



(51) International Patent Classification:

C10M 169/04 (2006.01) C10N 30/04 (2006.01)  
C10M 171/02 (2006.01) C10N 30/10 (2006.01)  
C10N 20/02 (2006.01) C10N 40/25 (2006.01)

(21) International Application Number:

PCT/US2015/016264

(22) International Filing Date:

18 February 2015 (18.02.2015)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

14/447,808 31 July 2014 (31.07.2014) US

(71) Applicants: **CHEVRON U.S.A. INC.** [US/US]; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US). **CHEVRON ORONITE COMPANY LLC** [US/US]; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US).

(72) Inventors: **GREEN, John Coakwell**; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US). **TOBIAS, Melanie Frances**; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US). **CARABELL, Kevin David**; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US). **ROSENBAUM, John Michael**; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US). **KRAMER, David Christian**; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US).

(74) Agents: **ABERNATHY, Susan M.** et al.; Chevron Services Company, Law Department, Post Office Box 6006, San Ramon, California 94583-0806 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

Published:

- with international search report (Art. 21(3))
- with amended claims (Art. 19(1))

(54) Title: SAE 15W-30 LUBRICATING OIL COMPOSITION HAVING IMPROVED OXIDATIVE STABILITY

(57) Abstract: We provide a SAE 15W-30 lubricating oil, comprising: a Group II base oil having a KV at 100°C from 5.0 to 8.0 mm<sup>2</sup>/s; a second Group II base oil having a KV at 100°C from 10 to 14 mm<sup>2</sup>/s; a DI additive package designed to meet API CJ-4; and 0.50 to 4.95 wt % viscosity modifier; wherein the lubricating oil has a TBN from 8.55 to 11.00 and provides an Induction Time in a CMOT from 270 to 450 minutes. We also provide a process for making the lubricating oil, comprising: blending the Group II base oils to make a blended base oil mixture and adding to the blended base oil mixture: a DI additive package designed to meet API CJ-4, and a viscosity modifier; wherein the lubricating oil has a TBN from 8.55 to 11.00 and provides an Induction Time in a CMOT from 270 to 450 minutes.



WO 2016/018462 A1

5           **SAE 15W-30 LUBRICATING OIL COMPOSITION HAVING IMPROVED  
                  OXIDATIVE STABILITY**

                                  TECHNICAL FIELD

                  This application is directed to a SAE 15W-30 lubricating oil composition having  
10 improved oxidative stability that is made using two different grades of Group II base oil, a  
detergent inhibitor additive package, a Total Base Number (TBN) booster, and a viscosity  
modifier.

                                  BACKGROUND

15           Lubricating oil compositions are needed that meet modern performance specifications  
and that show improved performance in oxidative stability and other tests.

                  A SAE 15W-30 lubricating oil composition can be a lower-cost alternative to SAE  
10W-30 lubricating oil compositions. In one embodiment, a SAE 15W-30 lubricating oil  
composition can provide similar fuel economy benefits as a SAE 10W-30 lubricating oil  
20 composition, but with enhanced engine wear protection due to the SAE 15W-30 lubricating  
oil composition having a base oil blend viscosity that is almost as high as a SAE 15W-40  
lubricating oil composition.

                                  SUMMARY

25           This application provides a lubricating oil composition, comprising:

- a. a first Group II base oil having a kinematic viscosity at 100°C from 5.0 to 8.0  
mm<sup>2</sup>/s;
- b. a second Group II base oil having a second kinematic viscosity at 100°C from 10  
to 14 mm<sup>2</sup>/s;
- 30           c. a detergent inhibitor additive package designed to meet an API CJ-4 service  
category;
- d. 0.50 to 4.95 wt % of a viscosity modifier; wherein the lubricating oil composition  
has an SAE 15W-30 viscosity grade by SAE J300, a TBN from 8.55 to 11.00 mg KOH/g by  
ASTM D2896-11; and wherein the lubricating oil composition provides an Induction Time in  
35 a Caterpillar Micro-Oxidation Test from 270 to 450 minutes.

                  This application also provides a process for making a lubricating oil composition,  
comprising:

- 5 a. blending a first Group II base oil having a kinematic viscosity at 100°C from 5.0 to 8.0 mm<sup>2</sup>/s with a second Group II base oil having a second kinematic viscosity at 100°C from 10 to 14 mm<sup>2</sup>/s to make a blended base oil mixture having a blended base oil kinematic viscosity at 100°C from 6.0 mm<sup>2</sup>/s to 7.3 mm<sup>2</sup>/s; and
- b. adding to the blended base oil mixture:
- 10 i. a detergent inhibitor additive package designed to meet an API CJ-4 service category; and
- ii. 0.5 to 4.95 wt% of a viscosity modifier, to make the lubricating oil composition; wherein the lubricating oil composition has an SAE 15W-30 viscosity grade by SAE J300, a TBN from 8.55 to 11.00 mg KOH/g by
- 15 ASTM D2896-11; and wherein the lubricating oil composition provides an Induction Time in a Caterpillar Micro-Oxidation Test from 270 to 450 minutes.

- This application also provides a method of operating an engine, comprising
- 20 lubricating an engine with a lubricating oil composition comprising:
- a. a first Group II base oil having a kinematic viscosity at 100°C from 5.0 to 8.0 mm<sup>2</sup>/s;
- b. a second Group II base oil having a second kinematic viscosity at 100°C from 10 to 14 mm<sup>2</sup>/s;
- 25 c. a detergent inhibitor additive package designed to meet an API CJ-4 service category; and
- d. 0.50 to 4.95 wt % of a viscosity modifier.

- The present invention may suitably comprise, consist of, or consist essentially of, the
- 30 elements in the claims, as described herein.

