Abstract: Base oil formulation containing a mineral derived base oil and a Fischer-Tropsch derived light base oil. The Fischer-Tropsch oil may be used to upgrade an under-processed mineral oil. The Fischer-Tropsch oil causes less of an increase in volatility than predicted by theory. It may therefore be used to improve a property of a base oil formulation containing a mineral derived base oil, the property being selected from cold flow properties, viscosity profile and oxidative stability, whilst still achieving a target maximum volatility $X$ for the formulation, by adding to the formulation a concentration $c$ of a Fischer-Tropsch derived light base oil, wherein $c$ is higher than the maximum concentration $c'$ of the Fischer-Tropsch derived light base oil which theory would predict could be added without increasing the volatility of the formulation above the target maximum $X$. 

Title: BASE OIL FORMULATIONS
BASE OIL FORMULATIONS

Field of the invention

This invention relates to base oil formulations and to their preparation and uses, as well as to the use of certain types of oils in base oil formulations for new purposes.

Background to the invention

It is known to use heavier hydrocarbon oils as base oils in a wide range of applications, for instance as bases for lubricant formulations, electrical oils and hydraulic fluids. Such base oils are typically mineral oils, for example petroleum derived.

It is also known to prepare base oils using a Fischer-Tropsch synthesis. The Fischer-Tropsch condensation process is a reaction which 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).

The Fischer-Tropsch process can be used to prepare a range of hydrocarbon fuels, including LPG, naphtha, kerosene and gas oil fractions. Of these, the gas oils have been used in middle distillate fuel compositions such as in particular automotive diesel fuels, typically in blends with petroleum derived gas oils. The heavier fractions (typically C23 to C40) can yield, following hydroprocessing and vacuum distillation, a series of base oils having different distillation properties and
viscosities, which are useful for example as lubricating base oil stocks.

WO-A-02070627 and WO-A-02070629, for example, describe processes for preparing iso-paraffinic base oils from a wax made by a Fischer-Tropsch process. Such Fischer-Tropsch derived base oils tend to have excellent low temperature properties, for example low pour points, and are also attractive because of the relatively simple process used to make them as compared to similar oils prepared from mineral crude sources.

Depending on their intended use, base oils often need to comply with strict requirements regarding their viscosity, flash point, distillation properties, oxidation stability and flow properties (in particular low temperature performance). A high flash point for example is particularly important for base oils which are intended for use as electrical oils, especially when used in a high temperature environment or in situations involving elevated peak temperatures. A low pour point is important if a base oil is intended to be used in a low temperature environment. Certain properties may be required for example to comply with legal requirements or customer specifications.

Base oils are classified into groups, depending on their properties. These properties are in turn influenced by the way in which, and often the degree to which, an oil has been processed. A so-called "Group I" base oil must contain less than 90 wt % of saturated hydrocarbon components, and/or greater than 0.03 wt % of sulphur, and must have a viscosity index of at least 80 and less than 120. It will typically contain 10 wt % or more, for example from 15 to 35 wt %, of aromatic components and from around 65 to 85 wt % of saturates,
and will have been subjected to relatively mild processing conditions such as solvent dewaxing and solvent extraction of other undesired components such as aromatics and naphthenics.

A "Group II" base oil is of a higher quality: it must contain at least 90 wt % of saturates and no more than 0.03 wt % sulphur, and again must have a viscosity index of at least 80 and less than 120. These qualities are achieved by subjecting the oil to more severe processing, typically hydroprocessing to convert rather than remove undesirable components, and the oil is therefore more expensive to produce. Typical Group II base oils contain from around 93 wt % of saturates, and less than about 7 wt % of aromatics.

A "Group III" base oil, of a higher quality still, must fulfil the same saturates and sulphur content requirements as a Group II base oil, but must also have a viscosity index of greater than 120. Again these properties are achieved by relatively severe hydroprocessing and catalytic dewaxing steps. Typical Group III base oils contain at least 95 wt % of saturates and less than 5 wt % of aromatics. Fischer-Tropsch derived base oils, of the type described above, are usually classified as Group III base oils.

It would generally be desirable to be able to produce base oils having improved properties for use in a particular context, and/or to produce base oils having a desired set of properties but using less time consuming and expensive production techniques.

It is known, from US-B-7144497, to blend a mineral derived base oil with a low viscosity Fischer-Tropsch derived base oil so as to produce, overall, a higher viscosity index base oil blend. One of the stated
purposes of this blending is to upgrade the lower viscosity Fischer-Tropsch oil to render it suitable for use as a lubricating base oil.

However it has now surprisingly been found that when certain types of base oil are blended together, the resultant blend can have better properties - in particular in the context of its viscometrics and its oxidative stability - than might have been predicted from those of the individual constituents, yet can still have an acceptable, often lower than predicted, volatility. This can allow the preparation of higher quality base oil blends, or can allow the preparation of a blend having a desired set of properties, using a lower quality (and hence less processed) base oil than would previously have been thought necessary. This in turn can facilitate the formulation of base oils to a desired specification, typically at lower production cost, and/or extend the areas of application for lower quality, yet typically cheaper, base oils.

**Statements of the invention**

According to a first aspect of the present invention there is provided a base oil formulation containing a blend of a mineral derived base oil and a Fischer-Tropsch derived light base oil.

The presence of the Fischer-Tropsch derived light base oil can improve the properties of the overall blend in a number of ways. Generally speaking it will increase the viscosity index and improve the oxidative stability and the cold flow properties (in particular the pour point) of the blend. It has also been found to cause a lower than expected increase in volatility when blended with a higher viscosity mineral derived base oil, despite the fact that the lower viscosity, light Fischer-Tropsch
derived base oil will typically have a higher volatility than the mineral base oil with which it is blended. This too can be advantageous, since low volatilities are often required of base oil formulations.

Moreover Fischer-Tropsch derived light base oils have also been found capable of reducing the cold crank simulator (CCS) dynamic viscosity of base oil blends, which again can be desirable in base oil formulations, in particular those intended for use as engine oils.

This means that a lower quality mineral derived base oil may effectively be "upgraded" (i.e. its properties improved) by the addition of a Fischer-Tropsch derived base oil, and moreover that the extent of the improvement can be greater than might have been predicted by theory, without undue detriment to other properties such as volatility. In turn, this can extend the potential applications of a lower quality, less processed, mineral base oil, and/or allow a reduction in the degree of processing of a given mineral base oil whilst still safeguarding the properties required of it at the point of use. Any reduction in the degree of processing can naturally reduce the cost and increase the efficiency of base oil production, and can lead to improvements in yield, a reduced potential for contamination and other practical process benefits.

In a base oil formulation according to the invention, the mineral derived base oil will typically be petroleum derived, for instance by a petroleum refining process. It may be a Group I, a Group II or a Group III base oil, typically either Group I or Group II. It may have a kinematic viscosity at 100 °C (VK 100) (ASTM D-445) of for example from 4 to 12.5 centistokes, or from 5 or 6 to 10 centistokes.
In particular, the mineral derived base oil may be an "under-processed" base oil, by which is meant a base oil which has been subjected, prior to use, to a lower degree of processing than might have been applied in order to achieve the properties required of it in the context of its intended use. The under-processing of mineral derived base oils is not something which is foreshadowed in US-B-7144497.

"Processing" in this context means the type of processing applied during the preparation of base oils, in particular mineral derived base oils, in order to remove undesired components. Such components typically include aromatic (in particular poly-aromatic) components and/or fused poly-naphthenic components, both of which can reduce the oxidative stability and viscosity index of an oil, and/or waxy components (species which are prone to crystallising out at low temperatures, primarily straight chain paraffins). The processing may involve for example solvent extraction of undesired components, as used for the production of a typical Group I base oil. It may instead or in addition involve hydroprocessing, and/or catalytic dewaxing, which are more severe forms of treatment typically used to produce the higher quality Group II and III base oils.

Thus for example, in accordance with the invention, an under-processed Group I base oil stream (i.e. one which has been less severely processed than a typical Group I base oil) may be "upgraded" to a fit-for-purpose Group I oil by blending with the Fischer-Tropsch derived base oil. Alternatively a Group II base oil stream may be under-processed, but its properties nevertheless upgraded to meet a certain desired standard (for example, a standard which would otherwise have been achieved using
more severe processing, typically as a fit-for-purpose Group II oil) on addition of the Fischer-Tropsch oil.

