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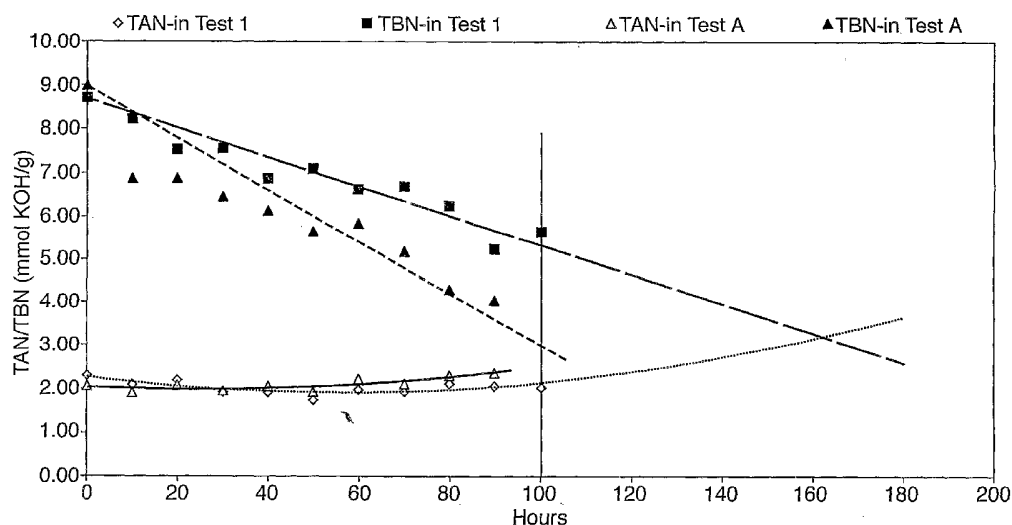
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(54) Title: LUBRICATING SYTEMS



(57) Abstract: In lubrication of an internal combustion engine equipped with a cooled exhaust gas re-circulation (EGR) system, a lubricant containing a minor amount of a dispersant is circulated through a lubricating system so that the dispersant forms salts with combustion acids therein, and the lubricant is then contacted with an, immobilised base, more strongly basic than the dispersant, that displaces the dispersant from the salts to form retained base: combustion acid salts and release the dispersant into the lubricant. The EGR system does not include a chemical filter and re-circulating exhaust combustion gases are chemically unfiltered.

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Lubricating Systems

This invention relates to lubrication of or for internal combustion engines, such as compression-ignited, e.g. diesel, engines and spark-ignited, e.g. gasoline, engines.

Exhaust Gas Recirculation (commonly abbreviated to EGR) is a known system for use in
5 or with internal combustion engines that recirculates exhaust gases back through the engine, via the air inlet manifold of a normally aspirated engine or to the compressor inlet or outlet of a turbocharged engine. EGR is used to reduce emission of oxides of nitrogen (NOx) from diesel engines by reducing peak combustion temperatures.

10 It is further known to cool the exhaust gases ("Cooled EGR") before they enter the engine in order to off-set some engine performance deficits arising from use of EGR.

A problem with EGR, including Cooled EGR, is that it significantly reduces the life of the lubricant used to lubricate the crankcase of the engine.

15

For example, under extreme operating conditions of high engine load and severely-cooled EGR, the lubricant can degrade, due to high soot content and/or excessive viscosity increase, to such an extent as to render the engine inoperable. Oil-based sludges that may form may cause the engine to over-heat and block oilways and oil
20 pump pick-up screens for example; the engine is thereby starved of lubricant which could ultimately cause the engine to fail catastrophically.

US-A-2004/0050373 describes a way of meeting this problem by employing a chemical filter in an area of relatively higher humidity either in the EGR stream or near the intake manifold or, in some cases, in both locations.

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The present invention, however, provides a way of enhancing and/or extending lubricant life that does not require use of a chemical filter in the EGR or chemical filtration of the EGR stream. This is done by employing an immobilised strong base in the lubricating system of the engine.

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Thus, in a first aspect, this invention provides a lubricating system of or for an internal combustion engine equipped with an exhaust gas recirculation (EGR) system having means for cooling gas in the EGR system comprising:

- a. a lubricant containing, in a minor amount, a first base in the form of a dispersant;
 - 15 b. means for circulating the lubricant; and
 - c. a second base, stronger than the first base, immobilised in the lubricating system;
- wherein the exhaust gas circulation system does not include a chemical filter.

