

1                                    **BLENDING OF LOW VISCOSITY**  
2                                    **FISCHER-TROPSCH BASE OILS WITH**  
3                                    **CONVENTIONAL BASE OILS TO PRODUCE**  
4                                    **HIGH QUALITY LUBRICATING BASE OILS**

5  
6                                    FIELD OF THE INVENTION

7  
8    The invention relates to the blending of a low viscosity Fischer-Tropsch  
9    derived base oil fraction with a higher viscosity conventional petroleum  
10   derived base oil fraction to produce a high quality lubricating base oil that is  
11   useful for preparing commercial finished lubricants such as crankcase engine  
12   oils.

13  
14                                   BACKGROUND OF THE INVENTION

15  
16   Finished lubricants used for automobiles, diesel engines, axles,  
17   transmissions, and industrial applications consist of two general components,  
18   a lubricating base oil and additives. Lubricating base oil is the major  
19   constituent in these finished lubricants and contributes significantly to the  
20   properties of the finished lubricant. In general, a few lubricating base oils are  
21   used to manufacture a wide variety of finished lubricants by varying the  
22   mixtures of individual lubricating base oils and individual additives.

23  
24   Numerous governing organizations, including original equipment  
25   manufacturers (OEM's), the American Petroleum Institute (API), Association  
26   des Consructeurs d' Automobiles (ACEA), the American Society of Testing  
27   and Materials (ASTM), and the Society of Automotive Engineers (SAE),  
28   among others, define the specifications for lubricating base oils and finished  
29   lubricants. Increasingly, the specifications for finished lubricants are calling for  
30   products with excellent low temperature properties, high oxidation stability,  
31   and low volatility. Currently, only a small fraction of the base oils  
32   manufactured today are able to meet these demanding specifications.

1 Syncrude prepared from the Fischer-Tropsch process comprise a mixture of  
2 various solid, liquid, and gaseous hydrocarbons. Those Fischer-Tropsch  
3 products which boil within the range of lubricating base oil contain a high  
4 proportion of wax which makes them ideal candidates for processing into  
5 lubricating base oil stocks. Accordingly, the hydrocarbon products recovered  
6 from the Fischer-Tropsch process have been proposed as feedstocks for  
7 preparing high quality lubricating base oils. When the Fischer-Tropsch waxes  
8 are converted into Fischer-Tropsch base oils by various processes, such as  
9 by hydroprocessing and distillation, the base oils produced fall into different  
10 narrow-cut viscosity ranges. Typically, the kinematic viscosity of the various  
11 cuts will range between 2.1 cSt and 12 cSt at 100 degrees C. Since the  
12 kinematic viscosity of lubricating base oils typically will fall within the range of  
13 from 3 to 32 cSt at 100 degrees C, the base oils that fall below 3 cSt at  
14 100 degrees C have limited use and, consequently, have less market value.

15  
16 The Fischer-Tropsch process typically produces a syncrude mixture  
17 containing a wide range of products having varying molecular weights but with  
18 a relatively high proportion of the products characterized by a low molecular  
19 weight and viscosity. Therefore, usually only a relatively low proportion of the  
20 Fischer-Tropsch products will have viscosities above 3cSt at 100 degrees C  
21 which would be useful directly as lubricating base oils for the manufacture of  
22 commercial lubricants, such as engine oil. Currently, those Fischer-Tropsch  
23 derived base oils having kinematic viscosities below 3cSt at 100 degrees C  
24 have a limited market and are usually blended or cracked into lighter  
25 products, such as diesel and naphtha. However, diesel and naphtha have a  
26 lower market value than lubricating base oil. It would be desirable to be able  
27 to upgrade these low viscosity base oils into products suitable for use as a  
28 lubricating base oil.

29  
30 Conventional base oils prepared from petroleum derived feedstocks having a  
31 kinematic viscosity below 3 cSt at 100 degrees C have a low viscosity index  
32 (VI) and high volatility. Consequently, low viscosity conventional base oils are  
33 unsuitable for blending with higher viscosity conventional base oils because

1 the blend will fail to meet the VI and volatility specifications for a  
2 lubricating base oil. Surprisingly, it has been found that Fischer-Tropsch  
3 derived base oils having a kinematic viscosity above 2 and below 3 cSt at  
4 100 degrees C have exceptionally low volatilities due to their extremely high  
5 VI's. Even more surprising was that when the low viscosity Fischer-Tropsch  
6 derived distillate fraction was blended with certain higher viscosity petroleum  
7 derived lubricating base oils, a VI premium was observed, i.e., the VI of the  
8 blend was significantly higher than would have been expected from a mere  
9 averaging of the VI's for the two fractions. In addition, due to the inherent  
10 oxidation stability of the Fischer-Tropsch derived base oils, finished lubricants  
11 prepared from blends containing them will generally require lower amounts of  
12 antioxidant additives and will be less likely to form insoluble oxidation  
13 products which result in the presence of sludge and deposits. Also due to the  
14 excellent UV stability of the Fischer-Tropsch derived base oils, the finished  
15 lubricants usually will require the addition of less UV stabilizers than needed  
16 with conventionally derived lubricating base oils. Finally, the Fischer-Tropsch  
17 derived distillate fraction is characterized by very low total sulfur which makes  
18 them excellent candidates for upgrading conventional petroleum derived base  
19 oils which typically contain between 10 and 5000 ppm total sulfur. Since the  
20 highest total sulfur usually will be found in the heaviest fractions derived from  
21 conventional oils, the present process is especially useful for upgrading heavy  
22 conventionally derived petroleum fractions. Consequently, it is has been  
23 discovered that the low viscosity Fischer-Tropsch derived base oils may be  
24 advantageously employed as blending stock with higher viscosity  
25 conventional petroleum derived base oils to prepare premium lubricating base  
26 oils and finished lubricants.

27

28 While lubricating base oil blends containing Fischer-Tropsch derived base oils  
29 have been described in the prior art, the method used to prepare the  
30 lubricating base oils and the properties of the prior art blends differ from the  
31 present invention. See, for example, U.S. Patent Nos. 6,332,974; 6,096,940;  
32 4,812,246; and 4,906,350. Specifically, it has not been previously taught that  
33 Fischer-Tropsch fractions having a kinematic viscosity of less than 3 cSt at

100 degrees C can be blended with conventional petroleum derived base oils to prepare lubricating base oils suitable for blending finished lubricants meeting the specifications for SAE Grade 0W, 5W, 10W, and 15W multi-grade engine oils; SAE 70W, 75W, and 80W gear lubricants; and ISO Viscosity Grade 22, 32, and 46 industrial oils. With the present invention, this becomes possible.

When referring to conventional lubricating base oils, this disclosure is referring to conventional petroleum derived lubricating base oils produced using petroleum refining processes well documented in the literature and known to those skilled in the art.

As used in this disclosure the word "comprises" or "comprising" is intended as an open-ended transition meaning the inclusion of the named elements, but not necessarily excluding other unnamed elements. The phrase "consists essentially of" or "consisting essentially of" is intended to mean the exclusion of other elements of any essential significance to the composition. The phrase "consisting of" or "consists of" are intended as a transition meaning the exclusion of all but the recited elements with the exception of only minor traces of impurities.

### SUMMARY OF THE INVENTION

In a first aspect, there is provided a process for producing a lubricating base oil blends which comprises (a) recovering a Fischer-Tropsch derived distillate fraction characterized by a viscosity of about 2 cSt or greater but

less than 3 cSt at 100 degrees C; and (b) blending the Fischer-Tropsch derived distillate fraction with a petroleum derived base oil selected from the group consisting of a Group I base oil, a Group II base oil, a Group III base oil, and a mixture of two or more of any of the foregoing conventional base oils in the proper proportion to produce a lubricating base oil blend characterized as having a viscosity of about 3 or greater at 100 degrees C. Using the process, lubricating base oils have been prepared which meet the specifications for a

premium lubricating base oil. The disclosed method makes it possible to upgrade low viscosity Fischer-Tropsch derived base oils into more valuable premium lubricants which otherwise would be cracked into lower value transportation fuels.

In a second aspect, there is provided a lubricating base oil blend having a viscosity of about 3 cSt or greater at 100 degrees C comprising

- (a) from about 10 to about 80 weight percent based upon the total blend of a Fischer-Tropsch derived distillate fraction characterized by a viscosity of about 2 cSt or greater but less than 3 cSt at 100 degrees C; and
- (b) from about 20 to about 90 weight percent based upon the total blend of a petroleum derived base oil selected from the group consisting of a Group I base oil, a Group II base oil, a Group III base oil, and a mixture of two or more of any of the foregoing conventional base oils.

The Fisher-Tropsch derived distillate fraction may typically comprise from about 10 weight percent to about 80 weight percent of the total lubricating base oil blend. The petroleum derived base oil may comprise from about 20 weight percent to about 90 weight percent of the total blend. The lubricating base oil blends may have a kinematic viscosity of about 3 cSt or greater. Typically, the lubricating base oil blends prepared according to the method above may have a TGA Noack volatility of greater than about 12 and more generally will have a TGA Noack volatility in excess of about 20. However when the lubricating base oil contains a high ratio of heavy neutral base oil or bright stock, the Noack volatility may be lower than 12 depending upon the amount of the heavy material present. The blends also typically will display a VI of at least 90, preferably of at least 100. The lubricating base oils may have good low temperature properties. For example, pour points of less than about -12 degrees C are typical. However, one skilled in the art will recognize that the properties of the lubricating base oil blend will depend upon factors such as the ratio of the Fischer-Tropsch derived distillate fraction to the petroleum derived base oil present in the total blend and the properties of the petroleum derived base oil.