## GLOSSARY

“Base oil” refers to a hydrocarbon fluid to which other oils or substances are added to produce a lubricant.

5 “Lubricant” refers to substances (usually a fluid under operating conditions) introduced between two moving surfaces so to reduce the friction and wear between them.

“Group II base oil” refers to a base oil which contains greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and has a viscosity index greater than or equal to 80 and less than 120 using the American Society for Testing and Materials (ASTM) methods  
10 specified in Table E-1 of American Petroleum Institute Publication 1509 (REV:01-SEP-2011). ASTM International, formerly known as the American Society for Testing and Materials (ASTM), is a globally recognized leader in the development and delivery of international voluntary consensus standards.

“Group II+ base oil” refers to a Group II base oil having a viscosity index greater than or  
15 equal to 110 and less than 120.

“Group I, II, III, IV, and V base oils” are defined in Table E-1 of American Petroleum Institute Publication 1509 (REV:01-SEP-2011)

“Kinematic viscosity” refers to the ratio of the dynamic viscosity to the density of a material at the same temperature and pressure. Kinematic viscosity (KV) is measured at a defined  
20 temperature (e.g., 100°C) by ASTM D445-12. Shorthand for kinematic viscosity at a defined temperature may be expressed as KV100 or KV40, for example.

“Viscosity index” (VI) is an empirical, unit-less number indicating the effect of temperature change on the kinematic viscosity of the base oil or lubricant. A higher VI indicates a smaller decrease in kinematic viscosity with increasing temperature. VI is measured according to  
25 ASTM D2270-10<sup>E1</sup>.

“Detergent inhibitor (DI) additive package” refers to a carefully blended mixture of additives used to formulate lubricating oil compositions that will meet certain performance criteria. DI additive packages are commercially available from a number of additive companies. Examples of companies that supply these DI additive packages include Oronite, Lubrizol, and  
30 Infineum.

“Succinimide” refers to the product of a reaction of an alkenyl substituted succinic acid or anhydride with a nitrogen-containing compound.

5 “Succinimide dispersants” are referred to as such since they normally contain nitrogen largely  
in the form of imide functionality, although the amide functionality may be in the form of  
amine salts, amides, imidazolines, as well as mixtures thereof. Procedures for preparing  
succinimide dispersants are described, for example, in U.S. Pat. Nos. 3,172,892; 3,219,666;  
3,272,746; 4,234,435; 6,165,235; and 6,440,905. “Trim stock” refers to a base oil that may  
10 be blended with two or more other base oils, in an amount less than the two or more other  
base oils, so as to bring a low-temp cranking viscosity and NOACK volatility of a blended  
base oil mixture into a range to meet SAE J300 and API CJ-4 requirements. A trim stock, for  
example, may be a Group II, a Group II+, a Group III, a Group IV, or a Group V base oil.  
The use and selection of a trim stock is described in U.S. Patent Publication No. 2010-  
15 0077842 A1.

“NOACK volatility” is determined using ASTM D5800 – 10, which is the Standard Test  
Method for Evaporation Loss of Lubricating Oils by the NOACK Method.

“Society of Automotive Engineers (SAE) J300” refers to the Engine Oil Viscosity  
Classification most recently updated and published by SAE on April 2, 2013. The standard  
20 includes the following table:

SAE J300

SAE Viscosity Grade	Low-Temp (°C) Cranking Viscosity	Low-Temp (°C) Pumping Viscosity	Low-Shear-Rate Kinematic Viscosity		High-Shear- Rate Viscosity
	mPa.s Max	mPa.s Max with no yield stress	mm <sup>2</sup> /s at 100°C Min	mm <sup>2</sup> /s at 100°C Max	mPa.s at 150°C Min
	ASTM D5293	ASTM D4684	ASTM D445		ASTM D4683, D4741, D5481 or CEC 1-36-90
0W	6200 at -35	60,000 at -40	3.8	-	-
5W	6600 at -30	60,000 at -35	3.8	-	-
10W	7000 at -25	60,000 at -30	4.1	-	-
15W	7000 at -20	60,000 at -25	5.6	-	-
20W	9500 at -15	60,000 at -20	5.6	-	-

SAE Viscosity Grade	Low-Temp (°C) Cranking Viscosity	Low-Temp (°C) Pumping Viscosity	Low-Shear-Rate Kinematic Viscosity		High-Shear-Rate Viscosity
25W	13000 at -10	60,000 at -15	9.3	-	-
16	-	-	6.1	<8.2	2.3
20	-	-	6.9	<9.3	2.6
30	-	-	9.3	<12.5	2.9
40	-	-	12.5	<16.3	3.5(*)
40	-	-	12.5	<16.3	3.7(**)
50	-	-	16.3	<21.9	3.7
60	-	-	21.9	<26.1	3.7

5 (\*) for 0W-40, 5W-40 and 10W-40 grades (\*\*) for 15W-40, 20W-40, 25W-40 and 40 grades

“Multigrade Engine Oil” refers to a lubricant meeting requirements of both a SAE viscosity grade in the upper portion of the SAE J300 table and an SAE viscosity grade in the lower portion of the SAE J300 table, as described previously. Two non-limiting examples of  
 10 multigrade engine oils are SAE 15W-40 or SAE 15W-30.

“TBN booster” refers to an additive, or mixture of additives, that comprises a nitrogen-containing dispersant having a Total Base Number (TBN) from 45 to 145 mg KOH/g by ASTM D2896-11. In some embodiments, the nitrogen-containing dispersant may be ashless, for example a succinimide dispersant. The TBN booster can be designed primarily to provide  
 15 additional basicity to the formulation (measured as Total Base Number [TBN], by ASTM D2896-11).

