derived base fuels. In this latter case, the Fischer-Tropsch derived component may be used to alter the properties of a fuel composition towards a desired goal of improved suitability for use in an area of restricted ventilation.

[0029] The concentration of the Fischer-Tropsch derived fuel component, in a composition prepared according to the present invention, may be 1% v/v or greater, such as 2 or 5 or 10 or 15% v/v or greater, for example 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. Suitably the concentration of Fischer-Tropsch derived fuel component(s) in the composition is from 20 to 100% v/v, from 20 to 90% v/v or from 20 to 80% v/v.

[0030] A fuel composition to which the present invention is or has been applied may be for example a naphtha, kerosene or diesel fuel composition, in particular a kerosene or diesel fuel composition. It may be a middle distillate fuel composition, an industrial gas oil, an automotive diesel fuel, a distillate marine fuel or a kerosene fuel such as an aviation fuel. It

may be for use in an engine such as an automotive engine. In one embodiment it is for use in an internal combustion engine; for instance it may be a diesel fuel composition which is suitable for use in a diesel (compression ignition) engine.

[0031] As described above, the Fischer-Tropsch derived fuel may be the only fuel component in a composition prepared according to the present invention. Alternatively, such a fuel composition may contain, in addition to the Fischer-Tropsch derived fuel component, one or more non-Fischer-Tropsch derived base fuels such as petroleum derived base fuels. In this case the fuel composition prior to incorporation of the Fischer-Tropsch derived component may 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, or 90 or 95% v/v or greater, or even 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, such as a diesel fuel.

[0032] 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 140 to 260° C. A diesel base fuel will typically boil in the range from 150 to 400° C.

[0033] 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 of 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 140 to 400° C.

[0034] A diesel base fuel may be an automotive gas oil (AGO), for either on- or off-road use. Typical 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 140 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.

[0035] Such fuels are generally suitable for use in a compression ignition (diesel) internal combustion engine, of either the indirect or direct injection type.

[0036] A diesel fuel composition which results from carrying out the present invention may also fall within these general specifications.

[0037] A petroleum derived gas oil may be obtained by 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.

[0038] 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 nitrogen-containing species.

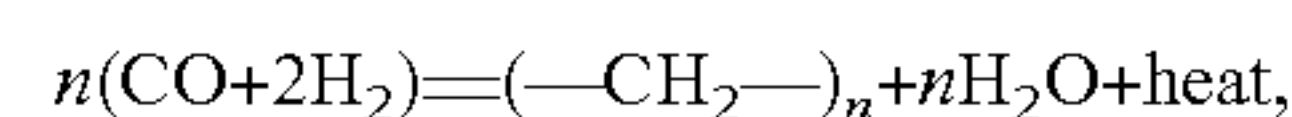
[0039] In the methods of the present invention, a base fuel may be or contain a so-called “biofuel” component such as a vegetable oil or vegetable oil derivative (e.g. a fatty acid ester, in particular a fatty acid methyl ester) or another oxygenate such as an acid, ketone or ester. Such components need not necessarily be bio-derived.

[0040] A fuel composition to which the present invention is or has been applied may have a sulphur content of 1000 mg/kg or less. It may have a low or ultra low sulphur content, for instance at most 500 mg/kg, or at most 350 mg/kg, suitably no more than 100 or 50 or 10 or even 5 mg/kg, of sulphur.

[0041] By “Fischer-Tropsch derived” is meant that a fuel component 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-Liquids) fuel. The term “non-Fischer-Tropsch derived” may be construed accordingly.

[0042] It is known to include such components in fuel compositions; in particular, Fischer-Tropsch derived gas oils have been included in automotive diesel fuels. What has not been appreciated before, to our knowledge, is their suitability for use in areas of restricted ventilation, for instance to power mining equipment and vehicles, where the balance between on the one hand CO₂ and SO_x emissions and on the other the energy content of the fuel is so important.

[0043] The Fischer-Tropsch reaction converts carbon monoxide and hydrogen into longer chain, usually paraffinic, hydrocarbons:



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.

[0044] 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.

[0045] 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.

[0046] 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.

[0047] 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 EP-A-0583836 (pages 3 and 4).

[0048] An example of a Fischer-Tropsch based process is the SMDS (Shell Middle Distillate Synthesis) described by van der Burgt 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 Bintulu, Malaysia and its gas oil products have been blended with petroleum derived gas oils in commercially available automotive fuels.

[0049] Gas oils, naphthas and kerosenes prepared by the SMDS process are commercially available for instance from Shell companies. Further examples of Fischer-Tropsch derived gas oils are described in EP-A-0583836, EP-A-1101813, WO-A-97/14768, WO-A-97/14769, WO-A-00/20534, WO-A-00/20535, WO-A-00/11116, WO-A-00/11117, WO-A-01/83406, WO-A-01/83641, WO-A-01/83647, WO-A-01/83648 and U.S. Pat. No. 6,204,426.