20 In a second aspect, this invention provides a method of lubricating an internal combustion engine, said method comprising:

- a. lubricating the engine with a circulating lubricant that contains, in a minor amount, a first base in the form of a dispersant;
- b. contacting the lubricant from step a. with second base, stronger than the first base, that is immobilised;

- c. re-circulating lubricant from step b.; and
- d. recirculating and cooling exhaust combustion gases from operation of the engine to the air intake stream for the engine,

without chemically filtering the re-circulating gases.

5

In a third aspect, this invention provides the use, in a lubricating system of or for an internal combustion engine, to inhibit viscosity increase, and/or maintain particulate combustion products, especially soot, in suspension and/or improve soot-handling characteristics; and/or control sludge deposits in the engine and/or moderate the rate of TBN depletion and inhibit the rate of TAN increase, in the crankcase lubricant of the engine, of a combination of an immobilised second base to displace a first base weaker than the second base, first base:acid salts in circulating lubricant, and of recirculated, cooled, chemically unfiltered exhaust gas.

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15 In a fourth aspect, this invention provides the use to inhibit viscosity increase in a lubricant, and/or to maintain particulate combustion products, especially soot, in suspension in a lubricant, and/or to improved the soot-handling characteristics of the lubricant, and/or to control sludge deposits in an internal combustion engine, and/or moderate the rate of lubricant TBN depletion and inhibit the rate of TAN increase, of an immobilised second base to displace a first base, weaker than the second base, from first base:acid salts in circulating lubricant in a lubricating system, the system being of or for an internal combustion engine in which the exhaust gas is recirculated, cooled and chemically unfiltered.

20

Above-mentioned US-A-2004/0050373 considers the possibility of using a heterogeneous strong base in the oil filter but concludes that “it is ... expected that the method of using heterogeneous base in the oil filter will not be sufficient to treat high concentration of acids and the oil will reach its maximum useful life in a very short
5 timeframe.” The reference thus teaches away from the present invention which, surprisingly, and as evidenced by the data in this specification, significantly extends useful engine oil life.

In the present invention and in contrast to the teaching of US-A-2004/0050373, a
10 chemical filter is not provided in the EGR system and recirculating exhaust gases are not chemically filtered. The EGR system and stream include all parts thereof positioned before the intake manifold of the engine and include those parts or operations positioned or occurring, as appropriate, both before and after the recirculating gases are mixed with intake air.

15

In this specification, the following words and expressions, if and when used, shall have the meanings ascribed below:

“active ingredient” or “(a.i.)” refers to additive material that is not diluent or solvent;

20

“comprising” or any cognate word specifies the presence of stated features, steps, or integers or components, but does not preclude the presence or addition of one or more other features, steps, integers, components or groups thereof; the expressions “consists of” or “consists essentially of” or cognates may be embraced within “comprises” or cognates, wherein “consists essentially of”

permits inclusion of substances not materially affecting the characteristics of the composition to which it applies;

“major amount” means in excess of 50 mass % of a composition;

“minor amount” means less than 50 mass % of a composition;

5 “TAN” means total acid number as measured by ASTM D664;

“TBN” means total base number as measured by ASTM D4739.

Furthermore in this specification:

“phosphorus content” is as measured by ASTM D5185;

10 “sulphated ash content” is as measured by ASTM D874;

“sulphur content” is as measured by ASTM D2622;

“KV100” means kinematic viscosity at 100°C as measured by ASTM D445.

Also, it will be understood that various components used, essential as well as optimal
15 and customary, may react under conditions of formulation, storage or use and that the invention also provides the product obtainable or obtained as a result of any such reaction.

Further, it is understood that any upper and lower quantity, range and ratio limits set
20 forth herein may be independently combined.

The features of the invention relating, where appropriate, to each and all aspects of the invention, will now be described in more detail as follows:

Lubricant

The lubricant contains a major proportion of an oil of lubricating viscosity (sometimes referred to as “base stock” or “base oil”) as the primary liquid constituent of the lubricant into which additives and possibly other oils are blended.

5

A base oil may be selected from natural (vegetable, animal or mineral) and synthetic lubricating oils and mixtures thereof. It may range in viscosity from light distillate mineral oils to heavy lubricating oils such as gas engine oil, mineral lubricating oil, motor vehicle oil and heavy duty diesel oil. Generally the viscosity of the oil ranges from 2 to 30, especially 5 to 20, mm^2s^{-1} at 100°C.

10

Natural oils include animal and vegetable oils (e.g. castor and lard oil), liquid petroleum oils and hydrorefined, solvent-treated mineral lubricating oils of the paraffinic, naphthenic and mixed paraffinic-naphthenic types. Oils of lubricating viscosity derived from coal or shale are also useful base oils.