“Viscosity Modifier” refers to polymeric additives that provide lubricants with high and low temperature operability. Viscosity modifiers are added to lubricants to change the lubricant’s viscous response to temperature, and they improve the lubricant’s viscosity index. Viscosity  
 20 modifiers are also known as VI improvers and viscosity index improvers.

“Pour Point Depressant” refers to an additive that lowers the pour point of a wax-containing lubricant by reducing the tendency of the wax to solidify.

“Oxidative Stability” refers to the resistance of a base oil or lubricant to react with oxygen, which can degrade the oil and contribute to varnish, deposits, and poor engine performance.

5 Oxidative stability can be measured by a number of oxidation tests, including pressurized differential scanning calorimeter (PDSC), Caterpillar Micro-Oxidation test (CMOT), and Moderately High Temperature Thermo-Oxidation Engine Test (TEOST MHT).

“Shear Stability Index” (SSI) refers to a polymer’s resistance to mechanical degradation (polymer coil breakage) under shearing stress in a European Diesel Injector Test by ASTM  
 10 D6022-06 (R 2012) and ASTM D7109. The European Diesel Injector Test (ASTM D7109-12) measures the permanent reduction in an oil’s viscosity after 30 cycles through the test apparatus. For example, a SSI of 50 means that the additive will lose 50% of the viscosity it contributes to a lubricant.

“American Petroleum Institute (API) CJ-4 service category” refers to lubricants for use in  
 15 high-speed four-stroke cycle diesel engines designed to meet 2010 model year on-highway and Tier 4 non-road exhaust emission standards as well as for previous model years. These lubricants are especially effective at sustaining emission control system durability where particulate filters and other advanced aftertreatment systems are used. API CJ-4 requirements were introduced in 2006 and are summarized below. The Standard Specification for  
 20 Performance of Active API Service Category Engine Oils is ASTM D4485-11b. The associated ASTM test numbers are shown in parentheses in the summarized requirements, below.

API CJ-4 Performance Specification (Bench Tests)

Requirements	Units	Limits (1)
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**Chemical Limits (Non-Critical)**

Sulfated Ash (D 874), max	%	1.0
Phosphorus (D 4951), max	%	0.12
Sulfur (D 4951), max	%	0.4

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**NOACK Volatility (D 5800)**

Evap Loss @250°C, Vis Grades other than 10W-30, max	%	13
Evap Loss @ 250°C, 10W-30, max	%	15

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<b>High Temp / High Shear</b>		
<b>Viscosity (D 4683)</b>		
Viscosity @150°C, min	cP	3.5
<b>Shear Stability (D 7109)</b>		
KV @100°C after 90-passes for XW-40, min	cSt	12.5
KV @100°C after 90-passes for XW-30, min	cSt	9.3
<b>Sooted Oil MRV (D 6896)</b>		
180 Hour Sample from Mack T-11 or T-11A		
Viscosity @-20°C, max	cP	25,000
Yield Stress	Pa	<35
<b>High Temp Corrosion, 135°C (D 6594)</b>		
Copper, used oil increase, max	ppm	20
Lead, used oil increase, max	ppm	120
Copper Strip Rating, max	-	3
<b>Seal Compatibility (D 7216)</b>		
<b>Nitrile/NBR</b>		
Volume Change	%	+5/-3
Hardness	Points	+7/-5
Tensile Strength	%	+10/-TMC1006
Elongation	%	+10/-TMC1006
<b>Silicone/VMQ</b>		
Volume Change	%	+TMC1006/-3
Hardness	Points	+5/-TMC1006
Tensile Strength	%	+10/-45
Elongation	%	+20/-30
<b>Polyacrylate/ACM</b>		
Volume Change	%	+5/-3
Hardness	Points	+8/-5
Tensile Strength	%	+18/-15
Elongation	%	+10/-35
<b>Fluoroelastomer/FKM</b>		
Volume Change	%	+5/-2
Hardness	Points	+7/-5
Tensile Strength	%	+10/-TMC1006
Elongation	%	+10/-TMC1006
<b>Vamac G</b>		
Volume Change	%	+TMC1006/-3
Hardness	Points	+5/-TMC1006
Tensile Strength	%	+10/-TMC1006

5	Elongation	%	+10/-TMC1006
<hr/>			
<b>Foaming (D 892)</b>			
Foaming / Settling			
	Sequence I, max	%	10 / 0
	Sequence II, max	%	20 / 0
	Sequence III, max	%	10 / 0

10

API CJ-4 Performance Specification (Engine Tests)

Requirements	Units	Limits (1)		
		<b>1-Test</b>	<b>2-Test</b>	<b>3-Test</b>

**Engine Oil Aeration (D 6894)**

Oil Aeration		8.0	8.0	8.0
Volume, max	%	(MTAC)	(MTAC)	(MTAC)

**Caterpillar 1N (D 6750)**

Top Land Heavy Carbon, max	%	3	4	5
Top Groove Fill, max	%	20	23	25
Weighted Demerits, max		demerits 286.2	311.7	323.0
Average Oil Consumption (0-252 hr), max		g/kW-hr 0.5	0.5	0.5
Ring / Liner Scuffing		None	None	None

**Caterpillar C13 (D 7549)**

Merits, min		1000 (3)	1000(3)	1000(3)
Hot Stuck Rings		None	None	None

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**Cummins ISB (D 7484)**

Tappet Wear, max	mg	100	108	112
Cam Wear, max	microns	55	59	61
Crosshead Weight Loss		Rate & Report	Rate & Report	Rate & Report

**Cummins ISM (D 7468)**

Merits, min		1000 (3)	1000(3)	1000(3)
Top Ring Wt Loss, max	mg	100	100	100

**Mack T-11 (D 7156)**

Soot at 4cSt Inc, min	%	3.5	3.4	3.3
Soot at 12cSt Inc, min	%	6.0	5.9	5.9
Soot at 15cSt Inc, min	%	6.7	6.6	6.5