[0050] 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.

[0051] Further, the Fischer-Tropsch process as usually operated produces no or virtually no aromatic components. 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.

[0052] 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.

[0053] 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 prefer-

ably of 180° C. or less. Its initial boiling point may be higher than 25° C., in cases 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.

[0054] In the context of the present invention, a Fischer-Tropsch derived naphtha fuel may have 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 may contain 95% w/w or greater of iso- and normal paraffins, preferably from 20 to 98% w/w or greater of normal paraffins. It may be the product of a SMDS process, suitable features of which may be as described below in connection with Fischer-Tropsch derived gas oils.

[0055] 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 from 190 to 260° C., for instance from 190 to 210° C. for a typical "narrow-cut" kerosene fraction or from 240 to 260° C. for a typical "full-cut" fraction. Its initial boiling point is preferably from 140 to 160° C., more preferably from 145 to 160° C.

[0056] A Fischer-Tropsch derived kerosene fuel may have 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 may be the product of a SMDS process, suitable features of which may be as described below in connection with Fischer-Tropsch derived gas oils.

[0057] 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% w/w or greater, thereof) should therefore have boiling points within the typical diesel fuel ("gas oil") range, i.e. from about 150 to 400° C. or from 170 to 370° C. It will suitably have a 90% w/w distillation temperature of from 300 to 370° C.

[0058] A Fischer-Tropsch derived gas oil will typically have a density from 0.76 to 0.79 g/cm³ at 15° C.; a cetane number (ASTM D613) greater than 70, suitably from 74 to 85; a kinematic viscosity (ASTM D445) from 2 to 4.5, such as from 2.5 to 4.0 or from 2.5 to 3.7, mm²/s at 40° C.; and/or a sulphur content (ASTM D2622) of 5 mg/kg or less, in cases of 2 or even 1 mg/kg or less.

[0059] A Fischer-Tropsch derived fuel component used in the present invention may for instance be a product prepared by a Fischer-Tropsch methane condensation reaction using a hydrogen/carbon monoxide ratio of less than 2.5, or of less than 1.75, or from 0.4 to 1.5, and suitably using a cobalt containing catalyst. It may have been obtained from a hydrocracked Fischer-Tropsch synthesis product (for instance as described in GB-B-2077289 and/or EP-A-0147873), or a product from a two-stage hydroconversion process such as that described in EP-A-0583836 (see above). In the latter case, suitable features of the hydroconversion process may be as disclosed at pages 4 to 6, and in the examples, of EP-A-0583836.

[0060] 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.

[0061] Suitably, in accordance with the present invention, a Fischer-Tropsch derived fuel component will consist of at least 70% w/w, or at least 80% w/w, or at least 90 or 95 or 98% w/w, or at least 99 or 99.5 or even 99.8% w/w, of paraffinic components, in particular 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 fuel component from the Fischer-Tropsch synthesis product.

[0062] The olefin content of the Fischer-Tropsch derived fuel component is suitably 0.5% w/w or lower.

[0063] In accordance with the present invention, the Fischer-Tropsch derived fuel component may be for example a naphtha, kerosene or diesel (gas oil) component, suitably a kerosene or diesel component, such as a diesel component.

[0064] A fuel composition prepared according to the present invention may contain a mixture of two or more Fischer-Tropsch derived fuel components.

[0065] The Fischer-Tropsch derived fuel component may be used in the fuel composition for one or more other purposes in addition to that of reducing CO₂ and/or SO_x emissions per unit of energy, for instance to reduce regulated emissions (e.g. particulate matter, carbon monoxide, nitrogen oxides and/or hydrocarbons) from a fuel consuming system running on the fuel composition, and/or to reduce the level of sulphur and/or aromatics and/or other polar components in the composition. Thus the present invention can be used to optimise the properties and performance of a fuel composition in a number of ways, and can therefore provide additional flexibility in fuel formulation.

[0066] A fuel composition to which the present invention is or has been applied may contain other standard fuel additives, many of which are known and readily available. The total additive content in the fuel composition may suitably be from 50 to 10000 mg/kg, such as below 5000 mg/kg.

[0067] A seventh aspect of the present invention provides a method for formulating a fuel composition, which method involves blending together a non-Fischer-Tropsch derived base fuel and a Fischer-Tropsch derived fuel component, optionally with other fuel components (such as fuel additives), for the purpose of reducing, and in cases minimising, the CO₂ and/or SO_x emissions produced per unit of energy provided, on combustion, by the fuel composition. The method of the seventh aspect of the present invention may be used for the purpose of achieving a desired target (typically maximum) level of CO₂ and/or SO_x emissions on combustion of the fuel composition.