The lubricating base oils may be used to prepare a finished lubricant, such as, for example, a commercial multi-grade crankcase lubricating oil meeting SAE J300, June 2001 specifications, by the addition of the proper additives. Disclosed is a process for preparing a finished lubricant which may comprise adding at least one additive to a lubricating base oil blend which is comprised of from about 10 to about 80 weight percent of a Fischer-Tropsch derived distillate fraction characterized by a viscosity of about 2 cSt or greater but less than 3 cSt at 100 degrees C and from about 20 to about 90 weight percent of a petroleum

derived base oil selected from the group consisting of a Group I base oil, a Group II base oil, and a mixture of Group I and Group II base oils.

Typical additives added to a lubricating base oil when preparing a finished lubricant include anti-wear additives, detergents, dispersants, antioxidants, pour point depressants, VI improvers, friction modifiers, demulsifiers, antifoaming agents, corrosion inhibitors, seal swell agents, and the like. In addition, commercial products meeting SAE standards for gear lubricants and ISO Viscosity Grade standards for industrial oils may be prepared from the lubricating base oils of the invention. Multi-grade crankcase engine oils meeting the SAE J300, June 2001 specifications for a 10W and 15W grade engine oil may be formulated from the lubricating base oils of the invention. More specifically, multi-grade crankcase engine oils meeting the SAE J300, June 2001 specifications for 10W-40, 15W-30, and 15W-40 grade engine oils have been formulated from the lubricating base oils.

Multi-grade crankcase engine oils prepared from the lubricating base oils may be highly stable and usually may display Oxidator B values of greater than 15 hours. Multi-grade crankcase oil prepared from lubricating base oils may be formulated to meet the SAE J300 specification for cold cranking viscosity (CCS) and the maximum gelation index specified by the API SJ and the ILSAC GF-3 Service Categories for Engine Oils.

Disclosed is a method for operating an internal combustion engine having a valve train, the internal combustion engine using a normally liquid or gaseous fuel, wherein the method comprises lubricating the internal combustion engine, including the valve train.

In a third aspect, there is provided a finished lubricant comprising (a) a lubricating base oil blend which is comprised of from about 10 to about 80 weight percent of a Fischer-Tropsch derived distillate fraction characterized by a viscosity of about 2 cSt or greater but less than 3 cSt at 100 degrees C and from about 20 to about 90 weight percent of a petroleum derived base oil selected from the group consisting of a Group I

1 base oil, a Group II base oil, and a mixture of Group I and Group II base oils,  
2 and (b) at least one additive.

3

4

#### DETAILED DESCRIPTION OF THE INVENTION

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6 Fischer-Tropsch wax processing typically produces a relatively high  
7 proportion of products of low molecular weight and low viscosity that are  
8 processed into light products such as naphtha, gasoline, diesel, fuel oil, or  
9 kerosene. A relatively small proportion of products have viscosities above  
10 3.0 cSt which are useful directly as lubricating base oils for many different  
11 products, including engine oils. Those base oils with viscosities below 3 cSt  
12 typically are blended or further processed into lighter products (e.g., gasoline  
13 or diesel) in order to be of much economic value. Alternatively, these low  
14 viscosity Fischer-Tropsch derived base oils may be used in light industrial oils,  
15 such as, for example, utility oils, spindle oils, pump oils, or hydraulic oils,  
16 spray oils, process oils, or diluent oils; all of which are in much lower demand  
17 than engine oils.

18

19 Lubricating base oils for use in engine oils are in higher demand than the light  
20 products. The ability to use a higher proportion of the products from  
21 Fischer-Tropsch processes in lubricating base oil blends for engine oils is  
22 highly desirable. By virtue of the present invention, Fischer-Tropsch derived  
23 lubricating base oils characterized by low viscosity are blended with medium  
24 or high viscosity conventional petroleum derived distillate fractions to produce  
25 compositions which are useful as lubricating base oils for preparing engine oil.  
26 Due to the relatively low volatility of the Fischer-Tropsch derived base oils as  
27 compared to conventionally derived base oils of similar viscosity, the volatility  
28 and viscosity of the blend is comparable to Group I and Group II Neutral oils  
29 prepared entirely from petroleum derived feedstocks. In addition, since the  
30 Fischer-Tropsch derived base oils have low total sulfur and good oxidation  
31 stability as compared to conventional base oils, the lubricating base oils of the  
32 present invention also have improved properties when compared to  
33 conventional lubricating base oils.

1 As noted above, lubricating base oils and commercial finished lubricants  
2 prepared from the lubricating base oils are required to meet certain minimum  
3 specifications established by various governing organizations. Petroleum  
4 derived base oils having a kinematic viscosity of less than 3 cSt are  
5 considered unsuitable for preparing engine lubricating base oils because  
6 blends containing them are generally unable to meet these engine oil  
7 specifications. Therefore, it is unexpected that Fischer-Tropsch derived  
8 fractions having a kinematic viscosity of about 2 cSt or greater but less than  
9 3 cSt at 100 degrees C may be used to prepare lubricating base oils meeting  
10 these requirements.

11

12 Lubricating base oils of the invention may be used to formulate either  
13 mono-grade or multi-grade crankcase engine oils. A mono-grade crankcase  
14 engine oil refers to an engine oil that has a viscosity which falls within the  
15 limits specified for a single SAE number in SAE J300. A mono-grade  
16 crankcase engine oil has no low temperature requirements. A multi-grade  
17 crankcase engine oil refers to an engine oil that has viscosity/temperature  
18 characteristics which fall within the limits of two different SAE numbers in  
19 SAE J300.

20

21 Cold-cranking simulator (CCS) apparent viscosity of automotive engine oils  
22 correlates with low temperature cranking. It is measured by ASTM D5293 at a  
23 set temperature between -5 and -30 degrees C. Engine oil specifications, e.g.,  
24 SAE J300, include maximum limits for CCS Viscosity for multi-grade engine  
25 oils.

26

27 The Gelation Index which is measured by ASTM D 5133 is a number  
28 indicating the oil's tendency to form a gelated structure in the oil at colder  
29 temperatures. Numbers above 6 indicate some gelation-forming tendencies.  
30 Numbers above 12 are of concern to engine makers. This is the maximum  
31 value for API SJ and ILSAC GF-3 Service Categories for Engine Oils.

32

High temperature high shear rate viscosity (HTHS) is a measure of a fluid's resistance to flow under conditions resembling highly-loaded journal bearings in fired internal combustion engines, typically  $1 \text{ million s}^{-1}$  at  $150^{\circ}\text{C}$ . HTHS is a better indication of how an engine operates at high temperature with a given lubricant than the kinematic low shear rate viscosities at  $100^{\circ}\text{C}$ . The HTHS value directly correlates to the oil film thickness in a bearing. SAE J300 June '01 contains the current specifications for HTHS measured by either ASTM D 4683, ASTM D 4741, or ASTM D 5481.

The specifications for 10W grade premium engine oils are shown in Table 1 below.

Table 1

| SAE J300 / API SJ                        | SAE 10W-30       | SAE 10W-40       |
|------------------------------------------|------------------|------------------|
| Viscosity at $100^{\circ}\text{C}$ , cSt | 4.1-12.5         | 4.1-16.3         |
| CCS, cP                                  | 7000 max @ $-25$ | 7000 max @ $-25$ |
| HTHS                                     | 2.9 min          | 2.9 min          |
| Scanning Brookfield Gelation Index       | 12 max           | 12 max           |

The specifications for 15W grade premium engine oils are shown in Table 2 below.

Table 2

| SAE J300 / API SJ                        | SAE 15W-30       | SAE 15W-40       |
|------------------------------------------|------------------|------------------|
| Viscosity at $100^{\circ}\text{C}$ , cSt | 5.6-12.5         | 5.6-16.3         |
| CCS, cP                                  | 7000 max @ $-20$ | 7000 max @ $-20$ |
| HTHS                                     | 2.9 min          | 3.7 min          |
| Scanning Brookfield Gelation Index       | 12 max           | 12 max           |

Multi-grade engine oils meeting the specifications for both 10W and 15W premium grade engine oils as shown in Tables 1 and 2 have been formulated with the lubricating base oils of the present invention.