**Mack T-12 (D 7156)**

Merits, min		1000 (3)	1000(3)	1000(3)
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**Roller Follower Wear**

**Test (D 5966)**

Roller Follower Pin	microns	7.6	8.4	9.1
Wear, max	(mils)	(0.30)	(0.33)	(0.36)

**Sequence IIIF**

**(D 6984) (4)**

Viscosity Inc at		275	275	275
EOT, max	%	(MTAC)	(MTAC)	(MTAC)

- (1) Limits approved at the ASTM HDEOCP meeting on January 26, 2006
- (2) Limits expressed as +/- TMC1006 determined and adjusted through reference testing
- (3) Requires all individual merit ratings to be equal to or greater than zero; see CJ-4 Merit System Summary
- (4) Passing Seq IIIF viscosity increase at API SM limits is an acceptable alternate

Summary of API CJ-4 Merit Systems

Engine Tests	Merit System Values				
	Max Merit (1)	Anchor (2)	Cap (3)	Parameter Weight	
<b>Caterpillar C13 (D 7549)</b>					
TLC	demerits	15	30	35	300
TGC	demerits	30	46	53	300
2RTC	demerits	5	22	33	100
Oil Consumption Increase	g/hr	10	25	31	300
<b>Cummins ISM (D 7468)</b>					
Crosshead Weight					
Loss	mg	4.3	5.7	7.1	350
Injector Screw Wear	mg	16	27	49	350
Oil Filter Pressure					
Delta	kPa	7	13	19	150
Sludge	merits	9.3	9.0	8.7	150
<b>Mack T-12 (D 7156)</b>					
Top Ring Weight Loss	mg	35	70	105	200
Cylinder Liner Wear	microns	12	20	24	250
Lead Increase 0-300 hrs					
	ppm	10	25	35	200
Lead Increase 250-300 hrs					
	ppm	0	10	15	200
Phase 2 Oil	g/hr	50	65	85	150

5

## Consumption

- (1) Results at the Max Merit point; merits are equal to twice the Parameter Weight; no additional merits awarded for performance better than the Max Merit level
- (2) Results at the Anchor receive merits equal to the Parameter Weight
- (3) Results at the Cap receive zero merits; performance worse than the Cap receives negative merits and the overall test result is a fail regardless of the total merit rating

## DETAILED DESCRIPTION

The lubricating oil composition comprises a combination of at least two Group II base oils and additives that are selected to meet heavy duty engine oil specifications, including  
 10 API-CJ-4.

## Base Oils

Each Group II base oil in the lubricating oil composition has a different kinematic viscosity at 100°C. A first Group II base oil has a first kinematic viscosity at 100°C from 5.0 to 8.0 mm<sup>2</sup>/s. In one embodiment the first kinematic viscosity at 100°C is from 6.2 to 7.0,  
 15 such as from 6.3 to 6.9 mm<sup>2</sup>/s. A second Group II base oil has a second kinematic viscosity from 10 to 14 mm<sup>2</sup>/s, such as from 11 to 13, or from 11.7 to 12.7 mm<sup>2</sup>/s. In one embodiment, at least one or all of the Group II base oils have viscosity indexes less than 110, such as from 90 to 109, or from 95 to 109. In one embodiment the first Group II base oil has a first  
 20 viscosity index less than 110 and the second Group II base oil has a second viscosity index less than 110.

When making the lubricating oil composition, at least two Group II base oils are blended together to make a blended base oil mixture having a blended base oil viscosity from 6.0 to 7.3 mm<sup>2</sup>/s. In one embodiment, the blended base oil mixture has a blended base oil  
 25 viscosity from 6.50 to 6.80 mm<sup>2</sup>/s. In one embodiment, no trim stock is blended into the blended base oil mixture or added to the blended base oil mixture, as trim stock is not needed to bring the lubricating oil composition to the SAE 15W-30 viscosity grade. In another embodiment, a trim stock can be added to the blended base oil mixture.

## Detergent Inhibitor Additive Package

5           The lubricating oil composition also comprises a detergent inhibitor additive package designed to meet a CJ-4 service category. In one embodiment, the detergent inhibitor additive package is one designed to meet the CJ-4 service category in a multigrade engine oil blended with one or more Group II base oils. Different detergent inhibitor additive packages are needed in Group II base oils because of their typically lower oxidative stability compared  
10 to more highly refined Group III or synthetic Group IV base oils. In one embodiment, the multigrade engine oil that the detergent inhibitor additive package is designed for is a SAE 15W-40.

          In one embodiment, the amount of the detergent inhibitor additive package in the lubricating oil composition can be from 12 to 20 wt%, such as from 13 to 19 wt%, or from 14  
15 to 17 wt%.

          In one embodiment, the detergent inhibitor additive package comprises at least one detergent, at least one dispersant, at least one antiwear agent, at least one antioxidant, and other additives.

          The detergent inhibitor additive package typically comprises at least one metal-  
20 containing detergent. The detergent can function as one or more of a) a detergent to reduce or remove deposits, b) as an acid neutralizer, or c) as a rust inhibitor. The metal-containing detergent can comprise a polar head with a long hydrophobic tail, with the polar head comprising a metal salt of an acid organic compound. In one embodiment the metal-containing detergent is overbased. Overbased metal-containing detergents can be single  
25 phase, homogeneous Newtonian systems characterized by a metal content in excess of that which would be present according to the stoichiometry of the metal and the particular acidic organic compound reacted with the metal to prepare the detergent. An overbased metal-containing detergent can be made by reacting an acidic material (typically an inorganic acid or lower carboxylic acid) with a mixture comprising an acidic organic compound in a  
30 reaction medium comprising at least one inert, organic solvent in the presence of a stoichiometric excess of a metal base and a promoter. Examples of acidic materials used to make metal-containing detergents are carboxylic acids, sulfonic acids, phosphorus-containing acids, phenols, and mixtures thereof. Mixtures of different metal-containing detergents can be present in the detergent inhibitor additive package.