[0068] According to an eighth aspect, the present invention provides a fuel composition preparable by, or which has been prepared by, a method according to any one of the first to the fifth or the seventh aspects of the present invention.

[0069] 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 do not exclude other moieties, additives, components, integers or steps.

[0070] 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.

[0071] Preferred features of each aspect of the present invention may be as described in connection with any of the other aspects.

[0072] Other features of the present invention will become apparent from the following examples. Generally speaking the 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 aspect, embodiment or example of the present invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith.

[0073] Moreover, unless stated otherwise, any feature disclosed herein may be replaced by an alternative feature serving the same or a similar purpose.

[0074] The following non-limiting example illustrates the properties of fuel compositions prepared in accordance with the present invention.

EXAMPLE

[0075] This example demonstrates the suitability of a Fischer-Tropsch derived fuel component, and of a fuel composition containing such a component, for use in an area of restricted ventilation.

[0076] A set of algorithms has been developed, based on both theoretical calculations and empirical relationships, which allows calculation of the levels of SO₂ and CO₂ emissions from a fuel based on its properties. These values can in turn be linked to the energy value of the fuel. The emissions per unit energy can thereby be calculated.

[0077] Levels of CO₂ and SO₂ generation were derived from mass balance of chemical equations, relating these to the mass of fuel consumed. Equations of energy available for work were derived by relating brake specific fuel consumption to fuel net calorific value using an engine efficiency term η .

1. CO₂ Emissions

[0078] The mass of CO₂ emitted on combustion of a hydrocarbon fuel (M_{CO_2}) may be calculated using Equation 1 below:

$$M_{CO_2} = M_{FC} \times \left[\frac{44}{12} \right] \times \left[\frac{12}{(12 + y)} \right] \quad \text{Equation 1}$$

where M_{FC} is the mass of fuel consumed and y is the molar H/C ratio for the fuel.

[0079] Thus, for example, for a fuel having a molar H/C ratio of 1.85 (a typical European automotive gas oil), Equation 1 becomes:

$$M_{CO_2} = M_{FC} (44/12) \times (12/13.85) = M_{FC} \times 3.18.$$

[0080] M_{FC} can be regarded as equivalent to the brake specific fuel consumption (BSFC) in g/kWh. Thus with simplification Equation 1 becomes Equation 2:

$$M_{CO_2} \text{ g/kWh} = BSFC \text{ g/kWh} \times \left[\frac{44}{(12 + y)} \right] \quad \text{Equation 2}$$

[0081] BSFC is itself related to the net calorific value (NCV) of the fuel, by Equation 3:

$$BSFC \text{ in g/kWh} = \frac{3600}{\eta \times NCV} \quad \text{Equation 3}$$

where η is the efficiency of the relevant engine.

[0082] Combining Equations 2 and 3 then gives the key Equation 4 below:

$$M_{CO_2} \text{ g/kWh} = \frac{3600}{\eta \times NCV} \times \left[\frac{44}{(12 + y)} \right] \quad \text{Equation 4}$$

[0083] A fuel which yields a low level of CO_2 emissions per unit power must have a low value for M_{CO_2} in Equation 4. Ideally, one would seek to minimise the value of M_{CO_2} when designing a fuel for use in an area of restricted ventilation. This would mean increasing the H/C ratio (y) of the fuel, which would also increase its net calorific value (as an extreme example, methane has a H/C ratio of 4 and thus a considerably higher calorific value than liquid distillate fuels). In the case of a diesel fuel, this could be achieved empirically by reducing the density (i.e. typically by changing the chemical composition) of the fuel.

[0084] For example, the approximate relationship between the H/C ratio y of a fuel and its density ρ (in g/cm^3 or $kg/litre$), determined from a graphical plot of y against ρ for a limited number of diesel blending components, is expressed in Equation 5 below:

$$y = -3.82\rho + 5.061 \quad \text{Equation 5}$$

[0085] Similarly, the approximate relationship between the net calorific value (NCV) and the density is expressed in Equation 6:

$$NCV = -12.78\rho + 53.82 \quad \text{Equation 6}$$

[0086] Reducing the density of a fuel will typically—as a result of volumetric fuelling systems—reduce the maximum power available from an engine running on the fuel. This may not be an issue if an engine is never operated near to its maximum power limits. Alternatively, an engine running on a low density fuel could be recalibrated to increase its volumetric fuelling rate and thus increase its maximum available power output.