A mineral derived base oil stream used in a formulation according to the invention may for instance have a viscosity index (ASTM D-2270) of less than 95 (typical fit-for-purpose high viscosity index mineral base oils are currently processed to a viscosity index of 95 or greater). It may have a viscosity index of less than 94 or 93, for example from 90 to 93. It may have a pour point of 1 or 2 or 3 °C or more lower than that of a typical fit-for-purpose mineral base oil in the same group, or of 6 °C or more lower, or of 12 °C or more lower. For example, its pour point (ASTM D-5950) may be -9 °C or above, or -6 °C or above, or in cases -3 °C or above.

In a base oil formulation according to the invention, the Fischer-Tropsch derived base oil will typically be a Group III base oil, although it may in cases be a Group II base oil, depending on its exact viscosity index. It is a light base oil, i.e. a base oil having a relatively low viscosity. It may for example have a VK 100 of 4 centistokes or lower, or of 3.5 or 3 centistokes or lower, such as from 2 to 3.5 or from 2 to 3 centistokes. Suitably it has a kinematic viscosity at 40 °C (VK 40) of from 7.5 to 25 centistokes, for example from 9 to 20 centistokes. Such a light base oil may for example have a total boiling point range of from 320 to 430 °C, more typically from 350 to 400 °C.

The Fischer-Tropsch derived light base oil will suitably have been subjected to catalytic dewaxing, ideally to a relatively severe dewaxing process. It will be largely paraffinic in nature, typically containing 80 wt % or greater, or 85 or 90 wt % or greater, of
paraffinic components, which helps to increase its viscosity index and thus to make it a higher quality base oil. It will typically have a viscosity index (ASTM D-2270) of 115 or greater, for example from 115 to 125.

Due to the processes used to prepare the oil, it will typically contain a relatively high proportion of iso- as opposed to normal paraffins; it may for example contain 90 or 95 wt % or greater of iso-paraffins on a molecular basis. This in turn will tend to give the Fischer-Tropsch oil improved flow properties; a Fischer-Tropsch derived base oil used in the present invention may for example have a pour point (ASTM D-5950) of -18 °C or lower, preferably -20 or -25 or -30 °C or lower, such as from -36 to -51 °C. The increased iso-paraffin content also serves to reduce the volatility of Fischer-Tropsch derived base oils compared to mineral derived base oils of comparable kinematic viscosity; the Fischer-Tropsch base oil used in the present invention will suitably have a Noack volatility (CEC L-40-A-93) of from 35 to 60 wt %, preferably from 40 to 50 wt %, more preferably from 42 to 45 wt %.

Such "light" base oils can on their own have too low a viscosity to be of use as lubricating oils. Thus, their use in base oil blends according to the present invention can effectively extend the applications of an otherwise less used product stream from a Fischer-Tropsch base oil production process. The invention can therefore provide alternative uses for both Fischer-Tropsch derived light base oils and mineral derived base oils, and increase the options available to those wishing to formulate base oil products.

In the present context, the term "Fischer-Tropsch derived" means that a material is, or derives from, a
synthesis product of a Fischer-Tropsch condensation process. The term "non-Fischer-Tropsch derived" may be interpreted accordingly. A Fischer-Tropsch derived base oil will therefore be a hydrocarbon stream of which a substantial portion, except for added hydrogen, is derived directly or indirectly from a Fischer-Tropsch condensation process.

A Fischer-Tropsch derived product may also be referred to as a GTL product.

Hydrocarbon 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 product. The desired fraction(s) may subsequently be isolated for instance by distillation.

Other post-synthesis treatments, such as polymerisation, alkylation, distillation, cracking-decarboxylation, isomerisation and hydrorefining, may be employed to modify the properties of Fischer-Tropsch

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-O 583 836 (pages 3 and 4).

An example of a Fischer-Tropsch process is the SMDS (Shell Middle Distillate Synthesis) described in "The Shell Middle Distillate Synthesis Process", van der Burgt et al, paper delivered at the 5th Synfuels Worldwide Symposium, Washington DC, 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. Base oils, having a range of viscosities and including both light and intermediate fractions as well as certain heavier oils, may also be produced by such a process.

By virtue of the Fischer-Tropsch process, a Fischer-Tropsch derived product 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 bring additional
benefits to base oil formulations in accordance with the present invention.

Further, the Fischer-Tropsch process as usually operated produces no or virtually no aromatic components. The aromatics content of a Fischer-Tropsch derived oil, suitably determined by ASTM D-4629 or IP-368 mod, will typically be below 1 wt %, preferably below 0.5 wt % and more preferably below 0.1 wt %. This in turn can improve the oxidative stability of the oil.

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

A Fischer-Tropsch derived light base oil, as is preferably used in a formulation according to the invention, is a base oil having a VK 100 of from about 2 to 4 centistokes or from 2 to 3.5 or from 2 to 3 centistokes, which is derived from a Fischer-Tropsch derived wax. Such oils tend to have good purity and a high paraffinic content, and to contain a continuous series of iso-paraffins having \( n, n+1, n+2, n+3 \) and \( n+4 \) carbon atoms, as described below. Fischer-Tropsch derived base oils also tend to have excellent low temperature properties, and are also relatively simple to produce in comparison to their mineral derived counterparts.
The Fischer-Tropsch derived base oil used in the present invention is suitably obtained by hydrocracking a Fischer-Tropsch wax and preferably dewaxing the resultant waxy raffinate. This raffinate can be distilled to produce a number of different products, including the light base oil stream described above.

The Fischer-Tropsch derived light base oil may for instance be of the type described in, and/or be prepared according to a process described in, WO-A-02070627, WO-A-02070629 or WO-A-2006136594, the entire contents of which documents are herein incorporated by reference.

Since the light base oil used in the present invention is derived from a Fischer-Tropsch wax, it will be largely paraffinic in nature, and will typically contain a major proportion of iso-paraffins as described above. It suitably has a saturates content (as measured by IP 386) of greater than 98 wt %, where the saturates content is taken as (100 - total polars content).

Preferably it comprises a series of iso-paraffins having n, n+1, n+2, n+3 and n+4 carbon atoms, where n is from 20 to 35. Preferably the saturates content of the base oil is greater than 99 wt %, more preferably greater than 99.5 wt %.

The Fischer-Tropsch derived light base oil preferably has a content of naphthenic compounds of from 0 to 15 wt %, more preferably of from 4 to 9 wt %.

The flash point of the Fischer-Tropsch derived base oil, as measured by ASTM D-92, is suitably 185 °C or greater. It has generally been found that the flash points of Fischer-Tropsch derived base oils can be advantageously high as compared to mineral derived base oils at a given viscosity.
The content of naphthenic compounds in the Fischer-Tropsch derived light base oil, and the presence of the desired continuous series of iso-paraffins, may be measured by the Field Ionisation Mass Spectrometry (FIMS) technique. According to this technique, an oil sample is firstly separated into a polar (aromatic) phase and a non-polar (saturates) phase by the high performance liquid chromatography (HPLC) method IP 368/01 but using pentane instead of hexane as the mobile phase. The aromatic and saturates fractions are then analysed using for instance a Finnigan MAT90 mass spectrometer equipped with a FD/FI interface, the FI (a "soft" ionisation technique) being used to determine hydrocarbon types in terms of carbon number and hydrogen deficiency.

The type classification of compounds in mass spectrometry is determined by the characteristic ions formed and is normally classified by "z number". This is given by the general formula for all hydrocarbon species: \( C_nH_{2n+z} \). Because the saturates phase is analysed separately from the aromatic phase it is possible to determine the content of the different iso-paraffins having the same stoichiometry or n-number. The results from the mass spectrometer can be processed using commercially available software (for example Poly 32, available from Sierra Analytics LLC, 3453 Dragoo Park Drive, Modesto, California GA95350 USA) to determine the relative proportions of each hydrocarbon type.