15

Synthetic lubricating oils include hydrocarbon oils such as polymerized and interpolymerized olefins (e.g. polybutylenes, polypropylenes, propylene-isobutylene copolymers, chlorinated polybutylenes, poly (1-hexenes), poly (1-octenes), poly (1-decenes)); alkylbenzenes (e.g. dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, di (2-ethylhexyl)benzenes); polyphenols (e.g. biphenyls, terphenyls, alkylated polyphenols); and alkylated diphenyl ethers and alkylated diphenyl sulfides and derivatives, analogues and homologues thereof.

20

Another suitable class of synthetic lubricating oils comprises the esters of dicarboxylic acids (e.g. phthalic acid, succinic acid, alkyl succinic acids and alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkylmalonic acids, alkenyl malonic acids) with a variety of
5 alcohols (e.g. butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol). Specific examples of these esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, and the
10 complex ester formed by reacting one mole of sebacic acid with two moles of tetraethylene glycol and two moles of 2-ethylhexanoic acid.

Esters useful as synthetic oils also include those made from C₅ to C₁₂ monocarboxylic acids and polyols, and polyol ethers such as neopentyl glycol, trimethylolpropane,
15 pentaerythritol, dipentaerythritol and tripentaerythritol.

Unrefined, refined and re-refined oils can be used in the lubricants of the present invention. Unrefined oils are those obtained directly from a natural or synthetic source without further purification treatment. For example, a shale oil obtained directly from
20 retorting operations, a petroleum oil obtained directly from distillation or ester oil obtained directly from an esterification process and used without further treatment would be unrefined oil. Refined oils are similar to the unrefined oils except they have been further treated in one or more purification steps to improve one or more properties. Many such purification techniques, such as distillation, solvent extraction, acid or base

extraction, filtration and percolation are known to those skilled in the art. Re-refined oils are obtained by processes similar to those used to obtain refined oils applied to refined oils which have been already used in service. Such re-refined oils are also known as reclaimed or reprocessed oils and often are additionally processed by techniques for approval of spent additive and oil breakdown products.

Other examples of base oil are gas-to-liquid ("GTL") base oils, i.e. the base oil may be an oil derived from Fischer-Tropsch-synthesised hydrocarbons made from synthesis gas containing hydrogen and carbon monoxide using a Fischer-Tropsch catalyst. These hydrocarbons typically require further processing in order to be useful as a base oil. For example, they may, by methods known in the art, be hydroisomerized; hydrocracked and hydroisomerized; dewaxed; or hydroisomerized and dewaxed.

Base oil may be categorised in Groups 1 to V according to the API EOLCS 1509 definition.

The oil of lubricating viscosity is provided in a major amount, in combination with a minor amount of at least one additive and, if necessary, one or more co-additives such as described hereinafter, constituting the lubricant. This preparation may be accomplished by adding the additive directly to the oil or by adding it in the form of a concentrate thereof to disperse or dissolve the additive. Additives may be added to the oil by any method known to those skilled in the art, either prior to, contemporaneously with, or subsequent to, addition of other additives.

The terms "oil-soluble" or "dispersible", or cognate terms, used herein do not necessarily indicate that the compounds or additives are soluble, dissolvable, miscible, or are capable or being suspended in the oil in all proportions. They do mean, however, that they are, for instance, soluble or stably dispersible in oil to an extent sufficient to exert
5 their intended effect in the environment in which the oil is employed. Moreover, the additional incorporation of other additives may also permit incorporation of higher levels of a particular additive, if desired.

First Base

10 The lubricant, as stated, contains, in a minor amount, a first base comprising a dispersant.

A dispersant is an additive for a lubricant whose primary function is to hold solid and liquid contaminants in suspension, thereby passivating them and reducing engine deposits at the same time as reducing sludge depositions. Thus, for example, a
15 dispersant maintains in suspension oil-insoluble substances that result from oxidation during use of the lubricant, thus preventing sludge flocculation and precipitation or deposition on metal parts of the engine.

Dispersants may be "ashless", i.e. non-metallic organic materials that form substantially
20 no ash on combustion, in contrast to metal-containing, and hence ash-forming, materials. They comprise a long chain hydrocarbon with a polar head, the polarity being derived from inclusion of, e.g. an O, P or N atom. The hydrocarbon is an oleophilic group that confers oil-solubility, having, for example 40 to 500 carbon atoms. Thus, ashless dispersants may comprise an oil-soluble polymeric hydrocarbon backbone having

functional groups that are capable of associating with particles to be dispersed.