2. Fuel Chemical Composition

[0087] The H/C molar ratio of a fuel, and consequently its calorific value, can be increased by increasing its paraffin content and reducing the concentration of unsaturated (including aromatic) hydrocarbons present. Alternatively, aromatic components can be replaced at least partially by naphthenic components, which would cause less of a reduction in density yet superior calorific values.

[0088] Fischer-Tropsch derived fuels have higher paraffin contents, and lower levels of aromatic species, than their petroleum derived counterparts. They will thus have relatively high H/C ratios and net calorific values. This is likely to make them suitable candidates for use as fuels in areas of

restricted ventilation, since they are likely to provide a better balance between CO_2 emissions and energy content.

3. Other Fuel Factors

[0089] Certain engines may benefit from further (typically smaller) reductions in CO_2 emissions by using fuels of higher cetane number, the benefit being of the order of a 0.5% reduction in emissions for an increase of 10 in the cetane number. This effect is believed to be due to an increase in the engine efficiency term η (see Equation 4).

[0090] Again this means that Fischer-Tropsch derived fuels, which typically have relatively high cetane numbers, are likely to be suitable for use in situations in which CO_2 emissions need to be minimised.

4. SO_2 Emissions

[0091] The mass of SO_2 emitted on combustion of a fuel (M_{SO_2}) may be calculated using Equation 7 below:

$$M_{SO_2} = M_{FC} \times \left[\frac{64}{32} \right] \times \left[\frac{A}{100} \right] \quad \text{Equation 7}$$

where M_{FC} is the mass of fuel consumed and A is the weight percentage of sulphur in the fuel.

[0092] By way of example, a typical European specification diesel fuel might have a sulphur content of around 0.05% w/w. When used in a heavy duty diesel engine with a fuel consumption of 210 g/kWh, then according to Equation 7:

$$M_{SO_2} = 210 \times 2 \times 0.05 / 100 \text{ g/kWh} = 0.21 \text{ g/kWh.}$$

[0093] Combining Equations 7 and 3 (see section 1 above) gives the key Equation 8:

$$M_{SO_2} \text{ g/kWh} = \frac{3600}{\eta \times NCV} \times \left[\frac{2A}{100} \right] \quad \text{Equation 8}$$

[0094] A small correction factor of 0.985 can be applied to Equation 8, to take account of the fact that 1.5% of the SO_2 will be further oxidised and will end up as part of the emitted particulate matter.

[0095] Thus, SO_2 emissions levels are directly proportional to the mass content of sulphur in the fuel and can be reduced by reducing the sulphur content of the fuel. Again, this points towards Fischer-Tropsch derived fuels—which by virtue of their production contain almost no sulphur—as suitable candidates for use in situations where reduced SO_2 emissions are desired.

[0096] SO_2 emissions are also proportional to fuel consumption. Using Equation 4 above to minimise CO_2 emissions will itself help to minimise fuel consumption per unit power; thus, reducing the sulphur content of a fuel represents an additional option for reducing emissions overall.

5. Combining all Criteria

[0097] Combining the factors discussed in sections 1 to 4 above, it can be seen that in order to reduce simultaneously both CO_2 and SO_2 emissions per unit energy, it is necessary to use a fuel having a relatively high H/C molar ratio and net calorific value, and a relatively low sulphur content.

[0098] Fischer-Tropsch derived fuels have the highest H/C molar ratios and net calorific values of any hydrocarbon fuels. They also contain virtually no sulphur. They are thus unique amongst the hydrocarbon fuels in being suitable for minimising both CO₂ and SO_x emissions simultaneously.

[0099] Moreover, the relatively high cetane numbers of Fischer-Tropsch derived fuels can in some cases serve to increase engine efficiency, which can help further to reduce CO₂ and SO_x emissions per unit energy.

[0100] Thus, based on the equations proposed above, it emerges that Fischer-Tropsch derived fuels can be the most suitable hydrocarbon fuels for use in areas of restricted ventilation. They can therefore be expected to be of use, and benefit, in diesel engine-powered machinery such as underground mining equipment.

[0101] Fischer-Tropsch derived fuel components may also be blended with conventional refinery fuels, such as diesel

fuels, in order to increase the net calorific value and H/C ratio of the resultant blend whilst at the same time reducing its overall sulphur content. Thus, non-Fischer-Tropsch derived fuels may be made more suitable for use in areas of restricted ventilation by the incorporation of Fischer-Tropsch derived fuels.

1. A method of operating a fuel consuming system in an area of restricted ventilation comprising introducing into the system a fuel composition which contains a Fischer-Tropsch derived fuel component in an amount from 20 to 100% v/v.

2. The method of claim 1 wherein the fuel composition is a diesel fuel composition.

3. The method of claim 1 wherein the area of restricted ventilation is a mine.

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