Noack volatility is defined as the mass of oil, expressed in weight percent, which is lost when the oil is heated at  $250^{\circ}\text{C}$  and 20 mmHg (2.67 kPa; 26.7 mbar) below atmospheric in a test crucible through which a

1 constant flow of air is drawn for 60 minutes (ASTM D-5800). A more  
2 convenient method for calculating Noack volatility and one which correlates  
3 well with ASTM D-5800 is by using a thermo gravimetric analyzer test (TGA)  
4 by ASTM D-6375. TGA Noack volatility is used throughout this disclosure  
5 unless otherwise stated. Noack volatility of engine oil, as measured by TGA  
6 Noack and similar methods, has been found to correlate with oil consumption  
7 in passenger car engines. Strict requirements for low volatility are important  
8 aspects of several recent engine oil specifications, such as, for example,  
9 ACEA A-3 and B-3 in Europe and ILSAC GF-3 in North America. Due to the  
10 high volatility of conventional low viscosity oils with kinematic viscosities  
11 below 3 cSt at 100 degrees C, they have limited their use in passenger car  
12 engine oils. Any new lubricating base oil stocks developed for use in  
13 automotive engine oils should have a volatility no greater than current  
14 conventional Group I or Group II Light Neutral oils. Lubricating base oils  
15 prepared according to the present invention generally will have a volatility  
16 within these ranges.

17

### 18 **Fischer-Tropsch Synthesis**

19

20 During Fischer-Tropsch synthesis liquid and gaseous hydrocarbons are  
21 formed by contacting a synthesis gas (syngas) comprising a mixture of  
22 hydrogen and carbon monoxide with a Fischer-Tropsch catalyst under  
23 suitable temperature and pressure reactive conditions. The Fischer-Tropsch  
24 reaction is typically conducted at temperatures of from about 300 degrees to  
25 about 700 degrees F (about 150 degrees to about 370 degrees C) preferably  
26 from about 400 degrees to about 550 degrees F (about 205 degrees to about  
27 230 degrees C); pressures of from about 10 to about 600 psia,  
28 (0.7 to 41 bars) preferably 30 to 300 psia, (2 to 21 bars) and catalyst space  
29 velocities of from about 100 to about 10,000 cc/g/hr., preferably  
30 300 to 3,000 cc/g/hr.

31

32 The products from the Fischer-Tropsch synthesis may range from C<sub>1</sub> to C<sub>200</sub>  
33 plus hydrocarbons with a majority in the C<sub>5</sub>-C<sub>100</sub> plus range. The reaction can

1 be conducted in a variety of reactor types, such as, for example, fixed bed  
2 reactors containing one or more catalyst beds, slurry reactors, fluidized bed  
3 reactors, or a combination of different types of reactors. Such reaction  
4 processes and reactors are well known and documented in the literature. The  
5 slurry Fischer-Tropsch process, which is preferred in the practice of the  
6 invention, utilizes superior heat (and mass) transfer characteristics for the  
7 strongly exothermic synthesis reaction and is able to produce relatively high  
8 molecular weight, paraffinic hydrocarbons when using a cobalt catalyst or  
9 cobalt in combination with other metals. In the slurry process, a syngas  
10 comprising a mixture of hydrogen and carbon monoxide is bubbled up as a  
11 third phase through a slurry which comprises a particulate Fischer-Tropsch  
12 type hydrocarbon synthesis catalyst dispersed and suspended in a slurry  
13 liquid comprising hydrocarbon products of the synthesis reaction which are  
14 liquid under the reaction conditions. The mole ratio of the hydrogen to the  
15 carbon monoxide may broadly range from about 0.5 to about 4, but is more  
16 typically within the range of from about 0.7 to about 2.75 and preferably from  
17 about 0.7 to about 2.5. A particularly preferred Fischer-Tropsch process is  
18 taught in European Patent Application No. 0609079, also completely  
19 incorporated herein by reference for all purposes.

20

21 Suitable Fischer-Tropsch catalysts comprise one or more Group VIII catalytic  
22 metals such as Fe, Ni, Co, Ru and Re, with cobalt being preferred.  
23 Additionally, a suitable catalyst may contain a promoter. Thus, a preferred  
24 Fischer-Tropsch catalyst comprises effective amounts of cobalt and one or  
25 more of Re, Ru, Pt, Fe, Ni, Th, Zr, Hf, U, Mg and La on a suitable inorganic  
26 support material, preferably one which comprises one or more refractory  
27 metal oxides. In general, the amount of cobalt present in the catalyst is  
28 between about 1 and about 50 weight percent of the total catalyst  
29 composition. The catalysts can also contain basic oxide promoters such as  
30 ThO<sub>2</sub>, La<sub>2</sub>O<sub>3</sub>, MgO, and TiO<sub>2</sub>, promoters such as ZrO<sub>2</sub>, noble metals (Pt, Pd,  
31 Ru, Rh, Os, Ir), coinage metals (Cu, Ag, Au), and other transition metals such  
32 as Fe, Mn, Ni, and Re. Suitable support materials include alumina, silica,  
33 magnesia and titania or mixtures thereof. Preferred supports for cobalt

1 containing catalysts comprise titania. Useful catalysts and their preparation  
2 are known and illustrated in U.S. Patent No. 4,568,663, which is intended to  
3 be illustrative but non-limiting relative to catalyst selection.

4  
5 The Fischer-Tropsch derived products generally contain a high proportion of  
6 wax. Therefore, prior to blending the Fischer-Tropsch distillate fraction with  
7 the petroleum derived base oil, it is usually desirable to first isomerizes the  
8 wax in order to improve its flow properties. Other processing steps used in  
9 preparing the Fischer-Tropsch distillate fraction may include solvent  
10 dewaxing, atmospheric and vacuum distillation, hydrocracking, hydrotreating,  
11 hydrofinishing, and other forms of hydroprocessing.

#### 12 13 Hydroisomerization and Solvent Dewaxing

14  
15 Hydroisomerization, or for the purposes of this disclosure simply  
16 "isomerization", is intended to improve the cold flow properties of the product  
17 by the selective addition of branching into the molecular structure.  
18 Isomerization ideally will achieve high conversion levels of the wax to  
19 non-waxy iso-paraffins while at the same time minimizing the conversion by  
20 cracking. Since wax conversion can be complete, or at least very high, this  
21 process typically does not need to be combined with additional dewaxing  
22 processes to produce a lubricating oil base stock with an acceptable pour  
23 point. Isomerization operations suitable for use with the present invention  
24 typically uses a catalyst comprising an acidic component and may optionally  
25 contain an active metal component having hydrogenation activity. The acidic  
26 component of the catalysts preferably includes an intermediate pore SAPO,  
27 such as SAPO-11, SAPO-31, and SAPO-41, with SAPO-11 being particularly  
28 preferred. Intermediate pore zeolites, such as ZSM-22, ZSM-23, SSZ-32,  
29 ZSM-35, and ZSM-48, also may be used in carrying out the isomerization.  
30 Typical active metals include molybdenum, nickel, vanadium, cobalt,  
31 tungsten, zinc, platinum, and palladium. The metals platinum and palladium  
32 are especially preferred as the active metals, with platinum most commonly  
33 used.

1 The phrase "intermediate pore size", when used herein, refers to an effective  
2 pore aperture in the range of from about 4.8 to about 7.1 Angstrom when the  
3 porous inorganic oxide is in the calcined form. Molecular sieves having pore  
4 apertures in this range tend to have unique molecular sieving characteristics.  
5 Unlike small pore zeolites such as erionite and chabazite, they will allow  
6 hydrocarbons having some branching into the molecular sieve void spaces.  
7 Unlike larger pore zeolites such as faujasites and mordenites, they are able to  
8 differentiate between n-alkanes and slightly branched alkenes, and larger  
9 alkanes having, for example, quaternary carbon atoms. See U.S. Patent  
10 No. 5,413,695. The term "SAPO" refers to a silicoaluminophosphate  
11 molecular sieve such as described in U.S. Patent Nos. 4,440,871 and  
12 5,208,005.

13

14 In preparing those catalysts containing a non-zeolitic molecular sieve and  
15 having an hydrogenation component, it is usually preferred that the metal be  
16 deposited on the catalyst using a non-aqueous method. Non-zeolitic  
17 molecular sieves include tetrahedrally-coordinated  $[AlO_2]$  and  $[PO_2]$  oxide  
18 units which may optionally include silica. See U.S. Patent No. 5,514,362.  
19 Catalysts containing non-zeolitic molecular sieves, particularly catalysts  
20 containing SAPO's, on which the metal has been deposited using a  
21 non-aqueous method have shown greater selectivity and activity than those  
22 catalysts which have used an aqueous method to deposit the active metal.  
23 The non-aqueous deposition of active metals on non-zeolitic molecular sieves  
24 is taught in U.S. Patent No. 5,939,349. In general, the process involves  
25 dissolving a compound of the active metal in a non-aqueous, non-reactive  
26 solvent and depositing it on the molecular sieve by ion exchange or  
27 impregnation.

28

29 Solvent dewaxing attempts to remove the waxy molecules from the product by  
30 dissolving them in a solvent, such as methyl ethyl ketone, methyl iso-butyl  
31 ketone, or toluene, or precipitating the wax molecules as discussed in  
32 Chemical Technology of Petroleum, 3rd Edition, William Gruse and  
33 Donald Stevens, McGraw-Hill Book Company, Inc., New York, 1960,

1 pages 566-570. See also U.S. Patent Nos. 4,477,333; 3,773,650; and  
2 3,775,288. In general, with the present invention isomerization is usually  
3 preferred over solvent dewaxing, since it results in higher yields of the  
4 products. However solvent dewaxing may be advantageously used in  
5 combination with isomerization to recover unconverted wax following  
6 isomerization.