Typically, dispersants comprise amine, alcohol, amide, or ester polar moieties attached to the polymer backbone often via a bridging group. Ashless dispersant may be, for

example, selected from oil-soluble salts, esters, amino-esters, amides, imides, and

- 5 oxazolines of long chain hydrocarbon-substituted mono- and dicarboxylic acids or their anhydrides; thiocarboxylate derivatives of a long chain of hydrocarbons; long chain aliphatic hydrocarbons having a polyamine attached directly thereto, and Mannich condensation products formed by condensing a long chain substituted phenol with formaldehyde and alkylene polyamine, such as described in US-A-3, 442, 808.

10

The oil-soluble polymeric hydrocarbon backbone is typically an olefin polymer or

polyene, especially a polymer comprising a major molar amount (i.e. greater than 50

mole %) of a C₂ to C₁₈ olefin (e.g. ethylene, propylene, butylenes, isobutylene, pentene, octane-1, styrene), and typically a C₂ to C₅ olefin. The oil-soluble polymeric

- 15 hydrocarbon backbone may be homopolymeric (e.g. comprising a copolymer of ethylene and an alpha-olefin such as propylene or butylenes, or a copolymer of two different alpha-olefins).

A preferred class of olefin polymers comprises polybutenes, specifically polyisobutenes

- 20 (PIB) or poly-n-butenes, such as may be prepared by polymerization of a C₄ refinery stream. Other classes of olefin polymers include ethylene alpha-olefin (EAO) copolymers and alpha-olefin homo- and copolymers.

Dispersants include, for example, derivatives of long chain hydrocarbon-substituted

carboxylic acids, examples being derivatives of high molecular weight hydrocarbyl-substituted succinic acid. A noteworthy group of dispersants are hydrocarbon-substituted succinimides, made, for example, by reacting the above acids (or derivatives) with a nitrogen-containing compound, advantageously a polyalkylene polyamine, such as polyethylene polyamine. Particularly preferred are the reaction products of polyalkylene polyamines with alkenyl succinic anhydrides, such as described in US-A-3,202,678; -3,154,560; -3,172,892; -3,024,195; -3,024,237; -3,219,666; and -3,216,936; and BE-A-66,875 that may be post-treated to improve their properties, such as borated (as described in US-A-3,087,936 and -3,254,025) fluorinated and oxylated.

For example, boration may be accomplished by treating an acyl nitrogen-containing dispersant with a boron compound selected from boron oxide, boron halides, boron acids and esters of boron acids.

Dispersants may also include metal-containing materials such as molybdenum-containing materials known in the art.

Preferred dispersants are polyalkene-substituted succinimides wherein the polyalkene group has a number-average molecular weight in the range of 900 to 5,000. The number-average molecular weight is measured by gel permeation chromatography (GPC). The polyalkene group may comprise a major molar amount (i.e. greater than 50 mole %) of a C₂ to C₁₈ alkene, e.g. ethene, propene, butene, isobutene, pentene, octane-1 and styrene. Preferably, the alkene is a C₂ to C₅ alkene; more preferably it is butene or isobutene, such as may be prepared by polymerisation of a C₄ refinery stream. Most preferably, the number average molecular weight of the polyalkene group is in the range

of 1,800 to 2,800, such as 2,000 to 2,500.

- The polyalkene-substituted succinimides wherein the polyalkene group has a number-average molecular weight in the range of 900 to 5,000 and more especially the latter,
- 5 most preferred, dispersant may be used in a lubricant having a phosphorus content, expressed as atoms of phosphorus, of less than 0.1 mass %, an ash content, expressed as sulphated ash, of less than 1.0 mass %, and optionally a sulphur content, expressed as atoms of sulphur, of less than 0.4 mass %.
- 10 The first base will normally be added to the lubricant during its formulation or manufacture. The first base must be strong enough to neutralize at least a portion of the combustion acids (i.e. form a salt or salts). A suitable first base will typically have a pKa from 4 to 12 and in many cases may be termed a "weak base".
- 15 The first base should be sufficiently soluble for the salt or salts formed to remain soluble in the lubricant and not to precipitate.

- The amount of first base in the lubricant will vary depending upon the amount of combustion acids present, the degree of neutralization desired, and the specific
- 20 applications of the lubricant. In general, the amount need only be that which is effective or sufficient to neutralize at least a portion of the combustion acids.

Typically, the amount of first base, as active ingredient, will range from 0.01 to 3 wt % or more such as up to 4 wt%, preferably from 0.1 to 1.0 wt %. This range is particularly

advantageous for polyalkene-substituted succinimides wherein the polyalkene group has a number-average molecular weight in the range of 900 to 5,000, and more especially the most preferred dispersant defined above.

- 5 In addition to the first base and as indicated above, other additives known in the art may be added to the lubricating base oil to form a fully-formulated lubricant. Such lubricating oil additives may include other dispersants, antiwear agents, antioxidants, corrosion inhibitors, detergents, pour point depressants, extreme pressure additives, viscosity index improvers and friction modifiers.