5           The detergent inhibitor additive package typically comprises dispersants that can be used to maintain in suspension insoluble materials resulting from oxidation during use. The dispersants can be ashless. Nitrogen-containing ashless dispersants are basic, and contribute to the TBN of the lubricating oil composition. Representative ashless dispersants include, but are not limited to, amines, alcohols, amides, or ester polar moieties attached to a polymer backbone via bridging groups. Ashless dispersants can be selected, for example, from  
10 soluble salts, esters, amino-esters, amides, imides, and oxazolines of long chain hydrocarbon substituted mono and dicarboxylic acids or their anhydrides; thiocarboxylate derivatives of long chain hydrocarbons, long chain aliphatic hydrocarbons having polyamine attached directly thereto; and Mannich condensation products formed by condensing a long chain  
15 substituted phenol with formaldehyde and polyalkylene polyamine. Carboxylic dispersants are reaction products of carboxylic acylating agents with nitrogen containing compounds, organic hydroxyl compounds, or aromatic compounds. Succinimide dispersants are a type of carboxylic dispersant. Examples of succinimide dispersants include those described, for example, U.S. Pat. Nos. 3,172,892, 4,234,435, and 6,165,235.

20           In one embodiment, the detergent inhibitor additive package comprises more than one dispersant, such as a blend of at least at least two of the following: a succinimide dispersant, a Mannich dispersant, an ester-containing dispersant, a condensation product of a fatty hydrocarbyl monocarboxylic acylating agent with an amine or ammonia, an alkyl amino phenol dispersant, a hydrocarbyl-amine dispersant, a polyether dispersant, a polyetheramine  
25 dispersant, a viscosity modifier containing dispersant functionality (for example polymeric viscosity index modifiers (VMs) containing dispersant functionality). In one embodiment, the detergent inhibitor additive package comprises at least one ethylene carbonate- treated bis-succinimide dispersant and at least one borated bis-succinimide dispersant, such as those described in US20030224948A1 . Examples of detergent inhibitor additive packages with  
30 more than one dispersant are described in U.S. Patent Nos. 7,902,130; 8,183,187; and 8,598,099; and in WO2010075103A2.

          The detergent inhibitor additive package can comprise antioxidant compounds. These oxidation inhibitors can include, for example, hindered phenols, ashless oil soluble phenates and sulfurized phenates, alkyl-substituted diphenylamine, alkyl-substituted phenyl,  
35 naphthylamines and the like, and mixtures thereof.

5           The detergent inhibitor additive package can comprise anti-wear agents, such as molybdenum-containing complexes and metal dihydrocarbyl dithiophosphate. As their name implies, anti-wear agents reduce wear of moving metallic parts. Examples of anti-wear agents include, but are not limited to, phosphates, carbamates, esters, molybdenum complexes, and mixtures thereof. In one embodiment, the detergent inhibitor additive package can comprise  
10 a molybdenum/nitrogen-containing complex. In one embodiment, the detergent inhibitor additive package can comprise a zinc dialkylthiophosphate.

          The detergent inhibitor additive package can comprise one or more other additives that impart auxiliary functions to help meet performance specifications. These other additives can include, for example, friction modifiers, rust inhibitors, dehazing agents,  
15 demulsifying agents, metal deactivating agents, pour point depressants, viscosity modifiers, antifoaming agents, co-solvents, package compatibilisers, corrosion-inhibitors, dyes, extreme pressure agents, multifunctional additives, and mixtures thereof.

          Examples of friction modifiers include fatty alcohol, fatty acid, amine, borated ester, other esters, phosphates, phosphites, phosphonates, molybdenum compounds, and mixtures  
20 thereof. Examples of molybdenum compounds that can be used as friction modifiers include organo molybdenum compounds, molybdenum dialkyldithiocarbamates, molybdenum dialkylthiophosphates, molybdenum disulphide, trimolybdenum cluster dialkyldithiocarbamates, non-sulphur molybdenum compounds and mixtures thereof.

          Examples of rust inhibitors include one or more of the following: nonionic  
25 polyoxyethylene surface active agents: polyoxyethylene lauryl ether, polyoxyethylene higher alcohol ether, polyoxyethylene nonyl phenyl ether, polyoxyethylene octyl phenyl ether, polyoxyethylene octyl stearyl ether, polyoxyethylene oleyl ether, polyoxyethylene sorbitol monostearate, polyoxyethylene sorbitol mono-oleate, and polyethylene glycol mono-oleate. Other compounds that can function as rust inhibitors are stearic acid and other fatty acids,  
30 dicarboxylic acids, metal soaps, fatty acid amine salts, metal salts of heavy sulfonic acid, partial carboxylic acid ester of polyhydric alcohol, and phosphoric ester.

          Examples of demulsifying agents include the addition product of alkylphenol and ethylene oxide, polyoxyethylene alkyl ether, polyoxyethylene sorbitan ester, and combinations thereof.

5           Examples of pour point depressants are polymethacrylates, polyalkylmethacrylates, polyacrylates, di(tetra paraffin phenol) phthalate, condensation products of tetra paraffin phenol, and condensation product of a chlorinated paraffin wax with naphthalene. Examples of viscosity modifiers include polymethacrylate-type polymers, ethylene-propylene copolymers, styrene-isoprene copolymers, hydrated styrene-isoprene copolymers,  
10 polyisobutylene, dispersant type viscosity modifiers, and mixtures thereof.

