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METHOD FOR OPTIMIZING FUEL ECONOMY OF LUBRICANT BASESTOCKS

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates to methods for optimizing fuel economy benefits of lubricant base oils used for passenger car motor oils. More particularly, lubricant base oils meeting defined parameters for viscosity and volatility result in base oils that give improved fuel economy and low temperature properties.

BACKGROUND OF THE DISCLOSURE

Federally mandated standards for fuel economy and emissions have placed increasing demands on passenger car manufacturers. This in turn has resulted in automobile manufacturers requesting high quality engine oils used for passenger car motor oils (PCMOs).

Under current GF-2 American Petroleum Institute (API) classification standards for PCMOs, SAE 5W-20, 5W-30 or 10W-30 oils must have volatilities as measured by gas chromatography distillation (GCD) of no more than 17%, or Noack volatilities of no more than 22%. GF-2 also requires a minimum level of fuel economy versus a reference oil (BC-2) in a standard engine test (Seq. VIA) which is tiered according to viscosity grade: 1.4% minimum for SAE 5W-20, 1.1% minimum for SAE 5W-30 and 0.5% minimum for SAE 10W-30. Basestocks from the Group I or Group II classification used by the American Petroleum Institute (API) can readily meet these requirements with suitable detergent inhibitor (DI) and viscosity index improver (VII) systems.

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In 1995, automakers requested higher quality engine oils to help meet stringent federally mandated passenger car fuel economy and emissions standards. The International Lubricant Standardization and Approval Committee (ILSAC), working with API, ASTM, and SAE has proposed a GF-3 Minimum Performance Standards for Passenger Car Motor Oils (PCMO) with significantly improved fuel economy and volatility requirements compared to previous GF-1 and current GF-2 PCMO standards. During the last five years, the petroleum industry has invested to make the higher viscosity index (VI) basestocks necessary to help meet these new engine oil requirements. It would be highly desirable to have basestocks that can be used to blend engine oils with improved volatility and fuel economy, while maintaining current engine durability/wear protection and providing improved low temperature performance. In order to meet these proposed new standards, many basestock manufacturers have invested in technology to produce higher VI basestocks. However, simply having high VI basestocks does not mean that such basestocks will necessarily meet ILSAC requirements with regard to fuel economy and volatility.

SUMMARY OF THE INVENTION

This invention relates to base oils that show improved fuel economy and cold flow properties. More particularly, the invention is directed to a method for improving the fuel economy and cold flow properties of lubricating base oils used to prepare 10W multigrade passenger car motor oils which comprises: blending a base oil wherein said base oil has a viscosity index greater than about 100, a finished oil Noack volatility less than about 15%, a finished oil Cold Cranking Simulator value at -20°C of less than about 2500 cP and a base oil kinematic viscosity at 100°C of from about 5.0 to about 6.0 cSt.

Another embodiment of the invention is a method for improving the fuel economy and cold flow properties of lubricating base oils used to

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prepare 5W multigrade passenger motor oils which comprises: blending a base oil wherein said base oil has a viscosity index greater than about 100, a finished oil Noack volatility less than or equal to about 15%, a finished oil Cold Cranking Simulator value at -25°C of less than about 2500 cP and a base oil kinematic viscosity at 100°C of from about 4.0 to about 5.0 cSt.

Yet another embodiment relates to a method for producing multi-grade lubricants which contain low volatility, high viscosity index (>100) base oil and which impart improved fuel economy, durability, and engine oil pumpability under most engine operating conditions, said method comprising blending basestock components to make a high VI base oil of the appropriate viscosity and volatility for each SAE multi-viscosity grade to produce a finished lubricant with a CCS viscosity of less than 2500 cP at the appropriate temperature for its SAE multi-viscosity grade.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a graph showing the relationship between basestock viscosity, VI, and Noack volatility.

Figure 2 is a graph showing relative fuel economy as a function of base oil viscosity for the Phase I portion (16 hr.) of a Sequence VIB test.

Figure 3 is a graph showing retained fuel economy as a function of base oil viscosity for the Phase II portion (96 hr.) of a Sequence VIB test.