The Fischer-Tropsch derived light base oil used in a formulation according to the invention, which preferably contains the above described continuous series of iso-paraffins, is suitably obtained by hydroisomerisation of a paraffinic wax, preferably followed by some type of dewaxing, such as solvent or catalytic dewaxing. The
paraffinic wax may be a slack wax. More preferably the paraffinic wax is a Fischer-Tropsch derived wax, because of its purity and high paraffinic content, as well as the fact that such waxes result in a product containing a continuous series of iso-paraffins having n, n+1, n+2, n+3 and n+4 carbon atoms in the desired molecular weight range.

Examples of Fischer-Tropsch processes which can be used to prepare the Fischer-Tropsch derived base oil are the so-called commercial Slurry Phase Distillate technology of Sasol, the Shell Middle Distillate Synthesis process referred to above and the "AGC-21" Exxon Mobil process. These and other processes are for example described in more detail in EP-A-776959, EP-A-668342, US-A-4943672, US-A-5059299, WO-A-9934917 and WO-A-9920720. Typically the products of these Fischer-Tropsch syntheses will comprise hydrocarbons having from 1 to 100 or even more than 100 carbon atoms. Such products may comprise normal paraffins, iso-paraffins, oxygenated components and unsaturated components.

Where a base oil is one of the desired iso-paraffinic products it may be advantageous to use a relatively heavy Fischer-Tropsch derived feed. Such a feed suitably contains at least 30 wt %, preferably at least 50 wt % and more preferably at least 55 wt % of compounds having at least 30 carbon atoms. Furthermore the weight ratio in the feed of compounds having at least 60 carbon atoms to those having at least 30 but fewer than 60 carbon atoms is preferably at least 0.2, more preferably at least 0.4 and most preferably at least 0.55.

Preferably the Fischer-Tropsch derived feed comprises a C20+ fraction having an ASF-alpha value (Anderson-Schulz-Flory chain growth factor) of at least 0.925,
preferably at least 0.935, more preferably at least 0.945, even more preferably at least 0.955. Such a Fischer-Tropsch derived feed can be obtained by any process which yields a suitably heavy product as described above. An example of a suitable Fischer-Tropsch process is described in WO-A-9934917.

A Fischer-Tropsch derived base oil will contain no or very little sulphur and nitrogen containing compounds. This is typical for a product derived from a Fischer-Tropsch reaction, which uses synthesis gas containing almost no impurities. Sulphur and nitrogen levels will generally be below the detection limits, which are currently 5 mg/kg for sulphur and 1 mg/kg for nitrogen respectively.

In its broadest sense, the present invention embraces the use of a first paraffinic light base oil having one or more of the above described properties, in a base oil formulation containing a second mineral derived base oil, whether or not the first base oil is actually Fischer-Tropsch derived.

However the process used to prepare the light base oil will conveniently comprise a Fischer-Tropsch synthesis, a hydroisomerisation step and an optional pour point reducing step, wherein the hydroisomerisation and optional pour point reducing steps are performed by:

(a) hydrocracking/hydroisomerising a Fischer-Tropsch product, and
(b) isolating from the product of step (a) a base oil or base oil intermediate fraction.

If the viscosity and/or pour point of the base oil obtained in step (b) are as desired no further processing is necessary and the oil can be used directly in a formulation according to the invention. If required,
however, the pour point of a base oil intermediate fraction may be further reduced in a step (c) by means of solvent or more preferably catalytic dewaxing.

A desired viscosity of base oil may be obtained by isolating (by means of distillation) a product having a suitable boiling range and corresponding viscosity, from an intermediate base oil fraction or from a dewaxed oil. The distillation may be a vacuum distillation step.

The hydroconversion/hydroisomerisation reaction of step (a) is preferably performed in the presence of hydrogen and a catalyst, which catalyst can be chosen from those known to one skilled in the art, examples of which are described in more detail below. The catalyst may in principle be any catalyst known in the art to be suitable for isomerising paraffinic molecules. In general, suitable hydroconversion/hydroisomerisation catalysts are those comprising a hydrogenation component supported on a refractory oxide carrier, such as amorphous silica-alumina (ASA), alumina, fluorided alumina, molecular sieves (zeolites) or mixtures of two or more of these.

Preferred catalysts for use in the hydroconversion/hydroisomerisation step (a) include those comprising platinum and/or palladium as the hydrogenation component. A very much preferred hydroconversion/hydroisomerisation catalyst comprises platinum and palladium supported on an amorphous silica-alumina (ASA) carrier. The platinum and/or palladium is suitably present in an amount of from 0.1 to 5.0 wt %, more suitably from 0.2 to 2.0 wt %, calculated as the element and based on the total weight of the carrier. If both elements are present, the weight ratio of platinum to palladium may vary within wide limits, but is suitably
in the range of from 0.05 to 10, more suitably from 0.1 to 5. Examples of suitable noble metal on ASA catalysts are, for instance, disclosed in WO-A-9410264 and EP-A-0582347. Other suitable noble metal-based catalysts, such as platinum on a fluorided alumina carrier, are disclosed in e.g. US-A-5059299 and WO-A-9220759.

A second type of suitable hydroconversion/hydroisomerisation catalyst includes those comprising at least one Group VIB metal, preferably tungsten and/or molybdenum, and at least one non-noble Group VIII metal, preferably nickel and/or cobalt, as the hydrogenation component. Either or both metals may be present as an oxide, a sulphide or a combination thereof. The Group VIB metal is suitably present in an amount of from 1 to 35 wt %, more suitably from 5 to 30 wt %, calculated as the element and based on the total weight of the carrier. The non-noble Group VIII metal is suitably present in an amount of from 1 to 25 wt %, preferably from 2 to 15 wt %, calculated as the element and based on the total weight of the carrier. A hydroconversion catalyst of this type, which has been found particularly suitable, is one comprising nickel and tungsten supported on fluorided alumina.

The above non-noble metal based catalysts are preferably used in their sulphided form. In order to maintain the sulphided form of the catalyst during use some sulphur needs to be present in the feed, for example at least 10 mg/kg or more preferably from 50 to 150 mg/kg of sulphur.

A preferred catalyst, which can be used in a non-sulphided form, comprises a non-noble Group VIII metal, e.g. iron or nickel, in conjunction with a Group IB
metal, e.g. copper, supported on an acidic support.
Copper is preferably present to suppress hydrogenolysis
of paraffins to methane. The catalyst preferably has a
pore volume in the range from 0.35 to 1.10 ml/g as
determined by water absorption, a surface area of from
200 to 500 m²/g as determined by BET nitrogen adsorption,
and a bulk density of from 0.4 to 1.0 g/ml. The catalyst
support is preferably made of an amorphous silica-alumina
wherein the alumina may be present within a range of from
5 to 96 wt %, preferably from 20 to 85 wt %. The silica
content of such a support, as SiO₂, is preferably from 15
to 80 wt %. The support may also contain small amounts,
for example from 20 to 30 wt %, of a binder such as
alumina, silica, a Group IVA metal oxide, a clay,
magnesia, etc., preferably alumina or silica.

The preparation of amorphous silica-alumina
microspheres has been described by Ryland, Lloyd B.,
Tamele, M.W. and Wilson, J.N., in "Cracking Catalysts",
The catalyst may be prepared by co-impregnating the
metals from solutions onto the support, drying at 100 to
150 °C and calcining in air at 200 to 550 °C. The
Group VIII metal may be present in an amount of about
15 wt % or less, preferably from 1 to 12 wt %, whilst the
Group IB metal is usually present in a lower amount: for
example the weight ratio of the Group IB metal to the
Group VIII metal may be from about 1:2 to about 1:20.
A typical catalyst is specified below:

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni, wt %</td>
<td>2.5-3.5</td>
</tr>
<tr>
<td>Cu, wt %</td>
<td>0.25-0.35</td>
</tr>
<tr>
<td>Al₂O₃-SiO₂, wt %</td>
<td>65-75</td>
</tr>
<tr>
<td>Al₂O₃ (binder), wt %</td>
<td>25-30</td>
</tr>
</tbody>
</table>
Surface area 290-325 m²/g
Pore volume (Hg) 0.35-0.45 ml/g
Bulk density 0.58-0.68 g/ml.