10

- In summary, the lubricant is not restricted to a conventionally-formulated lubricant, but may be any lubricant specifically or otherwise designed for the purposes described in this specification regardless of SAE viscosity grade; API, ILSEC, ACEA, JAMA, JASO or other performance credentials; base oil compositions as described below; and additive
15 compositions whether for heavy duty (HD) passenger car motor oil (PCMO), conventional, or low or ultra-low sulphated ash-phosphorus-sulphur (SAPS).

Second Base

- Following neutralization of the combustion acids, the neutral salts thereby formed are
20 passed or circulated from the piston ring zone with the lubricant and contacted with the second base. The second base is a base that will displace at least a portion of the first base from the neutral salts and return that portion of the first base to the lubricant for recirculation to the piston ring zone where the first base is reused to neutralize combustion acids. Examples of suitable second bases include, but are not limited to,

barium oxide, calcium carbonate, calcium oxide, calcium hydroxide, magnesium carbonate, magnesium hydroxide, magnesium oxide, sodium aluminate, sodium carbonate, sodium hydroxide, zinc oxide, or their mixtures; magnesium oxide is particularly preferred. In many cases the second bases may be termed "strong bases".

5

The second base may be adhered to or incorporated (e.g. impregnated) on or with a substrate immobilized in the lubricating system of the engine. The substrate can be located on the engine block or near the sump. Preferably, the substrate, if used, will be part of the filter system for filtering lubricant, although it could be separate therefrom.

10 Preferred substrates include paper, fabric, felt, glass, plastic, microglass and both woven and non-woven polymeric fibre. Other useful substrates include, but are not limited to, alumina, activated clay, cellulose, cement binder, silica-alumina, and activated carbon. The substrate may be inert or not inactive.

15 The second base may be incorporated into or adhered onto the substrate by methods known to those skilled in the art. For example, if the substrate is alumina, the second base can be deposited by using the following technique. A highly porous alumina is selected. The porosity of the alumina is determined by weighing dried alumina and then immersing it in water. The alumina is removed from the water and the surface water
20 removed by blowing with dry air. The alumina is then reweighed and compared with the dry alumina weight. The difference in weight is expressed as grams of water per gram of dry alumina. A saturated solution of calcium oxide in water is prepared and added to the dry alumina in an amount equal to the difference between the weight of the wet and dry alumina. The water is removed from the alumina by heating, leaving calcium oxide

deposited on the alumina as the product. This preparation can be carried out under ambient conditions, except that the water removal step is performed at about 100°C.

The amount of second base required will vary with the amount of first base in the lubricant and the amount of combustion acids formed during engine operation. However, since the second base is not being continuously regenerated for reuse (unlike the first base), the amount of second base must be at least equal to (and preferably be a multiple of) the equivalent weight of the first base in the lubricant. Therefore, the amount of second base should be from 1 to 15 times, preferably from 1 to 5 times, the equivalent weight of the first base in the lubricant.

Once the first base has been displaced from the soluble neutral salts, the second base: combustion acid salts thus formed will be immobilized as deposits with the second base, for example on the substrate, if used. Thus, deposits which would normally be formed in the piston ring zone are not formed until the soluble salts contact the second base. Preferably, the second base will be located such that it can be easily removed from the lubricating system, e.g. by including it as part of the oil filter system.

Engines

The invention is applicable to a wide range of internal combustion engines equipped with a Cooled EGR such as compression-ignited and spark-ignited engines. Examples include engines for power generation, locomotive and marine equipment and heavy duty on-highway trucks; heavy duty off-highway engines such as may be used for agriculture, construction and mining and engines for light duty commercial and passenger car

applications.

Particularly-preferred embodiments

- A particularly preferred embodiment of the first aspect of the invention is a lubricating
- 5 system of or for an internal combustion engine equipped with an exhaust gas recirculation (EGR) system having means for cooling gas in the EGR system comprising:
- a. a lubricant containing, in a minor amount, a first base in the form of a dispersant, being a polyalkene-substituted succinimide wherein the polyalkene group has a
- 10 number-average molecular weight in the range of 900 to 5,000 (wherein the number-average molecular weight is measured by gel permeation chromatography (GPC)), wherein the polyalkene group may preferably comprise a major molar amount (i.e. greater than 50 mole %) of a C₂ to C₅ alkene, and more preferably butene or isobutene, and wherein most preferably, the number
- 15 average molecular weight of the polyalkene group is in the range of 1,800 to 2,800, such as 2,000 to 2,500, the first base typically being present in an amount range from 0.01 to 3 wt % or more, preferably from 0.1 to 1.0 wt %;
- b. means for circulating the lubricant; and
- c. a second base, stronger than the first base and immobilised in the lubricating
- 20 system, the second base consisting essentially of magnesium oxide;
- the lubricant in a. having (after addition of the first base and any other additives) a total phosphorus content, expressed as atoms of phosphorus, of less than 0.1 mass %, an ash content, expressed as sulphated ash, of less than 1.0 mass %, and optionally a sulphur content, expressed as atoms of sulphur, of less than 0.4 mass %; and wherein the exhaust

gas circulation system does not include a chemical filter.