Figure 4 is a schematic showing blending options as a function of VI, viscosity, and CCS temperature.

Figure 5 is a graph showing blend options as a function Noack and viscosity.

Figure 6 is a graph showing the relationship between MRV and CCS viscosity for a well formulated SAE 10W-30 PCMO using basestocks of different viscosity.

DETAILED DESCRIPTION OF THE INVENTION

Base Oils

Suitable base oils for preparation of lubricating oils according to the invention have a viscosity index greater than 100, preferably greater than 100 and less than 130, more preferably greater than 105 and less than 125, most preferably greater than 105 and less than 120. Base oils can be prepared by processes including distillation, solvent extraction, hydrocracking, hydrotreating, raffinate hydroconversion, wax isomerization, oligomerization, or esterification/polymerization. The base oils are comprised of basestocks classified by the American Petroleum Institute in Publication 1509 as API Group I, II, III, IV, V, or mixtures thereof.

Suitable feeds include reduced crudes, raffinates, hydrotreated oils, hydrocrackates, atmospheric gas oils, vacuum gas oils, coker gas oils, atmospheric and vacuum resids, deasphalted oils, slack waxes and Fischer-Tropsch wax. Such feeds may be derived from distillation towers (atmospheric and vacuum), hydrotreaters and solvent extraction units, and may have wax contents of up to 50% or more.

Solvent extraction of lubricating oil feeds is well known and is described in Chapter 14 of *Petroleum Refining* by James H. Gary and Glenn I Handwerk, Third Edition, Marcel Dekker, Inc., NY, NY (1994).

Hydrocracking catalysts are typically bifunctional including at least one metal component in a catalytically effective amount on an amorphous

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or crystalline base. Preferred metals include at least one of Group VIII and Group VIB metals, preferably at least one of cobalt, nickel, tungsten, molybdenum, iron and chromium on an amorphous metal oxide support such as silica or silica-alumina. The acidity of metal oxide supports can be controlled by adding promoters and/or dopants, or by controlling the nature of the metal oxide support, e.g., by controlling the amount of silica incorporated into a silica-alumina support. Examples of promoters and/or dopants include halogen, especially fluorine, phosphorus, boron, yttria, rare-earth oxides and magnesia. Promoters such as halogens generally increase the acidity of metal oxide supports while mildly basic dopants such as yttria or magnesia tend to decrease the acidity of such supports. Crystalline bases used for catalysts employed in hydrocracking and wax isomerization typically include molecular sieves, preferably zeolites, especially zeolites such zeolite Y, ZSM-5, ZSM-22, ZSM-23, ZSM-35 as well as silicoaluminophosphates such as SAPO-11.

Typical hydrocracking conditions include hydrogen pressures of from 10,335 to 20,685 kPa (1500 to 3000 psia), temperatures of from 315 to 450°C, liquid hourly space velocity of 0.5 to 3 and hydrogen treat gas rate of 356 to 1780 m³/m³ (2000 to 10000 Scf/B).

High VI base oils can also be prepared by hydrotreating. Hydrotreating is generally associated with lower conversion to light products as compared to hydrocracking, especially when used in conjunction with solvent extraction. Hydrotreating is a well-known process and is described in *Petroleum Refining* cited above, Chapter 9.

A preferred hydrotreating process is directed to severe hydrotreatment of a raffinate. The solvent extraction process selectively dissolves the aromatic components in an extract phase while leaving the more paraffinic components in a raffinate phase. Naphthenes are distributed between the extract

and raffinate phases. Typical solvents for solvent extraction include phenol, furfural and N-methyl pyrrolidone. By controlling the solvent to oil ratio, extraction temperature and method of contacting feed to be extracted with solvent, one can control the degree of separation between the extract and raffinate phases.

The raffinate from the solvent extraction is preferably under-extracted, i.e., the extraction is carried out under conditions such that the raffinate yield is maximized while still removing most of the lowest quality molecules from the feed. Raffinate yield may be maximized by controlling extraction conditions, for example, by lowering the solvent to oil treat ratio and/or decreasing the extraction temperature. This raffinate feed has a dewaxed oil viscosity index of from about 80 to about 105, a boiling range not to exceed about 650°C, preferably less than 600°C, as determined by ASTM 2887 and a viscosity of from 3 to 10 cSt at 100°C.