#### 7 8 **Hydrotreating, Hydrocracking, and Hydrofinishing**

9  
10 Hydrotreating refers to a catalytic process, usually carried out in the presence  
11 of free hydrogen, in which the primary purpose is the removal of various metal  
12 contaminants, such as arsenic; heteroatoms, such as sulfur and nitrogen; or  
13 aromatics from the feed stock. Generally, in hydrotreating operations cracking  
14 of the hydrocarbon molecules, i.e., breaking the larger hydrocarbon molecules  
15 into smaller hydrocarbon molecules is minimized, and the unsaturated  
16 hydrocarbons are either fully or partially hydrogenated. Hydrocracking refers  
17 to a catalytic process, usually carried out in the presence of free hydrogen, in  
18 which the cracking of the larger hydrocarbon molecules is the primary  
19 purpose of the operation. During hydrocracking hydrogen is added to the  
20 molecules and the boiling range of the feed is reduced. Desulfurization and/or  
21 denitrification of the feedstock also usually will occur.

22  
23 Catalysts used in carrying out hydrotreating and hydrocracking operations are  
24 well known in the art. See for example U.S. Patent Nos. 4,347,121 and  
25 4,810,357, the contents of which are hereby incorporated by reference in their  
26 entirety, for general descriptions of hydrotreating, hydrocracking, and of  
27 typical catalysts used in each of the processes. Suitable catalysts include  
28 noble metals from Group VIIIA (according to the 1975 rules of the  
29 International Union of Pure and Applied Chemistry), such as platinum or  
30 palladium on an alumina or siliceous matrix, and unsulfided Group VIIIA and  
31 Group VIB, such as nickel-molybdenum or nickel-tin on an alumina or  
32 siliceous matrix. U.S. Patent No. 3,852,207 describes a suitable noble metal  
33 catalyst and mild conditions. Other suitable catalysts are described, for

1 example, in U.S. Patent Nos. 4,157,294 and 3,904,513. The non-noble  
2 hydrogenation metals, such as nickel-molybdenum, are usually present in the  
3 final catalyst composition as oxides, or more preferably or possibly, as  
4 sulfides when such compounds are readily formed from the particular metal  
5 involved. Preferred non-noble metal catalyst compositions contain in excess  
6 of about 5 weight percent, preferably about 5 to about 40 weight percent  
7 molybdenum and/or tungsten, and at least about 0.5, and generally about  
8 1 to about 15 weight percent of nickel and/or cobalt determined as the  
9 corresponding oxides. Catalysts containing noble metals, such as platinum,  
10 contain in excess of 0.01 percent metal, preferably between 0.1 and  
11 1.0 percent metal. Combinations of noble metals may also be used, such as  
12 mixtures of platinum and palladium.

13  
14 The hydrogenation components can be incorporated into the overall catalyst  
15 composition by any one of numerous procedures. The hydrogenation  
16 components can be added to matrix component by co-mulling, impregnation,  
17 or ion exchange and the Group VI components, i.e.; molybdenum and  
18 tungsten can be combined with the refractory oxide by impregnation,  
19 co-mulling or co-precipitation. During actual operation, these components can  
20 be employed as their sulfides, oxides, or in their reduced form.

21  
22 The matrix component can be of many types including some that have acidic  
23 catalytic activity. Ones that have acidity include amorphous silica-alumina or  
24 may be a zeolitic or non-zeolitic crystalline molecular sieve. Examples of  
25 suitable matrix molecular sieves include zeolite Y, zeolite X and the so called  
26 ultra stable zeolite Y and high structural silica:alumina ratio zeolite Y such as  
27 that described in U.S. Patent Nos. 4,401,556; 4,820,402; and 5,059,567.  
28 Small crystal size zeolite Y, such as that described in U.S. Patent  
29 No. 5,073,530 can also be used. Non-zeolitic molecular sieves which can be  
30 used include, for example, silicoaluminophosphates (SAPO),  
31 ferroaluminophosphate, titanium aluminophosphate and the various ELAPO  
32 molecular sieves described in U.S. Patent No. 4,913,799 and the references  
33 cited therein. Details regarding the preparation of various non-zeolite

1 molecular sieves can be found in U.S. Patent Nos. 5,114,563 (SAPO) and  
2 4,913,799 and the various references cited in U.S. Patent No. 4,913,799.  
3 Mesoporous molecular sieves can also be used, for example the M41S family  
4 of materials as described in J. Am. Chem. Soc., 114:10834-10843(1992)),  
5 MCM-41; U.S. Patent Nos. 5,246,689; 5,198,203; and 5,334,368; and  
6 MCM-48 (Kresge et al., Nature 359:710 (1992)). Suitable matrix materials  
7 may also include synthetic or natural substances as well as inorganic  
8 materials such as clay, silica and/or metal oxides such as silica-alumina,  
9 silica-magnesia, silica-zirconia, silica-thoria, silica-beryllia, silica-titania as well  
10 as ternary compositions, such as silica-alumina-thoria, silica-alumina-zirconia,  
11 silica-alumina-magnesia, and silica-magnesia zirconia. The latter may be  
12 either naturally occurring or derived from gelatinous precipitates or gels  
13 including mixtures of silica and metal oxides. Naturally occurring clays which  
14 can be composited with the catalyst include those of the montmorillonite and  
15 kaolin families. These clays can be used in the raw state as originally mined  
16 or initially subjected to dealumination, acid treatment or chemical modification.

17

18 In performing the hydrocracking and/or hydrotreating operation, more than  
19 one catalyst type may be used in the reactor. The different catalyst types can  
20 be separated into layers or mixed.

21

22 Hydrocracking conditions have been well documented in the literature. In  
23 general, the overall LHSV is about  $0.1 \text{ hr}^{-1}$  to about  $15.0 \text{ hr}^{-1}$  (v/v), preferably  
24 from about  $0.25 \text{ hr}^{-1}$  to about  $2.5 \text{ hr}^{-1}$ . The reaction pressure generally ranges  
25 from about 500 psig to about 3500 psig (about 3.5 MPa to about 24.1 MPa),  
26 preferably from about 1000 psig to about 2500 psig (about 6.9 MPa to  
27 about 17.2 MPa). Hydrogen consumption is typically from about 500 to about  
28 2500 SCF per barrel of feed ( $89.1$  to  $445 \text{ m}^3 \text{ H}_2/\text{m}^3$  feed). Temperatures in the  
29 reactor will range from about 400 degrees F to about 950 degrees F (about  
30 204 degrees C to about 510 degrees C), preferably ranging from about  
31 650 degrees F to about 850 degrees F (about 343 degrees C to about  
32 454 degrees C).

33

1 Typical hydrotreating conditions vary over a wide range. In general, the  
2 overall LHSV is about 0.25 to 3.0, preferably about 0.5 to 2.0. The hydrogen  
3 partial pressure is greater than 200 psia, preferably ranging from about  
4 300 psia to about 2000 psia. Hydrogen recirculation rates are typically greater  
5 than 50 SCF/Bbl, and are preferably between 500 and 5000 SCF/Bbl.  
6 Temperatures in the reactor will range from about 300 degrees F to about  
7 750 degrees F (about 150 degrees C to about 400 degrees C), preferably  
8 ranging from 450 degrees F to 600 degrees F (230 degrees C to about  
9 315 degrees C).

10

11 Hydrotreating may also be used as a final step in the lube base oil  
12 manufacturing process. This final step, commonly called hydrofinishing, is  
13 intended to improve the UV stability and appearance of the product by  
14 removing traces of aromatics, olefins, color bodies, and solvents. As used in  
15 this disclosure, the term UV stability refers to the stability of the lubricating  
16 base oil or the finished lubricant when exposed to UV light and oxygen.  
17 Instability is indicated when a visible precipitate forms, usually seen as floc or  
18 cloudiness, or a darker color develops upon exposure to ultraviolet light and  
19 air. A general description of hydrofinishing may be found in U.S. Patent  
20 Nos. 3,852,207 and 4,673,487. Clay treating to remove these impurities is an  
21 alternative final process step.

22

### 23 **Distillation**

24

25 The separation of the Fischer-Tropsch derived products into various fractions  
26 is generally accomplished by either atmospheric or vacuum distillation or by a  
27 combination of atmospheric and vacuum distillation. Atmospheric distillation is  
28 typically used to separate the lighter distillate fractions, such as naphtha and  
29 middle distillates, from a bottoms fraction having an initial boiling point above  
30 about 700 degrees F to about 750 degrees F (about 370 degrees C to about  
31 400 degrees C). At higher temperatures thermal cracking of the hydrocarbons  
32 may take place leading to fouling of the equipment and to lower yields of the

1 heavier cuts. Vacuum distillation is typically used to separate the higher  
2 boiling material, such as the lubricating base oil fractions.

3  
4 As used in this disclosure, the term "distillate fraction" or "distillate" refers to a  
5 side stream product recovered either from an atmospheric fractionation  
6 column or from a vacuum column as opposed to the "bottoms" which  
7 represents the residual higher boiling fraction recovered from the bottom of  
8 the column.