A particularly well-preferred second aspect of the invention is a method of lubricating an internal combustion engine, said method comprising:

- 5 a. lubricating the engine with a circulating lubricant that contains, in a minor amount, a first base in the form of a dispersant, being a polyalkene-substituted succinimide wherein the polyalkene group has a number-average molecular weight in the range of 900 to 5,000 (wherein the number-average molecular weight is measured by gel permeation chromatography (GPC)), wherein the
10 polyalkene group may preferably comprise a major molar amount (i.e. greater than 50 mole %) of a C₂ to C₅ alkene, and more preferably butene or isobutene, and wherein most preferably, the number average molecular weight of the polyalkene group is in the range of 1,800 to 2,800, such as 2,000 to 2,500, the first base typically being present in an amount range from 0.01 to 3 wt % or more,
15 preferably from 0.1 to 1.0 wt %;
 - b. contacting the lubricant from step a. with second base, stronger than the first base, that is immobilised, the second base consisting essentially of magnesium oxide;
 - c. re-circulating lubricant from step b.; and
 - d. recirculating and cooling exhaust combustion gases from operation of the engine
20 to the air intake stream for the engine,
- without chemically filtering the re-circulating gases; wherein the lubricant in step a. has (after addition of the first base and any other additives) a total phosphorus content, expressed as atoms of phosphorus, of less than 0.1 mass %, an ash content, expressed as sulphated ash, of less than 1.0 mass %, and optionally a sulphur content, expressed as

atoms of sulphur, of less than 0.4 mass %.

Particularly-preferred embodiments of the third and fourth aspects of the invention concern the uses of the particularly-preferred combination of first and second bases described in the two immediately-preceding paragraphs, in the lubricant composition defined therein, to inhibit viscosity increase in said lubricant; or to maintain particulate combustion products, especially soot, in suspension in said lubricant; or to control sludge deposits in a diesel engine employing said lubricant; or to moderate the rate of lubricant TBN depletion and inhibit the rate of TAN increase; the use being in a lubricating system of or for a diesel engine in which the exhaust gas is recirculated, cooled and chemically filtered.

EXAMPLES

The invention will now be described in the following examples which are not intended to limit the scope of the claims hereof:

In the examples, reference will be made to the accompanying drawings, Figure 1 of which is a graph of measurement of TBN and of TAN of lubricant (the “y” axis) against time (the “x” axis) in the tests described below.

20

A lubricant was blended, as an SAE 15W40 viscosity grade lubricant, with an all-Group I mineral base oil, a commercial viscosity modifier and commercial additive package for providing heavy duty performance according to the American Petroleum Institute (API) CI-4 category. The lubricant contained a “first” (weak) base in the form of a

polyisobutene succinimide dispersant (3.8 mass %) in which the polyisobutene had a number average molecular weight of 2225.

The lubricant was tested in a Volkswagen (RTM) (TDi) engine (1.9L), modified to replicate the operation of a heavy duty diesel engine provided with a Cooled EGR. An external supercharger was added to compensate for power loss due to use of EGR. Neither the EGR, nor the area adjacent the intake manifold, contained a chemical filter. The tests were carried out under identical high load conditions for a nominal duration of 100 hours with a wide open throttle at 1900 rpm giving rise to an increase of the average EGR rate to 14.8% by volume (being the ratio of the volume of exhaust gas in the intake stream to the volume flow of fresh air in the intake stream, determined by measuring the carbon dioxide (vol. %) in the intake manifold and in the exhaust gas after correction for "background" carbon dioxide in the ambient air, typically about 0.09 vol. %) and an average inlet manifold temperature of 40°C.

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Two tests were carried out in the same engine in each of which an oil filter in the form of a commercially-available Fleetguard (RTM) LF9028 filter was used. In the first test (Test 1), a test of the invention, the filter was impregnated with an essentially fully immobilised strong base, magnesium oxide (the "second base"). In the second test (Test A), a reference test, the filter was not impregnated with a strong base. Soot level, TBN depletion, TAN increase and KV₁₀₀ increase were measured.