The raffinate from the solvent extraction unit is stripped of solvent and then sent to a first hydroconversion unit containing a catalytically effective amount of a hydroconversion catalyst. Hydroconversion catalysts are those containing Group VIB metals (based on the Periodic Table published by Fisher Scientific), and non-noble Group VIII metals, i.e., iron, cobalt and nickel, and mixtures thereof. These metals or mixtures of metals are typically present as oxides or sulfides on refractory metal oxide supports.

The metal oxide support should be non-acidic so as to control cracking. The acidity of metal oxide supports can be controlled by adding promoters and/or dopants, or by controlling the nature of the metal oxide support, e.g., by controlling the amount of silica incorporated into a silica-alumina support. Examples of promoters and/or dopants include halogen, especially fluorine, phosphorus, boron, yttria, rare-earth oxides and magnesia.

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Promoters such as halogens generally increase the acidity of metal oxide supports while mildly basic dopants such as yttria or magnesia tend to decrease the acidity of such supports.

Suitable metal oxide supports include low acidic oxides such as silica, alumina or titania, preferably alumina. Preferred aluminas are porous aluminas such as gamma or eta having average pore sizes from 50 to 200Å, preferably 75 to 150Å, a surface area from 100 to 300 m²/g, preferably 150 to 250 m²/g and a pore volume of from 0.25 to 1.0 cm³/g, preferably 0.35 to 0.8 cm³/g. The supports are preferably not promoted with a halogen such as fluorine as this generally increases the acidity of the support.

Preferred metal catalysts include cobalt/molybdenum (1-5% Co as oxide, 10-25% Mo as oxide) nickel/molybdenum (1-5% Ni as oxide, 10-25% Co as oxide) or nickel/tungsten (1-5% Ni as oxide, 10-30% W as oxide) on alumina. Especially preferred are nickel/molybdenum catalysts such as KF-840.

Hydroconversion conditions in the first hydroconversion unit include a temperature of from 340 to 420°C, preferably 360 to 390°C, a hydrogen partial pressure of 800 to 2000 psig (5.5 to 13.8 MPa), preferably 800 to 1800 psig (5.5 to 12.5 MPa), a space velocity of from 0.2 to 3.0 LHSV, preferably 0.3 to 1.0 LHSV and a hydrogen to feed ratio of from 500 to 5000 Scf/B (89 to 890 m³/m³), preferably 2000 to 4000 Scf/B (356 to 712 m³/m³).

The hydroconverted raffinate from the first reactor is sent to a second reactor where it is subjected to further hydroconversion. The conditions and catalyst are the same as set forth above for the first reactor provided the temperature of the second reactor should not exceed that used in the first reactor.

The hydroconverted raffinate from the second reactor is then conducted to a third reactor where it is subjected to a cold (mild) hydrofinishing

step. The catalyst in this third reactor may be the same as those described above for the first reactor. However, more acidic catalyst supports such as silica-alumina, zirconia and the like may be used in the third reactor.

Conditions in the third reactor include temperatures of from 200 to 330°C, preferably 230 to 300°C, a hydrogen partial pressure of from 800 to 2000 psig (5.5 to 13.8 MPa), preferably 800 to 1800 psig (5.5 to 12.5 MPa), a space velocity of from 1 to 5 LHSV, preferably 1 to 3 LHSV and a hydrogen to feed ratio of from 500 to 5000 Scf/B (89 to 890 m³/m³), preferably 2000 to 4000 Scf/B (356 to 712 m³/m³).

Another method for preparing high VI base oils involves isomerization of waxy feeds such as deoiled wax, vacuum distillates derived from waxy crudes, slack wax, foots oil and Fischer-Tropsch wax. The hydro-isomerization of the paraffinic components of waxy feeds to isoparaffinic components is typically accomplished with a catalyst. Isomerization catalysts are normally bifunctional and comprise at least one metal component on a porous support. Preferred metals are Groups VIII metals, especially Group VIII noble metals, most preferably platinum and palladium in catalytically effective amounts.