### 9 10 **The Fischer-Tropsch Distillate Fraction**

11  
12 The Fischer-Tropsch distillate fraction used to prepare the lubricating base oil  
13 product of the invention represents that portion of the Fischer-Tropsch derived  
14 product having a viscosity of about 2 or greater but less than 3 cSt at  
15 100 degrees C, more preferably between about 2.1 and 2.8 cSt at  
16 100 degrees C, and most preferably between about 2.2 and 2.7 cSt at  
17 100 degrees C. As already noted, despite the low kinematic viscosity of the  
18 Fischer-Tropsch derived distillate fraction, the Noack volatility is very low  
19 compared to that for a petroleum derived conventional Group I and Group II  
20 base oil of equivalent viscosity.

21  
22 The Fischer-Tropsch distillate fraction used in the invention typically are  
23 prepared using the various processing steps discussed in detail above,  
24 i.e., Fischer-Tropsch synthesis, hydrotreating, hydrocracking, catalytic  
25 hydroisomerization dewaxing, hydrofinishing, atmospheric distillation, and  
26 vacuum distillation.

### 27 28 **The Petroleum Derived Base Oil**

29  
30 The petroleum derived base oil blended with the Fischer-Tropsch derived  
31 distillate fraction used to prepare the lubricating base oil of the invention will  
32 comprise a Group I, Group II, or a Group III base oil or a blend containing a  
33 mixture of two or more the foregoing conventional base oils. As used herein a

1 Group I base oil refers to a petroleum derived lubricating base oil having a  
2 total sulfur content of greater than 300 ppm, less than 90 weight percent  
3 saturates, and a viscosity index (VI) of between 80 and 120. Group II base oil  
4 refers to a petroleum derived lubricating base oil having a total sulfur content  
5 equal to or less than 300 ppm, saturates which are equal to or more than  
6 90 weight percent, and a VI of between 80 and 120. The Group III base oils  
7 have less than 300 ppm sulfur, saturates greater than 90 weight percent, and  
8 VI's of 120 or greater. The Group I or Group II base oil comprise light  
9 overhead cuts and heavier side cuts from a vacuum distillation column and  
10 include, for example, Light Neutral, Medium Neutral, and Heavy Neutral base  
11 stocks. The petroleum derived base oil also may include residual stocks or  
12 bottoms fractions, such as, for example, bright stock. Bright stock is a high  
13 viscosity base oil which has been conventionally produced from residual  
14 stocks or bottoms and has been highly refined and dewaxed. It is named for  
15 the SUS viscosity at 210°F. Bright stock has a kinematic viscosity above 180  
16 cSt at 40°C, more preferably above 250 cSt at 40°C, and still more preferably  
17 ranging from about 500 to 1100 cSt at 40°C. Blending heavy neutral or bright  
18 stock with the Fischer-Tropsch derived distillate fraction is a preferred  
19 embodiment of the invention, since the resulting lubricating base oil will have  
20 especially low volatility, good cold flow properties, and improved oxidation  
21 stability as compared to many conventional base oils.

22

23 With the exception of Fischer-Tropsch synthesis all of the various processing  
24 steps discussed in detail above also may be employed to prepare the desired  
25 petroleum derived base oil used in the invention.

26

### 27 **Lubricating Base Oil**

28

29 Lubricating base oils are base oils having a viscosity greater than 3 cSt at  
30 100 degrees C; a pour point below 20 degrees C, preferably below  
31 -12 degrees C; and a VI that is usually greater than 90, preferably greater  
32 than 100. As explained below and illustrated in the examples, the lubricating  
33 base oils prepared according to the process of the present invention meet

1 these criteria. In addition, the lubricating base oils of the invention display a  
2 unique combination of properties which could not have been predicted from a  
3 review of the prior art relating to both conventional and Fischer-Tropsch  
4 materials. The invention takes advantage of the high VI of the  
5 Fischer-Tropsch distillate fraction which when blended with the petroleum  
6 derived base oil will result in a final blend having a viscosity which is within  
7 acceptable limits for a lubricating base oil.

8  
9 In preparing the lubricating base oil of the invention, the Fischer-Tropsch  
10 derived distillate fraction and the petroleum derived base oils are usually  
11 blended together to achieve a target viscosity. Depending upon the viscosities  
12 of the different components, the proportions of the various fractions in the  
13 blend will need to be adjusted accordingly. One skilled in the art will recognize  
14 that any number of different petroleum derived fractions may be blended into  
15 the lubricating base oil so long as the kinematic viscosity remains within the  
16 target viscosity range selected for the final blend.

17  
18 Pour point is the temperature at which a sample of the lubricating base oil will  
19 begin to flow under carefully controlled conditions. In this disclosure, where  
20 pour point is given, unless stated otherwise, it has been determined by  
21 standard analytical method ASTM D-5950. Lubricating base oils prepared  
22 according to the present invention have excellent pour points which are  
23 comparable or even below the pour points observed for conventionally  
24 derived lubricating base oils.

25  
26 Due to the extremely low aromatics and multi-ring naphthene levels of blends  
27 of Fischer-Tropsch derived distillate fraction, the lubricating base oils of the  
28 invention will have an oxidation stability which will generally exceed that of  
29 conventional lubricating base oil blends. A convenient way to measure the  
30 stability of lube base oils is by the use of the Oxidator Test, as described by  
31 Stangeland et al. in U.S. Patent 3,852,207. There are two forms of this test:  
32 Oxidator BN and Oxidator B. The Oxidator BN test measures the resistance to  
33 oxidation by means of a Dornite-type oxygen absorption apparatus. See

1 R.W. Dornte "Oxidation of White Oils," Industrial and Engineering Chemistry,  
2 Vol. 28, page 26, 1936. Normally, the conditions are one atmosphere of pure  
3 oxygen at 340 degrees F. The results are reported in hours to absorb 1000 ml  
4 of O<sub>2</sub> by 100 g. of oil. In the Oxidator BN test, 0.8 ml of catalyst is used per  
5 100 grams of oil and an additive package is included in the oil. The catalyst is  
6 a mixture of soluble metal-naphthenates simulating the average metal  
7 analysis of used crankcase oil. The additive package is 80 millimoles of zinc  
8 bispolypropylenephenyldithiophosphate per 100 grams of oil. The  
9 Oxidator BN measures the response of a base oil or finished lubricant in a  
10 simulated application. High values, or long times to adsorb one liter of oxygen,  
11 indicate good stability. Generally, the Oxidator BN should be above about  
12 7 hours. For the present invention, the Oxidator BN value will be greater than  
13 about 15 hours, preferably greater than about 25 hours, and most preferably  
14 greater than about 30 hours. The Oxidator B test is conducted in the same  
15 fashion, except the additive package is omitted.

16

17 In general, lubricating base oils of the invention will have a Noack volatility of  
18 between about 12 weight percent and about 45 weight percent unless the  
19 blend contains an especially high proportion of heavy conventional petroleum  
20 derived base oil, such as heavy neutral or bright stock. In this instance the  
21 volatility may be less than 12 weight percent.

22

23 In the present invention, the Fisher-Tropsch derived distillate fraction will  
24 comprise from about 10 weight percent to about 80 weight percent of the total  
25 lubricating base oil blend. The petroleum derived base oil will comprise from  
26 about 20 weight percent to about 90 weight percent of the total blend. When a  
27 heavy petroleum derived base oil, such as heavy neutral oil or bright stock, is  
28 used in preparing the blend, less conventional base oil generally is required to  
29 achieve the desired properties of the lubricating base oil blend than if a lighter  
30 material is incorporated into the blend. With lighter weight petroleum derived  
31 base oil, such as Medium Neutral base oil, the petroleum derived base oil will  
32 typically comprise from about 40 weight percent to about 90 weight percent of  
33 the final blend. In this instance, the Fischer-Tropsch derived distillate fraction

1 will comprise from about 10 weight percent to about 60 weight percent of the  
2 final blend.

3  
4 Preferably, the boiling range distribution of the lubricating base oils of the  
5 invention will be significantly broader than those observed for lubricating base  
6 oils comprising only conventional petroleum derived base oils. The boiling  
7 range distribution for conventionally derived lubricating base oils typically will  
8 not exceed about 250 degrees F (about 139 degrees C). The boiling range  
9 distribution of the lubricating base oil blend of the invention will vary with the  
10 weight of the petroleum derived base oil and the ratio of the petroleum derived  
11 base oil to the Fischer-Tropsch derived distillate fraction. For example, when  
12 the petroleum derived base oil is a medium neutral base oil, the ratio of the  
13 Fischer-Tropsch derived distillate fraction to the medium neutral base oil will  
14 be such that the boiling range distribution preferably will be greater than  
15 250 degrees F. When the petroleum derived base oil is a heavy neutral base  
16 oil, the ratio of the Fischer-Tropsch derived distillate fraction to the heavy  
17 neutral base oil preferably will be such that the boiling range distribution will  
18 be greater than 350 degrees F. Finally, when the petroleum derived base oil is  
19 brightstock, the ratio of the Fischer-Tropsch derived distillate fraction to the  
20 brightstock preferably will be such that the boiling range distribution will be  
21 greater than 450 degrees F. In this disclosure when referring to boiling range  
22 distribution, the boiling range between the 5 percent and 95 percent boiling  
23 points is what is referred to. All boiling range distributions in this disclosure  
24 are measured using the standard analytical method D-6352 or its equivalent  
25 unless stated otherwise. As used herein, a equivalent analytical method to  
26 D-6352 refers to any analytical method which gives substantially the same  
27 results as the standard method.