          Examples of antifoaming agents are alkyl methacrylate polymers and dimethyl silicone polymers.

          Examples of extreme pressure agents include zinc dialky-1-dithiophosphate (primary alkyl, secondary alkyl, and aryl type), diphenyl sulfide, methyltrichlorostearate, chlorinated  
15 naphthalene, fluoroalkylpolysiloxane, lead naphthenate, neutralized phosphates, dithiophosphates, sulfur-free phosphates, and combinations thereof.

          Examples of metal deactivating agents include disalicylidene propylenediamine, triazole derivatives, mercaptobenzothiazoles, mercaptobenzimidazoles, and combinations thereof.

20           Examples of multifunctional additives include sulfurized oxymolybdenum dithiocarbamate, sulfurized oxymolybdenum organo phosphorodithioate, oxymolybdenum monoglyceride, oxymolybdenum diethylate amide, amine-molybdenum complex compound, and sulfur-containing molybdenum complex compound.

          The detergent inhibitor additive package is added to the blended base oil mixture,  
25 along with 0.50 to 4.95 wt% of a viscosity modifier.

#### Viscosity Modifier

          The lubricating oil composition comprises 0.5 to 4.95 wt% viscosity modifier, on an as received basis in a carrier oil. In other embodiments, the lubricating oil composition comprises 0.50 to 4.00 wt% or 0.75 to 3.5 wt% of the viscosity modifier. In one  
30 embodiment, the lubricating oil composition comprises 1.50 to 2.50 wt% of the viscosity modifier. Viscosity modifiers are usually supplied diluted in a carrier oil and they constitute about 5 to 50 wt% active ingredient.

5           The viscosity modifier imparts higher viscosity at elevated temperatures, and acceptable viscosity at low temperatures. Suitable viscosity modifiers are polymers and include high molecular weight (polymeric) hydrocarbons, polyesters and viscosity index improver dispersants that function as both a viscosity index improver and a dispersant. Typical molecular weights of these viscosity modifiers are from 10,000 to 1,000,000, such as  
10       from 20,000 to 500,000, or from 50,000 to 200,000.

          Examples of viscosity modifiers are polymers and copolymers of methacrylate, butadiene, olefins, or alkylated styrenes. Polyisobutylene is a specific example. Another suitable viscosity modifier is polymethacrylate (copolymers of various chain length alkyl methacrylates, for example). Other suitable viscosity modifiers include copolymers of  
15       ethylene and propylene, hydrogenated block copolymers of styrene and isoprene, hydrated styreneisoprene copolymers, polybutene, polyisobutylene, vinylpyrrolidone and methacrylate copolymers, and polyacrylates (copolymers of various chain length acrylates, for example). In one embodiment the viscosity modifier is an olefin copolymer or a hydrogenated styrene-isoprene copolymer of 50,000 to 200,000 molecular weight. In one embodiment, the  
20       viscosity modifier is a non-dispersant olefin copolymer. In one embodiment, the viscosity modifier is a shear stable polymer, such as a shear stable non-dispersant olefin copolymer. In the context of this disclosure a shear stable viscosity modifier has a shear stability index (SSI) of 10-40.

          In one embodiment, the viscosity modifier contains: a) an amino alcohol reaction  
25       product prepared by isomerizing a normal alpha olefin to form an internal olefin; epoxidizing said olefin; and reacting with a mono-hydroxyl hydrocarbyl amine; and b) an ester of glycerol and a carboxylic acid containing 0 to 3 double bonds. These friction modifiers are described in U.S. Pat. No. 8,703,680.

#### TBN Booster

30           The lubricating oil composition can also comprise a TBN booster that raises the TBN of the lubricating oil composition. In one embodiment, the TBN booster raises the TBN of the lubricating oil composition to from 8.55 to 11.00 mg KOH/g by ASTM D2896-11. As indicated previously, the TBN booster can be designed primarily to provide additional basicity to the formulation (measured as total base number (TBN), by ASTM D2896-11).  
35       The additional basicity provided by a TBN booster can be used to distinguish between

5 different formulations of lubricating oil compositions and can also provide additional corrosion protection, since corrosion is less likely to occur in a moderately alkaline environment. Acids can be generated from fuel combustion or from oxidation of engine oil in hot spots, and the additional basicity can neutralize these acids. If the TBN of the engine oil is too high, the engine oil can also become aggressive to metal surfaces and appear as  
10 wear in engine tests.

Examples of TBN boosters are described in US20130281336A1, US20120040876A1, WO2014033634A2, JP2013072088A, US8703682B2, US20110105374A1, US7749948B2, and EP708171B1. In one embodiment, the lubricating oil composition comprises 0.50 to 3.50 wt% of the TBN booster, such as (for example) 0.75 to 2.25 wt% of the TBN booster.

15 In one embodiment, the TBN booster comprises at least 60 wt% dispersants, at least an antioxidant, and less than 5 wt% overbased metal detergent. In another embodiment, the TBN booster comprises at least two dispersants, at least an anti-oxidant, and at least a detergent.

20 Examples of dispersants that can be used in the TBN booster include one or more of borated dispersants and non-borated dispersants. In one embodiment, the dispersants used in the TBN booster are ashless. Examples of ashless dispersants are alkenyl succinimides and succinimides. These dispersants can be further modified by reaction with, for example, with boron or ethylene carbonate. Ester-based ashless dispersants derived from long chain hydrocarbon-substituted carboxylic acids and hydroxy compounds may also be employed.  
25 Other ashless dispersants are those derived from polyisobutenyl succinic anhydride.