The support is a porous material such as a zeolite or a non-zeolitic molecular sieve such as a silicoaluminaphosphate. Preferred zeolites are large pore zeolites having at least one pore channel of at least about 7 Angstroms. Examples of such zeolites include zeolite beta, ZSM-20, zeolite Y and the like. Isomerization properties of these catalysts may be modified by adjusting the silica to alumina ratio. High silica to alumina ratios are preferred. Silica to alumina ratios are greater than 50:1, more preferably greater than 200:1 especially greater than 500:1. The catalyst may be in a matrix material such as alumina, low-acidity silica-alumina or silica.

Oligomerization and esterification/polymerization are well known processes and are described in *Lubricants and Related Products* by Dieter Klamann, Verlag Chemie, Weinheim, (1984), Chapter 6.

A feature of the base oils according to the invention relates to the volatility of said base oils. The loss of base oil components through volatilization of lighter materials during engine operation can adversely affect base oil properties such as viscosity. One measure of base oil volatility is the Noack test as described in DIN 51581 or ASTM D5800. Briefly, this test involves directing a defined air stream over oil contained in a specific type of cup for the designated time at the test temperature. The evaporation loss is measured by percent weight loss. The finished oil Noack volatility for the present base oils is less than or equal to about 15%, preferably less than about 14%, more preferably less than about 13%, most preferably less than about 11%. By finished oil is meant the base oil containing additives that comprise an engine oil. Another measure of volatility is the gas chromatography distillation (GCD) by ASTM D 2287 or ASTM D 5480. The evaporation loss is measured by % weight off the GCD instrument column at various temperatures. The finished oil GCD volatility for the present base oils is less than or equal to about 9%, preferably less than about 6%, more preferably less than about 4%, most preferably less than about 2%.

Another feature of the subject base oils are their cold flow properties. The viscosity of a passenger car motor oil (PCMO) affects the cold-cranking speed of an automobile engine, hence the ability of the engine to start at low temperatures. One measure of assessing the flow behavior of a PCMO at low temperatures is set forth in ASTM D5293-98 which measures viscosity at temperatures between -5 and -30°C in a Cold Cranking Simulator (CCS). The base oils for 10W multigrade blends according to the invention have finished oil

CCS values less than about 2500 cP, preferably less than 2100 cP, more preferably less than 1900 cP @-20°C.

A still further feature is the base oil viscosity at 100°C. For multigrade oils, the Society of Automotive Engineers (SAE) ranges are defined by the SAE J300 viscosity classification. For the present base oils, the kinematic viscosities at 100°C for a 10W-30 oil are in the range from about 5.0 to 6.0 cSt, preferably 5.1 cSt to 5.8 cSt, more preferably 5.2 cSt to 5.7 cSt. For a 5W-20 or 5W-30 oil, the viscosity ranges are from about 4.0 cSt to about 5.0 cSt, preferably 4.0 cSt to 4.8 cSt, more preferably 4.1 cSt to 4.7 cSt.

Base Oil Blending

Passenger Car Motor Oils with significantly improved volatility, fuel-economy and low temperature performance can be formulated with the newly available high VI (API Group II+) basestocks. The blending strategy is based on the following considerations: (1) High VI basestocks are required to blend low volatility engine oils; (2) for a given additive system and SAE viscosity grade, PCMO fuel economy is dependent on basestock viscosity and volatility; and (3) PCMO fuel economy can be optimized with low-viscosity, low-volatility basestocks that provide High Temperature High Shear (HTHS) viscosities at or above those found in conventional formulations.