28  
29 As already noted, when the low viscosity Fischer-Tropsch derived distillate  
30 fraction was blended with the petroleum derived lubricating base oils, a  
31 viscosity index (VI) premium was observed. The term "VI premium" refers to a  
32 VI boost in which the VI of the blend is significantly higher than would have  
33 been expected from a mere averaging of the VI's for the two fractions. This

1 effect was most noticeable when a heavier petroleum derived base oil was  
2 used in the blend.

3

#### 4 **Finished Lubricants**

5

6 Finished lubricants generally comprise a lubricating base oil and at least one  
7 additive. Finished lubricants are used in automobiles, diesel engines, axles,  
8 transmissions, and numerous other transportation and industrial applications.  
9 As noted above, finished lubricants must meet the specifications for their  
10 intended application as defined by the concerned governing organization.  
11 Lubricating base oils of the present invention have been found to be suitable  
12 for formulating finished lubricants intended for many of these applications. For  
13 example, lubricating base oils of the present invention may be formulated to  
14 meet SAE J300, June 2001 specifications for both mono-grade and multi-  
15 grade crankcase engine oils. For example, multi-grade crankcase engine oil  
16 meeting the specifications for 0W-XX, 5W-XX, 10W-XX, and 15W-XX  
17 multi-grade crankcase lubricating oils may be formulated. In addition,  
18 Fischer-Tropsch derived lubricating base oils of the invention may be used to  
19 formulate finished lubricants meeting the specifications for SAE 70W, 75W  
20 and 80W gear lubricants and ISO Viscosity Grade 22, 32, and 46 industrial  
21 oils.

22

23 Finished lubricants within the scope of the invention should have a  
24 cold-cranking simulator (CCS) apparent viscosity of less than 7000 cP at  
25 -25 degrees C and preferably of 6500 cP or less at -25 degrees C if the  
26 lubricant is intended for use in an automobile engine. The Gelation Index  
27 should not exceed 12 and preferably will be 6 or less.

28

29 The lubricating base oil compositions of the invention may also be used as a  
30 blending component with other oils. For example, the lubricating base oils of  
31 the invention may be used as a blending component with synthetic base oils,  
32 including polyalpha-olefins, diesters, polyol esters, or phosphate esters, to  
33 improve the viscosity and viscosity index properties of those oils. Lubricating

1 base oils of the invention may be combined with isomerized petroleum wax.  
2 They may also be used as process oils, diluent oils, workover fluids, packer  
3 fluids, coring fluids, completion fluids, and in other oil field and well-servicing  
4 applications. For example, they can be used as spotting fluids to release a  
5 drill pipe which has become stuck, or they can be used to replace part or all of  
6 the expensive polyalphaolefin lubricating additives in downhole applications.  
7 Additionally, lubricating base oils of the invention may be used in drilling fluid  
8 formulations where shale-swelling inhibition is important, such as described in  
9 U.S. Patent No. 4,941,981.

10  
11 Additives which may be blended with the lubricating base oil to form the  
12 finished lubricant composition include those which are intended to improve  
13 certain properties of the finished lubricant. Typical additives include, for  
14 example, anti-wear additives, detergents, dispersants, antioxidants, pour point  
15 depressants, VI improvers, friction modifiers, demulsifiers, antifoaming  
16 agents, corrosion inhibitors, seal swell agents, and the like. Other  
17 hydrocarbons, such as those described in U.S. Patent Nos. 5,096,883 and  
18 5,189,012, may be blended with the lubricating base oil provided that the  
19 finished lubricant has the necessary pour point, kinematic viscosity, flash  
20 point, and toxicity properties. Typically, the total amount of additives in the  
21 finished lubricant will fall within the range of from about 1 to about  
22 30 weight percent. However due to the excellent properties of the  
23 Fischer-Tropsch derived base oils present in the blend, less additives than  
24 required with conventional base oils derived entirely from petroleum stocks  
25 may be required to meet the specifications for the finished lubricant. For  
26 example, due to the inherent stability of the Fischer-Tropsch distillate fraction,  
27 lower amounts of antioxidant additives and UV stabilizers are generally  
28 required in preparing the finished lubricants. In addition, due to the excellent  
29 VI of the blends, VI target values may be achieved in some finished lubricants  
30 without the addition of viscosity improvers or with lower treat rates of viscosity  
31 improvers. The use of additives in formulating finished lubricants is well  
32 documented in the literature and well within the ability of one skilled in the art.  
33 Therefore, additional explanation should not be necessary in this disclosure.

1    **Use in Internal Combustion Engines**

2

3    As already discussed, the lubricating base oil blends may be formulated into  
4    premium finished lubricants which are suitable for use in an internal  
5    combustion engine having a valve train. As used in this disclosure, the term  
6    internal combustion engine refers to an engine which uses a normally liquid or  
7    gaseous fuel, such as, for example, natural gas, gasoline, and diesel fuel.  
8    Fuels which may be suitable for use in internal combustion engines and which  
9    are within the scope of this invention include mineral-derived fuels, such as  
10   from petroleum, shale, or coal; synthetic fuels, such as those derived from  
11   Fischer-Tropsch synthesis; fuels derived from vegetable matter such as  
12   ethanol; as well as other fuels such as methanol, ethers, organo-nitro  
13   compounds and the like. Gasoline fuels may be either leaded or unleaded.  
14   Diesel fuels may be low sulfur diesel fuels, i.e., diesel fuels containing less  
15   than about 0.05 weight percent sulfur.

16

17   Internal combustion engines include gasoline piston engines and diesel  
18   engines. The engine may be either of the two-stroke or four-stroke design.  
19   The finished lubricants of the invention are used to lubricate the various  
20   engine parts, including the cylinder walls, bearings, and the valve train,  
21   i.e., the valves and the camshaft. In automobile engines the valve train is  
22   generally one of two designs, the overhead valve design and the overhead  
23   cam design.

24

25   The internal combustion engine may include a turbocharger which as used  
26   herein refers to an exhaust driven pump that compresses the intake air and  
27   forces it into the combustion chambers at higher than atmospheric pressure.  
28   The internal combustion engine also may include an exhaust gas  
29   after-treatment device, such as a catalytic converter or particulate trap, which  
30   is intended to reduce pollutants in the engine exhaust

## EXAMPLES

The following examples are included to further clarify the invention but are not to be construed as limitations on the scope of the invention.

### Example 1

A Fisher-Tropsch distillate fraction (designated FTBO-2.5) having a viscosity between 2 and 3 cSt at 100 degrees C was produced as generally described above, i.e., by the Fischer-Tropsch process, hydrotreating, hydroisomerization dewaxing, hydrofinishing, atmospheric distillation, and vacuum distillation. The properties of FTBO-2.5 were analyzed and its properties compared to two commercially available conventional petroleum derived oils (Nexbase 3020 and Pennzoil 75HC) having viscosities within the same general range. A comparison between the properties of the three samples is shown below:

|                                    | FTBO-2.5 | Nexbase 3020 | Pennzoil 75HC |
|------------------------------------|----------|--------------|---------------|
| Viscosity at 100 degrees C (cSt)   | 2.583    | 2.055        | 2.885         |
| Viscosity Index (VI)               | 133      | 96           | 80            |
| Pour Point, C                      | -30      | -51          | -38           |
| TGA Noack Volatility (wt. percent) | 49       | 70           | 59            |

It should be noted that, although the viscosity at 100 degrees C of the Fischer-Tropsch derived material was comparable to those of the conventional oils, the VI was significantly higher and the TGA Noack volatility was significantly lower.

### Example 2

FTBO-2.5 was blended with two different Medium Neutral petroleum Group I or Group II base oils identified as ChevronTexaco 220R(Group II) and Exxon Europe MN (Group I). The weight percent of FTBO-2.5 in the total blend was selected to provide a kinematic viscosity at 100°C of approximately 3.9 cSt. The properties of these blends are summarized in Table 3. The excellent cold

1 cranking viscosities of the blends as compared to the conventional 100  
 2 Neutral oils with comparable Noack volatilities (shown in Table 5) should be  
 3 noted.