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Test 1 was satisfactorily completed to its intended 100 hour duration, and inspection of the engine showed acceptable cleanliness.

Test A was aborted after about 94 hours because it became impossible to control the engine operating temperature within defined limits. Inspection of the engine showed this to be due to severe sludge deposit formations on the engine temperature control probe and on most or all other internal engine surfaces thereby significantly reducing the volume of circulating lubricant.

The results at the end of the test are summarised below:

	<u>Soot Level</u>	<u>TBN Depletion</u>	<u>TAN Increase</u>	<u>KV₁₀₀ Increase</u>
Test 1	11.8%	35%	None	x 2.2
Test A	17.6%	55%	Slight	Too viscous to measure

Soot level was determined by thermogravimetric analysis.

Comparison of the results of Test 1 with those of Test A demonstrates that the system of the invention prevents or delays loss of viscosity control and formation of debilitating engine sludges, and reduces observed soot level.

Referring to Figure 1, the TBN and TAN results obtained are depicted as follows:

	<u>TAN</u>	<u>TBN</u>
Test 1	◇	□
Test A	△	△

Plots are made based on the results and extrapolated. The need for oil change may be regarded as being related to the point of intersection between the TBN and TAN lines or curves. It is seen from Figure 1 that the extrapolated intersect for reference Test A is at about 100 hours whereas the extrapolated intersect for Test 1 (of the invention) is at about 160 hours. Figure 1 therefore demonstrates that useful engine life (or oil drain interval) is significantly enhanced or extended.

CLAIMS

1. A lubricating system of or for an internal combustion engine equipped with an exhaust gas re-circulation (EGR) system having means for cooling gas in the EGR system comprising;
- 5
- a. a lubricant containing, in a minor amount, a first base in the form of a dispersant.
 - b. means for circulating the lubricant; and
 - c. a second base, stronger than the first base, immobilised in the lubricating
- 10 system;
- wherein the exhaust gas re-circulation system does not include a chemical filter.
2. A system as claimed in claim 1 wherein the lubricant is a heavy duty diesel lubricant and the engine is a compression-ignited engine.
- 15
3. A system as claimed in claim 1 or claim 2 wherein the dispersant is an ashless dispersant having basicity derived from nitrogen.
4. A system as claimed in claim 3 wherein the first base is in the form of a polyisobutene-substituted succinimide.
- 20
5. A system as claimed in any of claims 1 to 4 wherein the strong base is magnesium oxide.

6. A system as claimed in any of claims 1 to 4 wherein the second base is carried on a substrate.
7. A system as claimed in claim 5 wherein the substrate is part of the oil filter system of the engine.
8. A method of lubricating an internal combustion engine, said method comprising:
- a. lubricating the engine with a circulating lubricant that contains a first base in the form of a dispersant;
 - 10 b. contacting the lubricant from step a. with second base, stronger than the first base, that is immobilised;
 - c. recirculating lubricant from step b.; and
 - d. recirculating and cooling exhaust combustion gases from operation of the engine to the air intake stream for the engine,
 - 15 without chemically filtering recirculating gases.
9. The use, in a lubricating system of or for an internal combustion engine, to inhibit viscosity increase and/or maintain particulate combustion products in suspension, and/or improve soot-handling characteristics, and/or control sludge deposits in the engine, and/or moderate the rate of TBN depletion and inhibit the rate of TAN increase, in the crankcase lubricant of the engine, of a combination of an immobilised second base to displace first base, weaker than the second base, from first base:acid salts in circulating lubricant, and of recirculated, cooled, chemically unfiltered exhaust gas.
- 20

10. The use to inhibit viscosity increase in a lubricant, and/or to maintain particulate combustion products in suspension in a lubricant, and/or to improved the soot-handling characteristics of the lubricant, and/or to control sludge deposits in an internal combustion engine, and/or moderate the rate of lubricant TBN depletion and inhibit the rate of TAN increase, of an immobilised second base to displace a first base, weaker than the second base, from first base:acid salts in circulating lubricant in a lubricating system, the system being of or for an internal combustion engine in which the exhaust gas is recirculated, cooled and chemically unfiltered.