Another class of suitable hydroconversion/hydroisomerisation catalysts includes those based on molecular sieve type materials, suitably comprising at least one Group VIII metal component, preferably Pt and/or Pd, as the hydrogenation component. Suitable zeolitic and other aluminosilicate materials, then, include Zeolite beta, Zeolite Y, Ultra Stable Y, ZSM-5, ZSM-12, ZSM-22, ZSM-23, ZSM-48, MCM-68, ZSM-35, SSZ-32, ferrierite, mordenite and silica-aluminophosphates such as SAPO-11 and SAPO-31. Examples of suitable hydroconversion/hydroisomerisation catalysts are, for instance, described in WO-A-9201657. Combinations of these catalysts are also possible.

Suitable hydroconversion/hydroisomerisation processes are those involving a first step wherein a zeolite beta or ZSM-48 based catalyst is used and a second step wherein a ZSM-5, ZSM-12, ZSM-22, ZSM-23, ZSM-48, MCM-68, ZSM-35, SSZ-32, ferrierite or mordenite based catalyst is used. Of the latter group ZSM-23, ZSM-22 and ZSM-48 are preferred. Examples of such processes are described in US-A-20040065581, which discloses the use of a first step catalyst comprising platinum and zeolite beta and a second step catalyst comprising platinum and ZSM-48.

Combination processes in which the Fischer-Tropsch product is first subjected to a first hydroisomerisation step using an amorphous catalyst comprising a silica-alumina carrier as described above, followed by a second hydroisomerisation step using a catalyst which comprises a molecular sieve, have also been identified as preferred
processes by which to prepare a base oil for use in the present invention. Preferably the first and second hydroisomerisation steps are performed in series flow. More preferably the two steps are performed in a single reactor comprising beds of the above amorphous and/or crystalline catalysts.

In step (a) the Fischer-Tropsch feed is contacted with hydrogen in the presence of the catalyst at elevated temperature and pressure. The temperature will typically be in the range from 175 to 380 °C, preferably higher than 250 °C and more preferably from 300 to 370 °C. The pressure will typically be in the range from 10 to 250 bar and preferably from 20 to 80 bar. Hydrogen may be supplied at a gas hourly space velocity of from 100 to 10000 Nl/l/hr, preferably from 500 to 5000 Nl/l/hr. The hydrocarbon feed may be provided at a weight hourly space velocity of from 0.1 to 5 kg/l/hr, preferably higher than 0.5 kg/l/hr and more preferably lower than 2 kg/l/hr. The ratio of hydrogen to hydrocarbon feed may range from 100 to 5000 Nl/kg and is preferably from 250 to 2500 Nl/kg.

The conversion in step (a), defined as the weight percentage of the feed boiling above 370 °C which reacts per pass to a fraction boiling below 370 °C, is suitably at least 20 wt %, preferably at least 25 wt %, but preferably not more than 80 wt % and more preferably not more than 65 wt %. The feed as used in the above definition is the total hydrocarbon feed to step (a), thus including any optional recycle of a high boiling fraction which may be obtained in step (b).

In step (b) the product of step (a) is preferably separated into one or more distillate fuel fractions and a base oil or base oil precursor fraction having the
desired viscosity. If the pour point of the base oil or precursor is not in the desired range it may be further reduced by means of a dewaxing step (c), preferably by catalytic dewaxing. In such an embodiment it may be a further advantage to dewax a wider boiling fraction of the product of step (a). From the resulting dewaxed product the required, typically light, base oil and optionally other oils having desired viscosities can then be isolated for instance by distillation. Dewaxing is preferably performed by catalytic dewaxing, as for example described in WO-A-02070627, which publication is hereby incorporated by reference (see in particular page 8 line 27 to page 11 line 6 for examples of suitable dewaxing conditions and catalysts). The final boiling point of the feed to the dewaxing step (c) may be the final boiling point of the product of step (a) or lower if desired. Typically, the feed to the catalytic dewaxer will comprise C_{16} to C_{40} or C_{23} to C_{40} hydrocarbons.

Prior to use in a formulation according to the invention, for instance after a dewaxing step (c), the base oil may be subjected to one or more further treatments such as hydrofinishing, as described for example at page 11 line 7 to page 12 line 12 of WO-A-02070627.

According to the present invention, the base oil formulation may contain a mixture of two or more Fischer-Tropsch derived base oils. It may contain a mixture of two or more mineral derived base oils.

In a formulation according to the invention, the concentration of the Fischer-Tropsch derived light base oil may be from 2 to 50 wt % or from 2 to 45 wt %, for example from 10 to 45 wt % or from 15 or 20 to 45 wt %.
The concentration of the Fischer-Tropsch derived base oil will generally be chosen to ensure that the viscosity, viscosity index, volatility, pour point and/or other relevant properties of the overall formulation are within the desired ranges, for instance within commercial or regulatory specifications.

The concentration of the mineral derived base oil in the formulation may correspondingly be from 50 to 98 wt % or from 55 to 98 wt %, for example from 55 to 90 wt % or from 55 to 85 or 80 wt %.

The Fischer-Tropsch derived base oil and the mineral derived base oil may be the only base oil components in the formulation. Alternatively, they may be used in combination with one or more additional base oil components. Such additional base oil components may be Fischer-Tropsch derived or non-Fischer-Tropsch derived. The overall formulation will suitably contain less than 20 wt %, preferably less than 10 wt %, of such additional base oil components.

Examples of additional base oil components include mineral based paraffinic and naphthenic type base oils and synthetic base oils, for example esters, poly alpha olefins, poly alkylene glycols and the like. Of these, esters can be beneficial in order to improve the biodegradability of a base oil formulation. The content of an additional ester base oil, if present, may be from 1 to 30 wt % based on the overall formulation, more preferably from 5 to 25 wt %. Suitable esters are those derivable by reacting an aliphatic mono, di and/or poly carboxylic acid with isotridecyl alcohol under esterification conditions. Examples of such compounds are the isotridecyl ester of octane-1, 8-dioic acid, 2-ethylhexane-1, 6 dioic acid and dodecane-1, 12-dioic acid.
Preferably the ester is a so-called pentaerythritol tetra- fatty acid ester (PET ester), as made by esterification of pentaerythritol (PET) with branched or linear fatty acids, preferably Cg-C\textsubscript{10} acids. Such an ester may contain di-PET as an impurity.

A base oil formulation according to the invention may have a VK 100 (ASTM D-445) of from 3.8 to 5 centistokes. It may have a VK 40 (kinematic viscosity at 40 °C, also measured according to ASTM D-445) of from 18 to 27 centistokes. Its viscosity will suitably be tailored depending on its intended use.

The formulation may have a viscosity index (ASTM D-2270) of from 95 to 120. It may have a CCS dynamic viscosity (ASTM D-5293), measured at -25 °C, of from 1000 to 2000 centipoise.

The formulation may have a pour point (ASTM D-5950) of from -30 to -6 °C or from -25 to -10 °C. It may have a D-93 flash point (IP-34) of from 180 to 210 °C. It may have a Noack volatility (CEC L-40-A-93) of from 16 to 25 wt %.

For use in certain contexts, for example certain types of engine, it may be preferred for the formulation to be, overall, a moderately low sulphur formulation or a low sulphur formulation, for instance containing at most 100 ppmw (parts per million by weight), preferably no more than 50 ppmw, most preferably no more than 10 or 5 ppmw, of sulphur.

The formulation may contain other components in addition to the mineral derived base oil and the Fischer-Tropsch derived base oil. It may for example contain one or more base oil additives of the type which are conventional for use in base oil formulations. The nature of any such additives will depend on the intended
use of the formulation. They may for example be selected from anti-wear additives, antioxidants, dispersants, detergents, viscosity modifiers, antifoaming agents, pour point depressants such as of the hydrocarbon or oxygenated hydrocarbon type, emulsifiers, demulsifiers, corrosion inhibitors, seal swell agents, anti-staining additives, UV-stabilisers and friction modifiers.

Specific examples of such additives are described in for example the Kirk-Othmer Encyclopedia of Chemical Technology, third edition, volume 14, pages 477-526.