4  
 5 **Table 3**

|                                      | Blend 1                                | Blend 2                             |
|--------------------------------------|----------------------------------------|-------------------------------------|
| Composition                          | 47% FTBO-2.5/53%<br>ChevronTexaco 220R | 56% FTBO-2.5/44%<br>Exxon Europe MN |
| D-2887 Simulated TBP<br>(WT%), °F    |                                        |                                     |
| TBP @5                               | 627                                    | 623                                 |
| TBP @10                              | 649                                    | 641                                 |
| TBP @20                              | 688                                    | 674                                 |
| TBP @30                              | 722                                    | 706                                 |
| TBP @50                              | 779                                    | 772                                 |
| TBP @70                              | 832                                    | 830                                 |
| TBP @90                              | 910                                    | 901                                 |
| TBP @95                              | 943                                    | 929                                 |
| TBP @99.5                            | 1028                                   | 974                                 |
| Boiling Range<br>Distribution (5-95) | 316                                    | 306                                 |
| Viscosity at 40°C                    | 17.64                                  | 17.02                               |
| Viscosity at 100°C                   | 3.956                                  | 3.884                               |
| Viscosity Index                      | 121                                    | 123                                 |
| Pour Point, °C                       | -13                                    | -13                                 |
| CCS at -40°C, cP                     | 4432                                   | 4337                                |
| CCS at -35°C, cP                     | 2217                                   | 2152                                |
| CCS at -30°C, cP                     | 1173                                   | 1137                                |
| TGA Noack                            | 27.84                                  | 30.15                               |
| Oxidator BN, hrs.                    | 22.38                                  | 14.79                               |

6  
 7 **Example 3**

8  
 9 FTBO-2.5 was blended with two different Heavy Neutral conventional Group I  
 10 or Group II base oils identified as ChevronTexaco 600R (Group II) and  
 11 Exxon Europe HN (Group I). The viscosity and VI for each of the petroleum  
 12 derived base oils was as follows:  
 13

|   |                            |                   |     |
|---|----------------------------|-------------------|-----|
| 1 | Petroleum Derived Base Oil | Viscosity @ 100°C | VI  |
| 2 | ChevronTexaco 600R         | 12.37             | 100 |
| 3 | Exxon Europe HN            | 12.25             | 98  |

4

5 The weight percent of FTBO-2.5 blended with the petroleum derived base oils  
6 was selected to provide a kinematic viscosity at 100°C of approximately  
7 3.9 cSt. The properties of these blends are summarized in Table 4.

8

9

Table 4

|                                      | Blend 3                                    | Blend 4                             |
|--------------------------------------|--------------------------------------------|-------------------------------------|
| Composition                          | 67.2% FTBO-2.5/32.8%<br>ChevronTexaco 600R | 67% FTBO-2.5/33%<br>Exxon Europe HN |
| D-2887 Simulated<br>TBP (WT%), °F    |                                            |                                     |
| TBP @5                               | 622                                        | 622                                 |
| TBP @10                              | 638                                        | 638                                 |
| TBP @20                              | 668                                        | 669                                 |
| TBP @30                              | 696                                        | 698                                 |
| TBP @50                              | 756                                        | 759                                 |
| TBP @70                              | 831                                        | 872                                 |
| TBP @90                              | 981                                        | 982                                 |
| TBP @95                              | 1011                                       | 1009                                |
| TBP @99.5                            | 1061                                       | 1058                                |
| Boiling Range<br>Distribution (5-95) | 389                                        | 387                                 |
| Viscosity at 40°C                    | 16.6                                       | 16.5                                |
| Viscosity at 100°C                   | 3.904                                      | 3.881                               |
| Viscosity Index                      | 133                                        | 132                                 |
| Cloud Point, °C                      | -9                                         | -10                                 |
| Pour Point, °C                       | -18                                        | -13                                 |
| CCS at -40°C, cP                     | 3263                                       | 3640                                |
| CCS at -35°C, cP                     | 1561                                       | 1751                                |
| CCS at -30°C, cP                     | 852                                        | 950                                 |
| TGA Noack                            | 35.84                                      | 30.85                               |
| Oxidator BN, hrs.                    | 32.79                                      | 17.67                               |

10

11 It will be noted that the VI for Blend 3 was 133 and for Blend 4 was 132. This  
12 is a significantly higher value than would have been expected if the VI of the  
13 blend components had merely been averaged. In both blends the VI was  
14 essentially identical to the VI of the FTBO-2.5. This indicates that the blend

benefited from a VI premium. As in the previous example, the excellent CCS results at conventional Noack values makes these oils superior blend stocks.

#### Example 4

The properties of the lubricating base oils of examples 2 and 3 as shown in Tables 2 and 3 above may be compared to the properties of commercially available petroleum derived conventional Group I and Group II Light Neutral base oils as summarized in Table 5 below.

**Table 5**

|                                              | ChevronTexaco<br>100R | Gulf Coast<br>Solvent 100 | Gulf<br>Coast<br>H.P. 100 | Exxon<br>Americas<br>Core 100 |
|----------------------------------------------|-----------------------|---------------------------|---------------------------|-------------------------------|
| API Base Oil<br>Category<br>(API 1509 E.1.3) | II                    | I                         | II                        | I                             |
| D-6352 Simulated<br>TBP (WT%), °F            |                       |                           |                           |                               |
| TBP @5                                       | 412                   |                           |                           | 647                           |
| TBP @10                                      | 443                   |                           |                           | 672                           |
| TBP @20                                      | 449                   |                           |                           | 703                           |
| TBP @30                                      | 455                   |                           |                           | 725                           |
| TBP @50                                      | 472                   |                           |                           | 761                           |
| TBP @70                                      | 489                   |                           |                           | 796                           |
| TBP @90                                      | 516                   |                           |                           | 839                           |
| TBP @95                                      | 530                   |                           |                           | 858                           |
| TBP @99.5                                    | 576                   |                           |                           | 907                           |
| Boiling Range<br>Distribution (5-95)         | 118                   |                           |                           | 211                           |
| Viscosity at 40°C                            | 20.4                  | 20.4                      | 20.7                      | 20.2                          |
| Viscosity at<br>100°C                        | 4.1                   | 4.1                       | 4.1                       | 4.04                          |
| Viscosity Index                              | 102                   | 97                        | 97                        | 95                            |
| Pour Point, °C                               | -14                   | -18                       | -15                       | -19                           |
| CCS at -25°C, cP                             | 1450                  | 1430                      | 1550                      | 1513                          |
| CCS at -35°C, cP                             | >3000                 | >3000                     | >3000                     | >3000                         |
| Noack Volatility,<br>wt%                     | 26                    | 29                        | 25.5                      | 29.3                          |

1 A comparison of Table 3 and 4 with Table 5 illustrates that the  
2 Fischer-Tropsch derived lubricating base oils have a similar Noack volatility,  
3 pour point, and kinematic viscosity at 100 degrees C to conventional Group I  
4 and Group II Light Neutral oils. The Fischer-Tropsch derived lubricating base  
5 oils of the invention also display significantly better VI and lower CCS  
6 viscosity than the conventional Light Neutral oils.

#### 7 Example 5

9  
10 A crankcase engine oil meeting SAE J300 10W-40 grade viscosity definitions  
11 was formulated with a lubricating base oil of this invention. The lubricating  
12 base oil contained 12 weight percent FTBO-2.5 with 88 weight percent  
13 ChevronTexaco 220R. This base oil was used to prepare the automotive  
14 engine oil shown below in Table 6.

15  
16 **Table 6**

|                                           | Engine Oil |
|-------------------------------------------|------------|
| SAE Viscosity Grade                       | 10W-40     |
| Viscosity at 40°C                         | 92.68      |
| Viscosity at 100°C                        | 13.98      |
| Viscosity Index                           | 154        |
| CCS @ -25C                                | 4,749      |
| TGA Noack, wt. % loss                     | 15.41      |
| HTHS, cP                                  | 3.75       |
| Gelation Index                            | 4.5        |
| Oxidator B, Time to 1L O2/100 g oil, Hrs. | 30.75      |

17  
18 It should be noted that the blended engine oil was able to meet viscosity,  
19 CCS, HTHS, and Gelation Index Specifications for a premium automotive  
20 engine oil. The engine oil also demonstrated excellent oxidation stability.

#### 21 Example 6

22  
23  
24 A Fischer-Tropsch distillate fraction having a viscosity of 2.2 cSt at  
25 100 degrees C (designated FTBO-2.2) was blended with Heavy Neutral

1 conventional ChevronTexaco 600R (Group II) and Exxon Europe HN (Group I)  
 2 to form two lubricating base oil blends as shown in Table 7.

3

4

Table 7

|                   | Blend 5                                | Blend 6                             |
|-------------------|----------------------------------------|-------------------------------------|
| Composition       | 20% FTBO-2.2/80%<br>ChevronTexaco 600R | 20% FTBO-2.2/80% Exxon<br>Europe HN |
| Viscosity at 40C  | 51.63                                  | 52.88                               |
| Viscosity at 100C | 7.666                                  | 7.915                               |
| VI                | 113                                    | 117                                 |
| CCS @ -25 C       | 8,609                                  | 6,780                               |

5

6 Each blend was formulated into an engine oil meeting the specifications for  
 7 15W-30 and 15W-40 by blending in an additive package. A viscosity modifier  
 8 was added only the 15W-40 blends. No viscosity modifier was added to either  
 9 15W-30 blend. The properties of the finished lubricants are shown in Table 8.

10

11

Table 8

|                    | Blend 5 | Blend 5 | Blend 6 | Blend 6 |
|--------------------|---------|---------|---------|---------|
| Grade              | 15W-30  | 15W-40  | 15W-30  | 15W-40  |
| Viscosity Modifier | None    | present | None    | present |
| Vis @ 40°C         | 77.91   | 106.5   | 78.72   | 106.5   |
| Vis @ 100°C        | 10.55   | 14.22   | 10.76   | 14.21   |
| VI                 | 120     | 134     | 123     | 136     |
| Pour Point, °C     | -32     | -33     | -35     | -35     |
| CCS @ -20          | 7000    | 6,924   | 5,752   | 5,773   |
| Gelation Index     | 4.7     | 5.6     | 3.8     | 4       |
| HTHS               | 3.27    | 4.01    | 3.36    | 4.02    |
| TGA Noack          | 15.12   | 15.47   | 14.72   | 14.94   |

12

13 It will be noted that each blend was formulated to meet the specifications for  
 14 15W-30 and 15W-40. It should also be noted that both blend 5 and Blend 6  
 15 were able to meet the VI specification for 15W-30 without the addition of a  
 16 viscosity modifier.