There is a fundamental relationship between basestock viscosity, VI, and Noack volatility (Figure 1). At a constant VI, basestock volatility decreases as the viscosity increases; and at a constant viscosity, the basestock volatility decreases as the VI increases. The Noack volatility of blended engine oils is essentially equal to the Noack volatility of the basestocks used for blending the engine oils, since additives have only a minor effect on this bulk basestock property. In 1985, European automakers (ACEA) instituted a 15%

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maximum Noack volatility specification for engine oils. This Noack volatility specification has been shown to minimize oil consumption in engines operating at high speed and high temperature. Figure 1 shows that this Noack volatility requirement is easily met by existing European 105 VI basestocks in the most commonly used SAE 15W-40 engine oil viscosity grade. However, the lower viscosity grade engine oils (SAE 5W-30, 10W-XX), commonly used in North America, can not be blended to 15% maximum Noack volatility with the available 95 VI basestocks.

The fuel economy performance of engine oils is known to be dependent, in part, on basestock viscosity. ILSAC GF-2 fuel economy performance is measured in the ASTM Sequence VIA test and the specifications for SAE 5W-30 and SAE 10W-30 engine oils are different. The fuel economy specification for SAE 5W-30 GF-2 engine oils is 1.1% minimum vs. ASTM BC-2 reference oil and the fuel economy specification for SAE 10W-30 GF-2 engine oils is 0.5% minimum vs. ASTM BC-2. The major formulation difference to account for this 0.6% fuel economy delta between SAE 5W-30 and SAE 10W-30 engine oils is the viscosity of the basestocks from which they are blended: typically about 4 cSt at 100°C (S100N) for SAE 5W-30, and about 5 cSt at 100°C (S150N) for SAE 10W-30.

Fuel economy performance for ILSAC GF-3 will be determined in the new ASTM Sequence VIB engine test. The test measures initial or Phase I fuel economy (similar to Sequence VIA), and fuel economy retention or Phase II fuel economy after a 96 hour (4500-5000 mile) aging cycle. A series of tests were run in a single Sequence VIB engine test stand, using a single prototype GF-3 additive system, to determine the effect of basestock kinematic viscosity on Sequence VIB fuel economy performance. Basestocks from API Groups I, II,

III, and IV were used to maintain engine oil volatility as the basestock viscosity at 100°C was reduced from 5.4 cSt to 3.7 cSt. The Sequence VIB data plotted in Figure 2 show a linear dependence of initial (16 hour) fuel economy performance and basestock viscosity. The data are plotted as relative fuel economy performance, with the fuel economy of the PCMO blended with the 5.4 cSt Group I basestock arbitrarily set to zero. This provides a focus on basestock effects only, rather than the combined basestock and additive effects that determine absolute fuel economy performance. These data indicate the basestock viscosity effect of 0.6% fuel economy improvement previously observed in the Sequence VIA test when moving from an SAE 10W-30 PCMO to an SAE 5W-30 PCMO. The Sequence VIB data for the 96 hour retained fuel economy show a similar basestock viscosity effect. The 96 hour Sequence VIB data, also plotted as relative fuel economy, are shown in Figure 3. The data in Figures 2 and 3 indicate that a 0.3-0.4% fuel economy improvement can be readily obtained by moving from the top to the bottom of the SAE 5W-30 viscosity grade.

The data in Figures 2 and 3 also show that blending with very high VI API Group III basestocks does not necessarily produce PCMOs with the best possible fuel economy. The 16 hour fuel economy of the SAE 5W-30 PCMO blended with the 4.95 cSt viscosity Group III basestock was not as good as the fuel economy of the SAE 5W-30 PCMO blended with the 4.5 cSt API Group II+ basestock even though the former had a lower CCS viscosity at -25°C. A lower kinematic viscosity API Group III basestock could not be used to blend this SAE 5W-30 PCMO since its CCS viscosity would test as an SAE 0W-30 engine oil (SAE J300 requires that an oil be categorized as the lowest measured 'W' grade; hence an oil meeting the CCS viscosity requirements of a 5W-30 and a 0W-30 would be classified as a 0W-30). On the other hand, the very low volatility of

the 4.95 cSt Group III basestock (12% Noack) showed better than expected retained fuel economy (Figure 3) compared to PCMOs blended with 15% Noack basestocks. The loss of the lighter, more volatile fraction of the basestock during the 96 hour aging cycle of the Sequence VIB test increases the viscosity of the remaining fraction, and increased viscosity is known to reduce fuel economy.