Suitably the dispersant is an ashless dispersant, for example a polybutylene succinimide polyamine or Mannic base type dispersant. Suitably the detergent is an over-based metallic detergent, for example of the phosphonate, sulphonate, phenolate or salicylate type as described in the above mentioned Encyclopedia. Suitably the viscosity modifier is a viscosity modifying polymer, for example a polyisobutylene, an olefin copolymer, a polymethacrylate, a polyalkylstyrene or a hydrogenated polyisoprene star polymer (Shellvis). Examples of suitable antifoaming agents are polydimethylsiloxanes and polyethylene glycol ethers and esters.

In order to improve the gassing tendency of the base oil formulation it may be preferred to include an aromatic compound, for example from 0.05 to 10 wt % or from 0.1 to 5 wt % of an aromatic compound. Preferred aromatic compounds are for example tetrahydronaphthalene, diethylbenzene, di-isopropylbenzene, or mixtures of alkylbenzenes such as are commercially obtainable as "Shell Oil 4697" or "Shellsol A 150" (both "Shell" products obtainable from Shell Deutschland GmbH). Another preferred mixture of aromatic compounds comprises a mixture of 2,6-di-t-butyl phenol and 2,6-di-t-butyl
cresol. The base oil formulation may for instance comprise from 0.1 to 3 wt % of 2,6-di-t-butyl phenol and from 0.1 to 2 wt % of 2,6-di-t-butyl cresol, suitably in a weight ratio of from 1:1 to 1:1.5.

The base oil formulation may contain a copper passivator, sometimes referred to as an electrostatic discharge depressant or metal deactivator, for instance as described in WO-A-2006136594 at pages 16 to 18.

Unless otherwise stated, the concentration of each such additional component in the base oil formulation is preferably up to 50,000 ppmw or 10,000 ppmw or 1000 ppmw, for example from 5 to 1000 ppmw. (All additive concentrations quoted in this specification refer, unless otherwise stated, to active matter concentrations by mass. Further, all concentrations, unless otherwise stated, are quoted as percentages of the overall base oil formulation.)

If desired one or more additive components, such as those listed above, may be co-mixed – preferably together with one or more suitable diluents – in an additive concentrate, and the additive concentrate may then be dispersed into the mineral derived base oil, the Fischer-Tropsch derived base oil or a blend of the two, in order to prepare a formulation according to the invention.

The total additive content in the base oil formulation, including additive diluent oil, may suitably be from 0.5 to 20 wt %, preferably below 20 or 15 or in cases 10 wt %.

Where a formulation according to the invention contains one or more cold flow additives, for example pour point depressants, such additives may be present at reduced concentrations due to the presence of the Fischer-Tropsch derived base oil. Thus for example, the
formulation may contain up to 20 or 30 or 40 % lower concentrations of cold flow additives than would otherwise have been incorporated into it in order to achieve the properties and performance required or desired of it in the context of its intended use. The reduction may be as compared to the concentration of cold flow additives which was present in the base oil formulation prior to the realisation that a Fischer-Tropsch derived base oil could be used in the way provided by the present invention, or which was present in an otherwise analogous base oil formulation intended (e.g. marketed) for use in an analogous context, prior to adding a Fischer-Tropsch derived base oil to it.

Thus for example a base oil formulation according to the invention may contain less than 3000 ppmw of cold flow additives, in particular pour point depressants, suitably less than 1500 ppmw.

Similarly where a formulation according to the invention contains one or more viscosity modifying additives, such additives may be present at reduced concentrations due to the presence of the Fischer-Tropsch derived base oil. Thus for example, the formulation may contain up to 30 % lower concentrations of viscosity modifying additives than would otherwise have been incorporated into it in order to achieve the properties and performance required or desired of it in the context of its intended use. The reduction may be as compared to the concentration of viscosity modifying additives which was present in the base oil formulation prior to the realisation that a Fischer-Tropsch derived base oil could be used in the way provided by the present invention, or which was present in an otherwise analogous base oil formulation intended (e.g. marketed) for use in an
analogous context, prior to adding a Fischer-Tropsch derived base oil to it.

Thus for example a formulation according to the invention may contain 10 wt % or less of viscosity modifying additives (typically included as concentrated polymer solutions), suitably 9 or 8 or 7 or 6 or 5 wt % or less. In cases it may contain no viscosity modifying additives at all.

Where a formulation according to the invention contains one or more antioxidant or other stabilising additives, such additives may again be present at reduced concentrations due to the presence of the Fischer-Tropsch derived base oil. Thus for example, the formulation may contain up to 20 % lower concentrations of antioxidant additives than would otherwise have been incorporated into it in order to achieve the properties and performance required or desired of it in the context of its intended use. The reduction may be as compared to the concentration of antioxidant additives which was present in the base oil formulation prior to the realisation that a Fischer-Tropsch derived base oil could be used in the way provided by the present invention, or which was present in an otherwise analogous base oil formulation intended (e.g. marketed) for use in an analogous context, prior to adding a Fischer-Tropsch derived base oil to it.

Thus for example a formulation according to the invention may contain 5000 ppmw or less of antioxidant additives, suitably 4000 or 3000 ppmw or less.

A base oil formulation according to the invention may be suitable for a wide range of uses. It may for instance be suitable and/or adapted and/or intended for use as a lubricant, for example as an engine oil such as
for use in an internal combustion engine or as an industrial lubricant. It may be suitable and/or adapted and/or intended for use as a transmission fluid, in particular an automatic transmission fluid, a hydraulic oil, a compressor oil, a turbine oil (e.g. for use in a gas, steam or combined cycle turbine) or a process oil.

The formulation may be adapted for, and/or intended for, use in colder climates and/or during colder seasons. The cold flow performance of the formulation, when used in a system such as for example a vehicle engine, can impact upon the overall performance of the system under such conditions.

The relatively high biodegradability of Fischer-Tropsch derived base oils, as compared to their mineral derived counterparts, can make a formulation according to the invention particularly advantageous for use in situations where biodegradability is a concern, for example as a transformer oil in mobile electrical equipment such as trains, electrical powered cars or hybrid powered cars. Formulations according to the invention may similarly find application in equipment for use in environmentally sensitive areas, such as for example national parks, conservation areas, water protection areas, potable water storage facilities and the like.

The biodegradability of a base oil formulation according to the invention may be further improved by the inclusion of an ester based base oil, for instance as described above.

According to a second aspect, the present invention provides the use of a Fischer-Tropsch derived light base oil in a base oil formulation containing a mineral derived base oil, for the purpose of improving one or
more properties of the formulation, suitably without undue increase in its volatility and/or with a lower increase in volatility than theory would have predicted to be caused by the incorporation of the Fischer-Tropsch derived light base oil. As has been described above, incorporation of a Fischer-Tropsch derived light base oil into such formulations has been found to cause a lower than expected increase in volatility, whilst at the same time assuring desirable improvements in other properties.

Thus the volatility of the base oil formulation, after incorporation of the Fischer-Tropsch derived light base oil, is preferably still no higher than that of a conventional (typically mineral derived) base oil or base oil formulation which is intended (e.g. marketed) for use for the same purpose.

The Fischer-Tropsch derived light base oil may in particular be used for the purpose of improving a property selected from cold flow properties (in particular pour point), viscosity profile (in particular viscosity index and/or CCS dynamic viscosity) and oxidative stability. More particularly it may be used to improve the pour point, viscosity index and/or oxidative stability of the formulation. In some cases an improvement in oxidative stability may be particularly important.

A third aspect of the invention provides a method for formulating a mineral derived base oil, the method comprising (i) measuring a relevant property of the base oil and (ii) blending the base oil with a Fischer-Tropsch derived light base oil, in an amount sufficient to improve the relevant property in the overall blend. The relevant property may for example be selected from those listed above, in particular viscosity index and CCS
dynamic viscosity. The improvement is preferably achieved without undue increase in the volatility of the blend as compared to that of the mineral derived base oil alone, as described above in connection with the second aspect of the invention.

The volatility of a base oil or base oil formulation can suitably be assessed by measuring its Noack volatility, which reflects the percentage of oil which is lost when the oil or formulation is heated to a specified temperature under specified conditions. A reduction in this value indicates reduced volatility, which in the context of a base oil formulation may be considered as an improvement. Noack volatility may be measured using the standard test method CEC L-40-A-93 or an analogous technique.