17

1 **Example 7**

2

3 FTBO-2.5 was blended in various proportions with three different  
 4 conventionally derived bright stocks to yield six different blends. Each blend  
 5 was analyzed for its properties. The properties of FTBO-2.5 to bright stock  
 6 and the properties of each blend are shown in Table 9 below.

7

8

**Table 9**

9

| Description/Blend ID                | Blend 7 | Blend 8 | Blend 9 | Blend 10 | Blend 11 | Blend 12 |
|-------------------------------------|---------|---------|---------|----------|----------|----------|
| FTBO-2.5 (wt. %)                    | 30      | 60      | 25      | 60       | 30       | 40       |
| Chevron 150 BS (wt. %)              |         |         |         |          | 70       | 60       |
| IKC BS (wt. %)                      | 70      | 40      |         |          |          |          |
| Daqing BS (wt. %)                   |         |         | 75      | 40       |          |          |
| INSPECTIONS                         |         |         |         |          |          |          |
| Viscosity @ 40°C                    | 88.83   | 28.73   | 77.19   | 26.20    | 92.04    | 56.52    |
| Viscosity @ 100°C                   | 12.07   | 5.81    | 11.96   | 5.683    | 11.8     | 9.011    |
| VI                                  | 129     | 150     | 150     | 166      | 119      | 129      |
| Pour Point °C                       | -14     | -18     | -21     | -23      | -9       | -11      |
| CCS @ -25 °C                        | 14,822  | 1,601   | 8,009   | 1,177    | 20,543   | 7,877    |
| TGA Noack                           | 15.40   | 31.65   | 14.32   | 31.98    | 15.99    | 21.10    |
| Simulated TBP by D-2887 (wt. %), °F |         |         |         |          |          |          |
| TBP @0.5                            | 609     | 604     | 610     | 603      | 609      | 607      |
| TBP @5                              | 639     | 624     | 646     | 622      | 639      | 634      |
| TBP @10                             | 668     | 640     | 680     | 636      | 669      | 659      |
| TBP @20                             | 729     | 670     | 756     | 664      | 731      | 709      |
| TBP @30                             | 794     | 699     | 954     | 690      | 800      | 761      |
| TBP @40                             | 982     | 733     | 1014    | 720      | 977      | 826      |
| TBP @50                             | 1050    | 766     | 1052    | 750      | 1023     | 1002     |
| TBP @60                             | 1084    | 802     | 1083    | 782      | 1055     | 1043     |
| TBP @70                             | 1112    | 1012    | 1114    | 829      | 1081     | 1073     |
| TBP @80                             | 1141    | 1090    | 1149    | 1048     | 1111     | 1105     |
| TBP @90                             | 1175    | 1144    | 1189    | 1113     | 1149     | 1145     |
| TBP @95                             | 1200    | 1177    | 1215    | 1153     | 1175     | 1175     |
| TBP @99.5                           | 1243    | 1234    | 1264    | 1211     | 1224     | 1223     |

10

1 WHAT IS CLAIMED IS:

2

3 1. A process for producing a lubricating base oil blends which comprises:

4

5 (a) recovering a Fischer-Tropsch derived distillate fraction  
6 characterized by a viscosity of about 2 cSt or greater but less  
7 than 3 cSt at 100 degrees C; and

8

9 (b) blending the Fischer-Tropsch derived distillate fraction with a  
10 petroleum derived base oil selected from the group consisting of  
11 a Group I base oil, a Group II base oil, a Group III base oil, and  
12 a mixture of two or more of any of the foregoing conventional  
13 base oils in the proper proportion to produce a lubricating base  
14 oil blend characterized as having a viscosity of about 3 cSt or  
15 greater at 100 degrees C.

16

17 2. The process of claim 1 wherein the Fischer-Tropsch derived distillate  
18 fraction has a viscosity between about 2.2 and 2.7 cSt at  
19 100 degrees C.

20

21 3. The process of claim 1 wherein the Fischer-Tropsch derived distillate  
22 fraction is blended with the petroleum derived base oil in such  
23 proportion that the lubricating base oil blend comprises from about  
24 10 to about 80 weight percent of the Fischer-Tropsch derived distillate  
25 fraction.

26

27 4. The process of claim 3 wherein the Fischer-Tropsch derived distillate  
28 fraction is blended with a medium neutral base oil in such proportion  
29 that the boiling range distribution of the lubricating base oil blend is  
30 greater than 250 degrees F between the 5 percent and 95 percent  
31 points as measured by analytical method D-6352 or its equivalent.

- 1 5. The process of claim 3 wherein the Fischer-Tropsch derived distillate  
2 fraction is blended with a heavy neutral base oil in such proportion that  
3 the boiling range distribution of the lubricating base oil blend is greater  
4 than 350 degrees F between the 5 percent and 95 percent points as  
5 measured by analytical method D-6352 or its equivalent.  
6
- 7 6. The process of claim 1 wherein the petroleum derived base oil is  
8 blended in such proportion that the lubricating base oil blend comprises  
9 from about 20 to about 90 weight percent of the petroleum derived  
10 base oil.  
11
- 12 7. The process of claim 1 wherein the TGA Noack volatility of the  
13 lubricating base oil blend is less than about 45 weight percent.  
14
- 15 8. The process of claim 7 wherein the TGA Noack volatility of the  
16 lubricating base oil blend is greater than about 12 weight percent.  
17
- 18 9. The process of claim 1 including the additional step of adding to the  
19 lubricating base oil blend at least one additive to produce a finished  
20 lubricant.  
21
- 22 10. A lubricating base oil blend having a viscosity of about 3 cSt or greater  
23 at 100 degrees C comprising  
24  
25 (a) from about 10 to about 80 weight percent based upon the total  
26 blend of a Fischer-Tropsch derived distillate fraction  
27 characterized by a viscosity of about 2 cSt or greater but less  
28 than 3 cSt at 100 degrees C; and  
29  
30 (b) from about 20 to about 90 weight percent based upon the total  
31 blend of a petroleum derived base oil selected from the group  
32 consisting of a Group I base oil, a Group II base oil, a Group III

- 1                   base oil, and a mixture of two or more of any of the foregoing  
2                   conventional base oils.  
3
- 4    11.   The lubricating base oil blend of claim 10 wherein the Fischer-Tropsch  
5           derived distillate fraction has a viscosity between about 2.2 and 2.7 cSt  
6           at 100 degrees C.  
7
- 8    12.   The lubricating base oil blend of claim 10 wherein the TGA Noack  
9           volatility is less than about 45 weight percent.  
10
- 11   13.   The lubricating base oil blend of claim 12 wherein the TGA Noack  
12          volatility is greater than about 12 weight percent.  
13
- 14   14.   The lubricating base oil of claim 10 wherein the pour point is no more  
15          than -12 degrees C.  
16
- 17   15.   The lubricating base oil blend of claim 10 wherein the VI is 100 or  
18          greater.  
19
- 20   16.   The lubricating base oil blend of claim 10 wherein the oxidator BN  
21          value is at least 15 hours.  
22
- 23   17.   The lubricating base oil blend of claim 16 wherein the oxidator BN  
24          value is at least 30 hours.  
25
- 26   18.   The lubricating base oil blend of claim 10 wherein the boiling range  
27          distribution is greater than 250 degrees F between the 5 percent and  
28          95 percent points as measured by analytical method D-6352 or its  
29          equivalent.  
30
- 31   19.   The lubricating base oil blend of claim 18 wherein the boiling range  
32          distribution is greater than 350 degrees F between the 5 percent and

- 1           95 percent points as measured by analytical method D-6352 or its  
2           equivalent.  
3
- 4    20.    The lubricating base oil blend of claim 10 wherein the boiling range  
5           distribution is greater than 450 degrees F between the 5 percent and  
6           95 percent points as measured by analytical method D-6352 or its  
7           equivalent.  
8
- 9    21.    A finished lubricant comprising:  
10
- 11           (a)    a lubricating base oil blend which comprises from about 10 to  
12                   about 80 weight percent of a Fischer-Tropsch derived distillate  
13                   fraction characterized by a viscosity of about 2 cSt or greater but  
14                   less than 3 cSt at 100 degrees C and from about 20 to about  
15                   90 weight percent of a petroleum derived base oil selected from  
16                   the group consisting of a Group I base oil, a Group II base oil, a  
17                   Group III base oil, and a mixture of two or more of any of the  
18                   foregoing conventional base oils; and  
19
- 20           (b)    at least one additive.  
21
- 22    22.    The finished lubricant of claim 21 which is suitable for use as a  
23           multi-grade crankcase engine oil.  
24
- 25    23.    The finished lubricant of claim 22 which meets the SAE J300,  
26           June 2001 specifications for a 10W grade engine oil.  
27
- 28    24.    The finished lubricant of claim 21 which is suitable for use as a  
29           mono-grade crankcase engine oil.