When using higher VI basestocks, engine oil formulators must choose a blending strategy (See Figure 4 schematic). At temperatures above their cloud points, basestocks are Newtonian fluids (i.e., measured viscosity is independent of shear rate). Additionally, their viscosity-versus-temperature relationship can be depicted as a straight line using the MacCoull, Walther, and Wright mathematical transformation. A 95 VI basestock and a 115 VI basestock have different viscosity temperature relationships (slopes) and their viscosities can be equal at only one temperature. Figure 4 depicts two important viscosity temperature points used to formulate engine oils: Cold Cranking Simulator (CCS) viscosity at one low temperature (for example either -20 or -25°C depending upon the 'W' grade), and Kinematic Viscosity (KV) at 100°C. A formulator can choose to make the viscosities of the 115 VI and 95 VI basestocks equal at either one of these temperatures; however once that temperature is selected, the viscosity of the 115 VI basestock at all other temperatures is higher or lower as shown.

OPTION 1: Equal CCS Viscosity

Higher VI basestocks that have CCS viscosities equivalent to the 95 VI basestock will have higher basestock viscosity at all other engine operating temperatures. Higher basestock viscosity at 100°C reduces VI improver (polymer) concentration needed to meet finished oil KV targets. Higher basestock viscosity in the 110-150°C severe operating temperature range of the

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engine may also provide benefits of increasing the load carrying capability of the oil. However, increased viscosity at normal engine operating temperatures (~70-110°C) will also increase hydrodynamic friction (drag) and will result in reduced fuel efficiency. As noted above, the magnitude of this fuel economy reduction was found to be 0.3-0.4% in the new ASTM Sequence VIB engine test that will be used to define GF-3. This reduction is significant when compared to the 1-2% fuel economy benefit targeted for the new GF-3 specification.

OPTION 2: Equal Kinematic Viscosity at 100°C

Matching the kinematic viscosity at 100°C of higher VI and 95 VI basestocks has been found to offer significant technical benefits. The VI improver concentration needed to meet finished engine oil KV at 100°C targets will be similar for the two basestocks. Thus the finished oils will have comparable visco-elastic properties. At severe engine operating temperatures (110-150°C) the viscosity of the 115 VI basestock will be equal to or slightly higher than the viscosity of the 95 VI basestock. This viscosity similarity will maintain or potentially improve engine durability/wear protection, while not significantly reducing fuel economy contrasted to Option 1. At normal operating temperatures (~70-110°C) the viscosity of the high VI basestock will be lower than the 95 VI basestock. This will lead to improved fuel economy under hydrodynamic conditions, and will also provide improved engine starting and engine oil pumpability at low temperatures. Improved engine oil pumpability at low temperature should reduce wear during the first few minutes after engine start-up by reducing the time it takes for oil to reach the crank and cam shaft areas. Matching the viscosity of the higher VI and 95 VI basestocks at or near 100°C (Option 2) will result in engine oils with comparable durability, superior fuel economy, and better low temperature performance characteristics compared to Option 1. This

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preferred blending range, which is the major element one this invention, is shown on Figure 4.

Viscometric data for blending SAE 5W-30 and SAE 10W-30 engine oils with higher VI basestocks by Options 1 and 2 can be calculated using the MacCoull, Walther, and Wright mathematical transformation equations plus density to convert kinematic viscosity (KV) in cSt to CCS viscosity in cP (Table 1). Some assumptions must be made to define the basestock CCS viscosity to use for blend Option 1 analysis. Formulators have historically targeted engine oil blends to a CCS viscosity of 3250 cP at the appropriate temperature for each SAE viscosity grade (-25°C for 5W, -20°C for 10W). Assuming an additive CCS viscosity contribution of 1250 cP at -25°C and 1050 cP at -20°C, the required basestock CCS viscosity for Option 1 is about 2000 cP at -25°C for SAE 5W-30 engine oils and about 2300 cP at -20°C for SAE 10W-30 engine oils. Blend Option 2 uses basestock KV at the high end of that historically used to blend SAE 5W-30 and SAE 10W-30 engine oils with 95 VI basestocks (i.e., 4.4 cSt and 5.3 cSt at 100°C respectively).