The cold flow properties of a base oil or base oil formulation can suitably be assessed by measuring its pour point, which is the lowest temperature at which movement of the formulation can be observed. A reduction in pour point indicates an improvement in cold flow properties, which in turn can increase the range of conditions in which the formulation can efficiently be used. Pour points can suitably be measured using the standard test method ASTM D-5950 or an analogous technique.

Cold flow properties may also be assessed by measuring cloud point, for example using the standard test method ASTM D-5771 or an analogous technique. Again a reduction in cloud point indicates an improvement in cold flow properties. They may instead or in addition - in particular in the context of base oils intended for use in or as automatic transmission fluids - be assessed by measuring Brookfield viscosities, for instance using...
the standard test method ASTM D-2983. A reduction in Brookfield viscosity indicates an improvement in cold flow properties.

In general, an improvement in cold flow properties may be manifested by a reduction in the minimum temperature at which a system which uses the base oil formulation can perform to a given standard.

The viscosity index of a base oil or base oil formulation, which is a measure of the extent to which its kinematic viscosity varies with temperature, can suitably be assessed using the standard test method ASTM D-2270 or an analogous technique. An increase in this index may, in the context of a base oil formulation, be considered as an improvement.

The CCS dynamic viscosity of a base oil or base oil formulation can suitably be assessed using the standard test method ASTM D-5293 or an analogous technique. A reduction in this value may, in the context of a base oil formulation, be considered as an improvement, as it can extend formulation options, assist in tailoring a base oil blend to give a desired overall viscosity and contribute to improved wear and volatility performance.

The oxidative stability of a base oil or base oil formulation can suitably be assessed using the TOST or Turbine Oil Stability Test (ASTM D-943) or an analogous technique. An increase in the TOST lifetime of the formulation (for example measured in hours) may, in the context of a base oil formulation, be considered as an improvement.

In the context of the second and third aspects of the invention, "improving" a property of a base oil formulation embraces any degree of improvement compared to the performance of the formulation before the Fischer-
Tropsch derived light base oil is incorporated. This may for example involve adjusting the relevant property of the formulation, by means of the Fischer-Tropsch derived base oil, in order to meet a desired target, for instance a desired target Noack volatility, pour point, viscosity index, CCS dynamic viscosity or oxidative stability. Similarly, "increasing" or "reducing" a measured property of a base oil formulation embraces any degree of increase or reduction, as the case may be, compared to the properties of the formulation before the Fischer-Tropsch derived light base oil is incorporated.

In the context of the present invention, "use" of a Fischer-Tropsch derived light base oil in a base oil formulation means incorporating the light base oil into the formulation, as a blend (i.e. a physical mixture) with one or more other base oil components (including the mineral derived base oil) and optionally with one or more base oil additives. The Fischer-Tropsch derived light base oil is conveniently incorporated before the formulation is introduced into a system (for example an engine) which is to be run using the formulation. Instead or in addition the use may involve running such a system, using in it the base oil formulation containing the Fischer-Tropsch derived light base oil.

"Use" of a Fischer-Tropsch derived light base oil may also embrace supplying such a base oil together with instructions for its use in a base oil formulation to achieve the purpose(s) of the second, third, fourth and/or fifth aspects of the invention, for instance to achieve a desired target volatility, and/or a desired target pour point, viscosity index, CCS dynamic viscosity or oxidative stability, and/or to reduce the concentration of an additive in the formulation.
The Fischer-Tropsch derived light base oil may itself be supplied as a component of a composition which is suitable for and/or intended for use as a base oil additive, in which case the Fischer-Tropsch derived base oil may be included in such a composition for the purpose of influencing its effects on the relevant properties, as described above, of a base oil formulation. Thus the Fischer-Tropsch derived light base oil may be incorporated into an additive composition or package along with one or more other base oil additives.

According to a fourth aspect of the present invention there is provided a method for improving one or more properties - for example selected from those listed above - of a base oil formulation which contains a mineral derived base oil, whilst still achieving a target maximum volatility X for the formulation, which method involves adding to the formulation a concentration c of a Fischer-Tropsch derived light base oil, wherein c is higher than the maximum concentration c' of the Fischer-Tropsch derived light base oil which theory would predict could be added to the formulation without increasing the volatility of the formulation above the target maximum X.

The theoretical maximum Fischer-Tropsch base oil concentration, c', and its relationship to the volatility of the formulation, are suitably calculated using linear blending rules, based on the volatilities of the individual constituents of the formulation (i.e. typically the mineral derived base oil and the Fischer-Tropsch derived light base oil).

A fifth aspect of the invention provides the use of a Fischer-Tropsch derived light base oil, at a concentration c, in a base oil formulation containing a mineral derived base oil, for the purpose of improving
one or more properties of the formulation, whilst at the same time achieving a volatility for the formulation which is lower than that which theory would predict to be achievable using the Fischer-Tropsch derived light base oil at concentration c. Again linear blending rules may be used to predict the theoretical volatility of a formulation containing both a mineral derived base oil and a Fischer-Tropsch derived light base oil at any given weight ratio.

If theory applied as expected to formulations containing both a Fischer-Tropsch derived light base oil and a mineral derived base oil, it would then be straightforward to calculate the amount of the Fischer-Tropsch base oil which could be included in the formulation without increasing the volatility above a desired target maximum. However it has now been found that a Fischer-Tropsch derived light base oil can cause less of an increase in volatility, when blended with a higher viscosity mineral derived base oil, than would have been predicted to occur if theory applied. This allows a higher amount of the Fischer-Tropsch derived base oil to be included in the formulation, in turn allowing greater improvements in for instance cold flow performance, viscosity profile and/or oxidative stability than would otherwise have been thought possible, ideally with lower concentrations of, or no, cold flow additives, viscosity improvers or antioxidants present, as discussed above.

A certain maximum volatility is often desirable in order for a base oil formulation to meet current health and safety specifications, and/or to satisfy consumer demand. Equally, a certain level of cold flow performance (for example, a maximum pour point) may be
desirable to meet relevant base oil specifications, as may a certain minimum viscosity index, a certain maximum CCS dynamic viscosity and/or a certain minimum level of oxidative stability. According to the present invention, such standards may all be achievable simultaneously, often with reduced levels of or no additives present, due to the inclusion of the Fischer-Tropsch derived light base oil.

A sixth aspect of the present invention provides the use of a Fischer-Tropsch derived light base oil, in a base oil formulation or in the preparation of a base oil formulation, for the purpose of allowing the use of a lower quality mineral derived base oil in the formulation than would otherwise have been necessary in order to achieve one or more desired target properties for the formulation.

As discussed above, a "lower quality" mineral derived base oil in this context is typically one which has been subjected to a lower degree of processing, in particular hydroprocessing and/or dewaxing. A "lower degree" of processing may involve processing for a shorter period of time, and/or under less severe conditions (for example at a lower hydroprocessing temperature, or using a lower extraction severity in the upgrading step, or by solvent as opposed to catalytic dewaxing, or by reducing the extent of wax removal or conversion in solvent or catalytic dewaxing steps respectively), and/or complete removal of a processing step. A lower quality mineral derived base oil typically has a lower viscosity index and/or a higher volatility. It may contain a higher concentration of one or more components selected from unsaturates (in particular aromatics), naphthenics and waxes.
The one or more desired target properties for the formulation may for instance be selected from volatility, cold flow properties (in particular pour point), viscosity index, CCS dynamic viscosity and oxidative stability.

According to a seventh aspect of the invention, there is provided a method for preparing a base oil formulation, such as a formulation according to the first aspect, the method involving blending a mineral derived base oil with a Fischer-Tropsch derived light base oil. The blending may be carried out for one or more of the purposes described above in connection with the second to the sixth aspects of the invention, in particular with respect to the viscosity index, the cold flow properties, the oxidative stability, the CCS dynamic viscosity and/or the volatility of the resultant base oil formulation.

This method may in particular be carried out for the purpose of improving the quality of the mineral derived base oil. It may for instance be used to "upgrade" a Group I mineral derived base oil to a Group II one, or a Group II to a Group III oil, or to improve the properties of a relatively low quality Group II mineral derived base oil.