In one embodiment, the dispersant used in the TBN booster is a non-conventional polysuccinimide dispersant derived from terpolymer PIBSA, N-phenylenediamine and a polyether amine. Dispersants of this type are described in U.S. Pat. No. 7,745,541.

30 Examples of antioxidants that can be used in the TBN booster include one or more of esters of thiodicarboxylic acids, di-thiocarbamates, such as 15-methylenebis (di-butyl di-thiocarbamate), salts of di-thiophosphoric acids, alkyl or aryl phosphates. Molybdenum compounds, such as amine-molybdenum complex compound and molybdenum di-thiocarbamates may also be used as anti-oxidants and hindered phenols, such as 4,4'-methylene-bis(2,6-di-tert-butylphenol), 4,4'-bis(2,6-di-tert-butylphenol), 4,4'-bis(2-methyl -

5 6-tert-butylphenol), 2,2'-methylene-bis(4-methyl-6-tert-butylphenol), 4,4'-butylidene-bis  
(3-methyl-6-tertbutylphenol), 4,4'-isopropylidene-bis(2,6-di-tertbutylphenol), 2,2'-  
methylene-bis(4-methyl-6-nonylphenol), 2,2'-isobutylidene-bis(4,6-dimethylphenol), 2,2'-  
5-methylene-bis(4-methyl-6-cyclohexylphenol), 2,6-di-tert-butyl-4-methylphenol, 2,6-di-  
tert-butyl-4-ethylphenol, 2,4-dimethyl-6-tert-butyl-phenol, 2,6-di-tert-butyl-dimethylamino-p-  
10 cresol, 2,6-di-tert-butyl-4-(N,N'-dimethylaminomethylphenol), 4,4'-thio-bis(2-methyl-6-tert-  
butylphenol), 2,2'-thiobis(4-methyl-6-tert-butylphenol), bis(3-methyl-4-hydroxy-5-tert-butyl-  
benzyl)-sulfide, and bis(3,5-di-tert-butyl-4-hydroxybenzyl). In one embodiment the  
TBN booster comprises hindered phenols that do not contribute to the phosphorus, sulfur and  
sulfated ash content of the engine oil.

15 In one embodiment, the TBN booster comprises 15 to 30 wt% of a diphenyl amine  
antioxidant. In one embodiment, the TBN booster comprises 20 to 40 wt% of an ashless non-  
borated dispersant. In one embodiment, the TBN booster comprises 35 to 50 wt% of a  
borated dispersant. In one embodiment, the TBN booster comprises 0.5 to 3 wt% of a  
magnesium sulfonate detergent. For example, the TBN booster can comprise 15 to 30 wt%  
20 of a diphenyl amine antioxidant, 20 to 40 wt% of an ashless non-borated dispersant, 35 to 50  
wt% of an ashless borated dispersant, and 0.5 to 3 wt% of a magnesium sulfonate detergent.

Examples of diphenyl amine antioxidants that may be included in the TBN booster  
include monoalkylated diphenylamine, dialkylated diphenylamine, trialkylated  
diphenylamine, and mixtures thereof. Some of these include butyldiphenylamine, di-  
25 butyldiphenylamine, octyldiphenylamine, di-octyldiphenylamine, nonyldiphenylamine, di-  
nonyldiphenylamine, t-butyl-t-octyldiphenylamine, and mixtures thereof.

Examples of overbased metal detergents that can be included in the TBN booster are  
low and high overbased sulfonic acids or phenols or Mannich condensation products of  
alkylphenols, aldehydes and amines. In one embodiment, the overbased metal detergent in  
30 the TBN booster does not include overbased salicylic acids or carboxylic acids. In one  
embodiment the overbased metal detergent that can be included in the TBN booster is a  
highly overbased magnesium sulfonate detergent having a TBN of about 300 or greater, such  
as about 350 to 500. For example, the highly overbased magnesium sulfonate detergent can  
be a highly overbased magnesium alkyltoluene sulfonate, such as described in U.S. Patent  
35 Pub. No. 20110136711 A1.

## 5 Other Additives

A small amount of pour point depressant can also be blended into the lubricating oil composition. When used, the amount of pour point depressant included in the lubricating oil composition can be 0.01 to 2.00 wt%. Examples of pour point depressants are polymethacrylates, polyalkylmethacrylates, polyacrylates, di(tetra paraffin phenol) phthalate, 10 condensation products of tetra paraffin phenol, and condensation product of a chlorinated paraffin wax with naphthalene. These pour point depressants, and other suitable additives that can be included in the lubricating oil composition, are described in Chemistry and Technology of Lubricants (Google eBook), R. M. Mortier, Malcolm F. Fox, S. T. Orszulik, Springer, Apr 14, 2011.

15 Other suitable additives that can be blended into the lubricating oil composition can include friction modifiers, rust inhibitors, dehazing agents, demulsifying agents, metal deactivating agents, antifoaming agents, co-solvents, package compatibilisers, corrosion-inhibitors, dyes, extreme pressure agents, and mixtures thereof.

In one embodiment, the step of adding the detergent inhibitor additive package, the TBN booster (when used), and the viscosity modifier to the blended base oil mixture is done 20 such that the resulting lubricating oil composition comprises 70 to 85 wt% of the first Group II base oil and from 2.0 to 6.5 wt% of the second Group II base oil.

In one embodiment, the step of adding the detergent inhibitor additive package, the TBN booster (when used), and the viscosity modifier to the blended base oil mixture is done 25 such that the resulting lubricating oil composition has a sulfated ash from 0.50 to 1.10 wt%, such as from 0.60 to 1.05 wt%. In another embodiment, the step of adding the detergent inhibitor additive package, the TBN booster (when used), and the viscosity modifier to the blended base oil mixture is done such that the resulting lubricating oil composition has a sulfated ash of 1.0 or less, such as 0.65 to 1.00 wt%

30 In one embodiment, the step of adding the TBN booster to the blended base oil mixture is done such that the lubricating oil composition comprises 0.75 to 2.25 wt% of the TBN booster.