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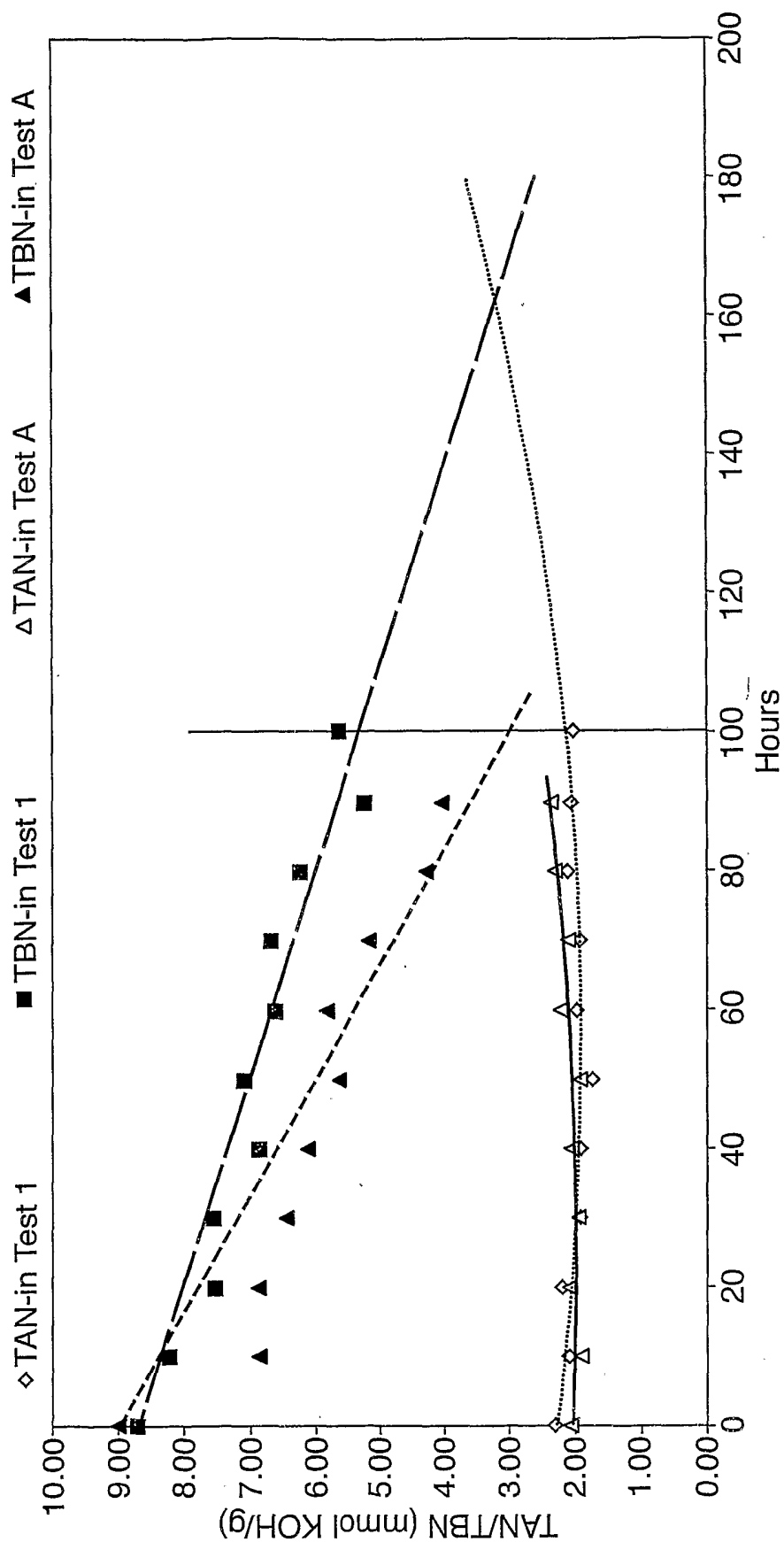
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Fig.1.



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2005/013421

A. CLASSIFICATION OF SUBJECT MATTER

INV. C10M141/06 C10M175/00
ADD. C10N10/02 C10N30/04 C10N40/25

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C10M B01D

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

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

EPO-Internal, WPI Data, PAJ, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 164 101 A (BROWNAWELL ET AL) 17 November 1992 (1992-11-17) column 5, line 14 - column 7, line 30; claims 1-44; example 3	1-12
A	GB 476 422 A (JOHN KAY RUSSELL; WILLIAM BENTLEY COLLINS; WALTER WILLIAM BOGGS) 6 December 1937 (1937-12-06) page 4, line 60 - page 4, line 89	1-12
A	US 2003/111398 A1 (EILERS DEREK ET AL) 19 June 2003 (2003-06-19) paragraphs [0054], [0059]; claims 1-12	1-12
A	US 2003/148899 A1 (KURIBAYASHI TOSHIKI ET AL) 7 August 2003 (2003-08-07) paragraphs [0010] - [0016]; claims 1,2	1-12



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search

19 April 2006

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2005/013421

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US 2003148899	A1	07-08-2003	NONE	