In a preferred embodiment of the invention, the method may involve preparing the mineral derived base oil using a lower degree of processing than would previously have been used in order to achieve one or more desired properties in the base oil or a formulation containing it. This may for example involve reducing the length and/or severity of a processing step used in the preparation of the mineral derived base oil, or omitting a processing step altogether. Thus a method according to the seventh aspect of the invention may involve the
deliberate under-processing of a mineral derived base oil, as compared to the processing previously applied during its preparation, and using the Fischer-Tropsch derived light base oil in order to compensate, at least partially, for the changes in properties of the mineral derived base oil which result from the lower degree of processing to which it is now subjected. The method may for example involve processing the mineral base oil to a lower viscosity index.

An eighth aspect of the invention provides a system, for example an engine or part thereof, which contains a base oil formulation according to the first aspect, and/or a base oil formulation prepared according to any one of the second to the seventh aspects.

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.

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

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 and drawings). Thus features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, 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 and performance of base oil formulations in accordance with the invention, and assess the effects of Fischer-Tropsch derived light base oils on the properties of formulations containing mineral derived base oils.

Example 1

An "under-processed" mineral derived Group I base oil may be blended with a Group II/III Fischer-Tropsch derived light base oil (FTBO) to produce a formulation according to the present invention. The mineral oil may for example have been processed only to a viscosity index of about 93 or 92, whereas more typical Group I base oils are processed to a viscosity index of at least 95.

In this experiment, the under-processed Group I mineral base oil used had a VK 100 (ASTM D-445) of 5.341 centistokes, a VK 40 (ASTM D-445) of 33.02 centistokes and a viscosity index (ASTM D-2270) of 92. It had an estimated total polars content of 32.8 wt %.

The Fischer-Tropsch base oil had a VK 100 of 2.68 centistokes and a viscosity index of 119. The two components were blended at a weight ratio of 71.0 to 29.0 so as to produce a blend having an overall VK 100 of approximately 4 centistokes.
The experimentally determined properties of such a blend are shown in Table 1 below. The table also shows the relevant properties for a typical conventionally processed Group I mineral base oil (in this case HVI-55, ex-Shell CAPSA, Argentina), which may be regarded as "target" properties for the blend prepared according to the invention.
Table 1

<table>
<thead>
<tr>
<th>Property</th>
<th>Test method</th>
<th>Under-processed mineral base oil</th>
<th>FTBO</th>
<th>Blend</th>
<th>Target (conventionally processed mineral base oil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VK 40 (centistokes)</td>
<td>ASTM D-445</td>
<td>33.02</td>
<td>9.58</td>
<td>20.95</td>
<td>22.41</td>
</tr>
<tr>
<td>VK 100 (centistokes)</td>
<td>ASTM D-445</td>
<td>5.34</td>
<td>2.68</td>
<td>4.20</td>
<td>4.304</td>
</tr>
<tr>
<td>Viscosity index</td>
<td>ASTM D-2270</td>
<td>92</td>
<td>119</td>
<td>103</td>
<td>95</td>
</tr>
<tr>
<td>Noack volatility (wt %)</td>
<td>CEC L-40- A-93</td>
<td>14.6</td>
<td>42.4</td>
<td>21.3</td>
<td>26.7</td>
</tr>
<tr>
<td>Oxidative stability (TOST lifetime, hours) in additivated formulation*</td>
<td>ASTM D-934</td>
<td>1680</td>
<td>&gt;3000</td>
<td>&gt;2424</td>
<td>&gt;2000</td>
</tr>
</tbody>
</table>

*Additive included in base oils for stability testing = OLOA 4994S (ex-Chevron-Oronite Additive Company), which includes both anti-wear and antioxidant components; additive treat rate = 0.75 wt %.

Table 1 shows how the Fischer-Tropsch derived light base oil may be used to increase the viscosity index, and hence the quality, of the mineral oil. Although it increases the volatility of the blend compared to that of the mineral oil alone, due to the inherently higher volatility of the Fischer-Tropsch oil, it is of note that
the increase does not take the overall blend beyond acceptable values for crankcase oil formulation blending.

The Fischer-Tropsch oil can also be seen to improve the oxidative stability of the mineral oil.

Indeed for all the parameters shown, the blend prepared according to the invention not only meets but actually improves upon the "target" properties of the conventionally processed Group I base oil.

The concentration of the Fischer-Tropsch oil in a blend according to the invention may be altered so as to tailor one or more such properties, to meet desired specifications - for instance to achieve a desired minimum viscosity index - and/or to mimic the properties of another base oil or base oil formulation produced in a different way.

Example 2

A base oil formulation according to the invention was prepared by blending together 22.7 wt % of a Fischer-Tropsch derived light base oil (VK 100 approximately 3 centistokes) and 77.3 wt % of a commercially available standard Group I mineral base oil (HVI-65, ex-Shell Pernis Refinery, Rotterdam, The Netherlands; VK 100 approximately 5 centistokes, viscosity index 100).

The Fischer-Tropsch derived base oil (FTBO) had been prepared using a process of the general type described above, including relatively severe hydroprocessing and catalytic dewaxing steps. Its properties are shown in Table 2 below.

Table 2

<table>
<thead>
<tr>
<th>Property</th>
<th>Test method</th>
<th>FTBO</th>
</tr>
</thead>
<tbody>
<tr>
<td>VK 40 (centistokes)</td>
<td>ASTM D-445</td>
<td>9.581</td>
</tr>
<tr>
<td>VK 100 (centistokes)</td>
<td>ASTM D-445</td>
<td>2.68</td>
</tr>
<tr>
<td>Viscosity index</td>
<td>ASTM D-2270</td>
<td>119</td>
</tr>
<tr>
<td>Property</td>
<td>Test method</td>
<td>FTBO</td>
</tr>
<tr>
<td>---------------------------------------------------</td>
<td>----------------</td>
<td>----------</td>
</tr>
<tr>
<td>Brookfield dynamic viscosity at -40 °C (centipoise)</td>
<td>ASTM D-2983</td>
<td>3120/3220</td>
</tr>
<tr>
<td>Brookfield dynamic viscosity at -25 °C (centipoises)</td>
<td>ASTM D-2983</td>
<td>180/180</td>
</tr>
<tr>
<td>Total polar content:</td>
<td>IP-368 mod</td>
<td></td>
</tr>
<tr>
<td>Aromatics (wt %)</td>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td>Saturates (wt %)</td>
<td></td>
<td>99.5</td>
</tr>
<tr>
<td>Recovery (wt %)</td>
<td></td>
<td>100.2</td>
</tr>
<tr>
<td>Density at 15 °C (kg/m3)</td>
<td>IP-365/97</td>
<td>806.6</td>
</tr>
<tr>
<td>Filterability (mins)</td>
<td>TMS-371</td>
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<td>Noack volatility (wt %)</td>
<td>CEC L-40-A-93</td>
<td>42.4</td>
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<td>Flash point D-93 (°C)</td>
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<td>Flash point D-92 (°C)</td>
<td>ASTM D-92</td>
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<tr>
<td>Pour point (°C)</td>
<td>ASTM D-5950</td>
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<td>Pour point response (+ 0.15 wt % polymethacrylate pour point depressant) (°C)</td>
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<td>Cloud point (°C)</td>
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<td>Saybolt colour</td>
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<td>Aniline point (°C)</td>
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<td>Air release (mins)</td>
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<td>5 %</td>
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<td>15 %</td>
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<td>367.0</td>
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The properties of the base oil blend, which had a VK 100 of approximately 4 centistokes, are shown in Table 3 below. Also shown in the table are the target properties required of the blend, these being the properties of a standard, straight run 4 centistoke Group I mineral base oil.
Again these data show that blending a mineral derived base oil with a Fischer-Tropsch derived light base oil, in appropriate proportions, can be used to tailor the properties of the overall blend in order to achieve a desired target specification. In this case the viscosity index of the blend is higher than the target value, whilst the Noack volatility and the pour point are lower. The CCS dynamic viscosity is also much lower than the target value. Thus the overall quality of the blend, and its fitness-for-purpose, may be improved without undue detriment to its volatility; indeed, despite the presence of the relatively high volatility Fischer-Tropsch component, the volatility of the overall blend is still well within the desired specification.