Table 1

HIGH VI BASESTOCK PCMO BLEND OPTION VISCOMETRICS

	SAE 5W-30 Blend Option 1						SAE 5W-30 Blend Option 2					
	Constant CCS, Target = 2000 Cp						Constant KV @ 100°C, Target = 4.4 cSt					
BASESTOCK VI	95	105	110	120	130	140	95	105	110	120	130	140
KV @ 100°C	4.4	4.7	4.8	5.2	5.6	6.0	4.4	4.4	4.4	4.4	4.4	4.4
KV @ 40°C	23.3	25.0	25.6	27.7	29.7	31.4	23.3	22.4	21.9	21.0	20.2	19.5
SSU @ 100°F	121	130	133	143	152	161	121	117	114	110	106	102
CCS @ -25°C, cP	2030	2080	2040	2090	2060	1970	2030	1630	1440	1150	930	770
CCS @ -30°C, cP	-	-	-	-	-	-	3800	2960	2590	2000	1580	1270

	SAE 10W-30 Blend Option 1						SAE 10W-30 Blend Option 2					
	Constant CCS, Target = 2300 Cp						Constant KV @ 100°C, Target = 5.3 cSt					
BASESTOCK VI	95	105	110	120	130	140	95	105	110	120	130	140
KV @ 100°C	5.3	5.7	6	6.6	7.2	8.0	5.3	5.3	5.3	5.3	5.3	5.3
KV @ 40°C	32.1	34.4	36.2	40.0	43.2	47.8	32.1	30.6	29.9	28.4	27.3	26.2
SSU @ 100°F	166	177	186	205	221	244	166	158	154	146	140	135
CCS @ -20°C, cP	2310	2290	2310	2340	2300	2320	2310	1820	1610	1260	1040	860
CCS @ -25°C, cP	-	-	-	-	-	-	4310	3300	2870	2170	1760	1410

Calculations made using Wright Mathematical Transformation Plus Density

Assume additive contribution to CCS is 1250 cP @ -25°C and 1050 cP @ -20°C

The Option 1 and Option 2 blend data in Table 1 for 95 through 120 VI basestocks is shown graphically in Figure 5. Changes to the KV and CCS viscosity targets assumed for blend Options 1 and 2 will shift the triangular area shown in Figure 5 for blending SAE 5W-30 and SAE 10W-30 engine oils slightly to the right or left; but will not change the overall picture.

The viscosity calculations in Table 1 were extended to 130 VI and 140 VI in order to show the engine oil viscometric effects of blending with very high VI API Group III and IV basestocks. At constant CCS viscosity (Option 1) API Group III and IV basestock have very high KVs at 100°C that will reduce fuel economy. At constant KV at 100°C (Option 2) they have very low CCS viscosities that will drop them below the targeted SAE 'W' viscosity grade. An experienced formulator must consider these viscometric effects when formulating low volatility fuel-efficient engine oils with these very high VI basestocks. For example, due to their very low CCS viscosity, these very high VI API Group III and IV basestocks are most useful in blending SAE 0W-XX engine oils.

Prototype ILSAC GF-3 engine oils were blended with the new high VI (API Group II+) basestocks produced by Exxon Company, U.S.A. Two SAE 5W-20 and three SAE 10W-30 engine oils were blended using prototype GF-3 additive packages obtained from three major additive companies. The prototype GF-3 engine oils were tested in ASTM, Test Monitoring Center referenced, Sequence VIB engine test stands, except as noted in Table 2. The prototype GF-3 engine oils were formulated using "Option 2" blend strategy and all have Noack volatilities below the 15% maximum proposal. All five of these prototype engine oils met the proposed ILSAC GF-3 fuel economy limits as originally proposed for their respective viscosity grade. The high temperature high shear viscosities at 150°C of these prototype engine oils were well above the HTHS limits for SAE 5W-20 and SAE 10W-30 engine oils and were at least equivalent

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to the HTHS viscosities of past GF-1 and GF-2 PCMOs. Based on basestock viscosity alone, these prototype GF-3 engine oils should have engine durability and wear protection at least equivalent to currently marketed PCMOs of the same viscosity grade.