Example 3

Further base oil formulations according to the invention were prepared by blending together: B-I 41 wt % of the Fischer-Tropsch derived light base oil used in Examples 1 and 2 and 59 wt % of MO-I, a commercially available standard mineral derived Group II base oil (VK 100 approximately 6 centistokes, Star 6 ex-Motiva LLC, Port Arthur, Texas, USA), in order to create
a blend having an overall VK 100 of approximately 4 centistokes.

B-2 44 wt % of the Fischer-Tropsch derived light base oil used in Examples 1 and 2 and 56 wt % of a commercially available standard mineral derived Group II base oil MO-2 (VK 100 6.85 centistokes, Star 6 ex-Motiva LLC, Port Arthur, Texas, USA), again in order to create a blend having an overall VK 100 of approximately 4 centistokes.

The properties of the two blends B-1 and B-2, and of their individual components, are shown in Table 4 below. Also shown in the table are the target properties required of the blends, these being the measured properties of a commercially available mineral derived base oil of VK 100 approximately 4 centistokes (i.e. a standard, fit-for-purpose 4 centistoke Group II base oil).

The test methods used were the same as in Example 2.

Table 4

<table>
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<tr>
<th>Property</th>
<th>MO-1</th>
<th>MO-2</th>
<th>FTBO</th>
<th>B-1</th>
<th>B-2</th>
<th>Target</th>
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<tbody>
<tr>
<td>VK 40 (centistokes)</td>
<td>43</td>
<td>44.09</td>
<td>9.58</td>
<td>20.87</td>
<td>20.30</td>
<td>21.5</td>
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<tr>
<td>VK 100 (centistokes)</td>
<td>6.45</td>
<td>6.85</td>
<td>2.68</td>
<td>4.296</td>
<td>4.305</td>
<td>4.24</td>
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<tr>
<td>Viscosity index</td>
<td>100</td>
<td>111</td>
<td>119</td>
<td>112</td>
<td>120</td>
<td>100</td>
</tr>
<tr>
<td>CCS dynamic viscosity at -25 °C (Vd ccs) (centipoises)</td>
<td>5600</td>
<td>5433</td>
<td>Too low to measure</td>
<td>1123</td>
<td>1008</td>
<td>1441</td>
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<tr>
<td>Reduction in measured Vd</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>22.07</td>
<td>30.05</td>
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</table>
The test method used was as described in US-6008164 (isothermal pressure DSC @ 200 psig inhibited with 0.5 wt % 4′-methylene bis (2, 6-di-tert-butylphenol)).

Table 4 shows that the properties of a mineral base oil may be upgraded, to meet a certain desired standard, by blending with a Fischer-Tropsch derived light base oil. Indeed in this case the properties of the blends of the invention have again improved upon those of the

<table>
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<tr>
<th>Property</th>
<th>MO-1</th>
<th>MO-2</th>
<th>FTBO</th>
<th>B-1</th>
<th>B-2</th>
<th>Target</th>
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<td>ccs compared to target value (%) relative</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8275</td>
<td>6725</td>
<td>17690</td>
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<td>Brookfield viscosity - 40°C, mPa.s (with 0.15wt % pour point depressant) by ASTM D-2983</td>
<td>-15</td>
<td>-18</td>
<td>-42</td>
<td>-18</td>
<td>-24</td>
<td>-15</td>
</tr>
<tr>
<td>Pour point (°C)</td>
<td>11</td>
<td>12.9</td>
<td>42</td>
<td>24</td>
<td>26</td>
<td>26</td>
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<tr>
<td>Noack volatility (wt %)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>25.4</td>
<td>-</td>
<td>22.5</td>
</tr>
<tr>
<td>Oxidational stability test - induction period, minutes*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
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* The test method used was as described in US-6008164 (isothermal pressure DSC @ 200 psig inhibited with 0.5 wt % 4′-methylene bis (2, 6-di-tert-butylphenol)).
"target" 4 centistoke base oil. In the case of blend B-2, the Group II mineral base oil MO-2 has been upgraded to have a viscosity index within the Group III range.

It follows that any given mineral base oil may be processed to a lower degree, i.e. to a lower quality than usual, and subsequently upgraded to its original standard (or indeed to another desired standard) by blending with a Fischer-Tropsch light base oil.

In particular the Table 4 data show significant increases in viscosity indices for the overall blends, as compared to the mineral oils alone, as well as reductions in pour point, in both cases improving on the target values. The Noack volatilities of the blends are also comfortably below the target value, the presence of the Fischer-Tropsch oil having caused less of an increase in volatility than might have been predicted.

The cold crank simulator viscosities of the blends are also significantly reduced, and indeed are well below that of the target mineral base oil.
CL A I M S

1. A base oil formulation containing a blend of a mineral derived base oil and a Fischer-Tropsch derived light base oil.

2. A base oil formulation according to claim 1, wherein the mineral derived base oil has a viscosity index (ASTM D-2270) of less than 95.

3. A base oil formulation according to claim 1 or claim 2, wherein the Fischer-Tropsch derived light base oil has a viscosity index (ASTM D-2270) of 115 or greater.

4. A base oil formulation according to any one of the preceding claims, wherein the concentration of the Fischer-Tropsch derived light base oil is from 2 to 45 wt %.

5. Use of a Fischer-Tropsch derived light base oil in a base oil formulation containing a mineral derived base oil, for the purpose of improving a property of the formulation selected from cold flow properties, viscosity profile and oxidative stability, with a lower increase in volatility than theory would have predicted to be caused by the incorporation of the Fischer-Tropsch derived light base oil.

6. A method for improving a property of a base oil formulation containing a mineral derived base oil, the property being selected from cold flow properties, viscosity profile and oxidative stability, whilst still achieving a target maximum volatility X for the formulation, which method involves adding to the formulation a concentration c of a Fischer-Tropsch derived light base oil, wherein c is higher than the
maximum concentration $c'$ of the Fischer-Tropsch derived light base oil which theory would predict could be added to the formulation without increasing the volatility of the formulation above the target maximum $X$.

7. Use of a Fischer-Tropsch derived light base oil, in a base oil formulation or in the preparation of a base oil formulation, for the purpose of allowing the use of a lower quality mineral derived base oil in the formulation than would otherwise have been necessary in order to achieve one or more desired target properties for the formulation.

8. A method for preparing a base oil formulation, the method involving blending a mineral derived base oil with a Fischer-Tropsch derived light base oil, wherein the method is carried out for the purpose of upgrading the mineral derived base oil, and involves preparing the mineral derived base oil using a lower degree of processing than would previously have been used in order to achieve one or more desired properties in the base oil or a formulation containing it.

9. A method according to claim 8, which involves the deliberate under-processing of the mineral derived base oil, and using the Fischer-Tropsch derived light base oil in order to compensate, at least partially, for the changes in properties of the mineral derived base oil which result from the lower degree of processing to which it is now subjected.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. C10M111/04  C10M169/04
ADD. C10N20/02  C10N30/02  C10N3Q/10  C10N30/06

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)

C1OM

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Category</th>
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<td>US 2004/094453 A1 (LOK BRENT K [US] ET AL) 20 May 2004 (2004-05-20) cited in the application paragraphs [0004], [0005], [0009], [0010], [0016], [0051] - [0059], [0061]; claims 1-35; examples 5-7</td>
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<td>X</td>
<td>WO 2006/136591 A (SHELL INT RESEARCH [NL]; NULL VOLKER KLAUS [DE]; HILKER ANDREE [DE]) 28 December 2006 (2006-12-28) page 9, lines 24-26; page 10, lines 11-14; page 21, lines 16-25; claims 1,13-15; examples 3(Table,4),4(Table,6); table 1</td>
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</table>

X Further documents are listed in the continuation of Box C.  
X See patent family annex.

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Date of the actual completion of the international search: 19 February 2009

Date of mailing of the international search report: 26/02/2009

Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk
Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016

Authorized officer
Renoth, Heinz
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<td>WO 2006/108839 A [SHELL INTERNATIONALE RES MIJ [NL]; ANSELL CLAIRE [GB]; CLARK RICHARD H]; 19 October 2006 (2006-10-19) page 2, line 15 - page 6, line 31; claims 1, 4, 8; example</td>
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