Table 2
PROTOTYPE GF-3 FUEL ECONOMY AND VISCOMETRIC DATA

<u>GF-3 PROTOTYPE ADDITIVE</u>	<u>SAE 5W-20</u>		<u>SAE 10W-30</u>	
	<u>A</u>	<u>B</u>	<u>A</u>	<u>C</u>
Seq VIB FE: 16 hr/96 hr, %	2.0/1.8*	2.2/1.7	1.4/1.1	1.4/1.1
PCMO: KV @ 100°C, cSt	8.4	8.3	10.7	10.7
CCS @ -20°C, cP	-	-	1910	2000
CCS @ -25°C, cP	2250	1990	3840	3960
CCS @ -30°C, cP	4490	3730	-	-
MRV @ -30°C, cP	-	-	11,460	12,200
MRV @ -35°C, cP	16,400	28,100	-	-
MRV, Yield Stress, Pa	<35	<35	<35	<35
HTHS @ 150°C, cP	2.75	2.60	3.22	3.33
PCMO: Noack Volatility, wt%	15.3	14.8	10.1	11.4
BASESTOCK: KV @ 100°C, cSt	4.7	4.5	5.3	5.3

ILSAC proposed GF-3 Sequence VIB Fuel Economy Minimum Limits:

2.0/1.7 for 5W-20 and 1.3/1.0 for 10W-30 (16 hr/96 hr), %

* Non-referenced Stand

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In addition to excellent fuel economy and volatility, PCMOs blended with these new high-VI, low-viscosity, low-volatility basestocks would be expected to have improved low temperature engine starting characteristics based on their CCS viscosities, while MRV viscosities/yield stresses were all well within the grade limits (60,000 cP maximum). Figure 6 shows the relationship between MRV and CCS viscosity for a well formulated SAE 10W-30 PCMO using basestocks of different viscosity. The MRV, measured at -30°C and -35°C, reduces at a uniform rate as the CCS viscosity is reduced from 3200 to 1900 cP at -20°C.

CLAIMS:

1. A method for producing multi-grade lubricants which contain low volatility, viscosity index greater than 100 base oil and which impart improved fuel economy, durability, and engine oil pumpability under most engine operating conditions, said method comprising blending basestock components to make a high VI base oil of the appropriate viscosity and volatility for each SAE multi-viscosity grade to produce a finished lubricant with a CCS viscosity of less than 2500 cP at the appropriate temperature for its SAE multi-viscosity grade.
2. A method for improving the fuel economy and cold flow properties of lubricating base oils used to prepare 10W multigrade passenger car motor oils (PCMOs) which comprises blending a base oil wherein said base oil has a viscosity index greater than about 100, a finished oil Noack volatility less than or equal to about 15%, a finished oil Cold Cranking Simulator value less than about 2500 cP @ -20°C, and a base oil kinematic viscosity at 100°C of from about 5.0 to about 6.0 cSt.
3. A method for improving the fuel economy and cold flow properties of lubricating base oils used to prepare 5W multigrade passenger motor oils which comprises: blending a base oil wherein said base oil has a viscosity index greater than about 100, a finished oil Noack volatility less than or equal to about 15%, a finished oil Cold Cranking Simulator value less than about 2500 cP @ -25°C, and a base oil kinematic viscosity at 100°C of from about 4.0 to about 5.0 cSt.
4. The method of claim 2 wherein the Noack volatility is less than 13%.



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5. The method of claim 3 wherein the Noack volatility is less than 13%.
6. The method of claim 3 wherein the 5W multigrade oil is 5W-20 or 5W-30.
7. The method of claim 2 wherein the Cold Cranking simulator value is less than 2100 cP at -20°C.
8. The method of claim 3 wherein the Cold Cranking simulator value is less than 2100 cP at -25°C.