5            In one embodiment, the step of adding the viscosity modifier to the blended base oil mixture is done such that the lubricating oil composition comprises 0.75 to 3.5 wt% of the viscosity modifier.

#### Lubricating Oil Composition Performance

10            In one embodiment the SAE 15W-30 lubricating oil composition of the present invention meets API CJ-4. Other industry specifications that the SAE 15W-30 lubricating oil composition can meet include API SM, Cummins CES 20081, Daimler MB 228.31, Volvo VDS-4, Mack Trucks (Volvo) EO-O Premium Plus 2007, Renault Trucks (Volvo) RLD-3, Caterpillar ECF-3, Detroit Diesel Power Guard 93K218, Deutz DQC III-10 LA, MAN Truck & Bus M3575.

15            The SAE 15W-30 lubricating oil composition of the present invention has excellent oxidative stability as demonstrated in the Caterpillar Micro-Oxidation Test (CMOT). CMOT is a test used to measure the thermal and oxidative stability of fully formulated diesel engine oils under thin film conditions. This test provides an indication as to whether a candidate oil is worthy of field trial in a Caterpillar 3600 series engine. The results generated in the  
20            CMOT give an Induction Time in minutes indicating relative time for antioxidants in the oil to deplete. The development of the Caterpillar Micro-Oxidation Test (CMOT) is discussed in #890239 of the SAE Technical Paper Series "Evaluation of Diesel Engine Lubricants by Micro-Oxidation," authored by Fulvio N. Zerla and Robert A. Moore. The induction time to deposit formation in the CMOT can be determined by calculating the intercept between a  
25            baseline formed where minimal deposits are seen, and the slope formed where a rapid rise in deposit formation is seen. Longer induction times correspond to improved deposit control. An Induction Time of 70 minutes or greater is generally considered acceptable for some heavy duty engine oils. In its publication SEBU7003-4 "Caterpillar 3600 Series and C 280 Series Diesel Engines Fluids Recommendation", Caterpillar specifies that engine oil must  
30            demonstrate a minimum Induction Time of 90 minutes in the CMOT. The SAE 15W-30 lubricating oil composition provides an Induction Time in the CMOT from 270 to 450 minutes, such as from 330 to 400 minutes, or 350 to 400 minutes. In one embodiment, the SAE 15W-30 lubricating oil composition also provides less than 20 mg total deposits, such as only 5 to 16 mg total deposits, in a Moderately High Temperature (MHT) Thermo-Oxidation  
35            Engine Test by ASTM D7097-09.

5           The SAE 15W-30 lubricating oil composition additionally can provide excellent engine wear protection. In one embodiment, the SAE 15W-30 lubricating oil composition provides an average cam lobe wear in the Cummins ISB test less than 49  $\mu\text{m}$ , such as from 15 to 48  $\mu\text{m}$  or from 20 to 45  $\mu\text{m}$ . In one embodiment, the SAE 15W-30 lubricating oil composition provides an average cam and lifter wear in a Sequence III G test less than 22  $\mu\text{m}$ ,  
10           such as from 5 to 20  $\mu\text{m}$ . In one embodiment, the SAE 15W-30 lubricating oil composition provides a cam wear average in a Sequence IVA test less than 11  $\mu\text{m}$ , such as from 1 to 10  $\mu\text{m}$ .

          In one embodiment, the SAE 15W-30 lubricating oil provides superior shear stability. In one embodiment, the SAE 15W-30 lubricating oil composition provides a percent  
15           viscosity loss of the 30-cycle sheared oil (PVL30) of less than 0.80%, such as from 0.20 to 0.60%. In one embodiment, the SAE 15W-30 lubricating oil composition provides a percent viscosity loss of the 90-cycle sheared oil (PVL90) of less than 1.00%, such as from 0.20 to 0.80%. In one embodiment, the SAE 15W-30 lubricating oil composition provides a percent change in viscosity at 100°C in the KRL Shear Stability Test, performed according to CEC-  
20           L-45-99, less than 20%, such as from 6 to 16%.

## EXAMPLES

### **Example 1:** Lubricating Oil Compositions

          Three different lubricating oil compositions with different viscosity grades were blended as described in Table 1. These lubricating oil compositions were formulated to  
25           meet heavy duty engine oil specifications and major diesel engine manufacturers' requirements.

          Base oil blends were mixed to meet defined base oil blend viscosities and then engine oil additives were mixed into the base oil blends in proportions needed to give a  
30           sulfated ash of 0.65 to 1.00 wt%, a TBN from 7.5 to 9.5 mg KOH/g, a High-Temperature High-Shear (HTHS) from 3.5 to 4.0 mPa·s, and a kinematic viscosity at 100°C within the defined viscosity grades of SAE 10W-30, SAE 15W-30, or SAE 15W-40. Less than 7 wt% of a trim stock, Chevron 110RLV, was used to bring the blend oil viscosity into the desired range for the SAE 10W-30 lubricating oil  
35           composition. No trim stock was used in formulating the SAE 15W-30 or SAE 15W-40 lubricating oil compositions.

5 Table 1

Components, wt%	SAE 10W-30	SAE 15W-30	SAE 15W-40
	Chevron Ursa® Super Plus EC 10W-30	Example Lubricating Oil Composition	Chevron Ursa® Super Plus EC 15W-40
Chevron 220R	33.69	77.12	69.98
Chevron 600R	7.84	4.22	8.62
Chevron 110RLV	5.66	0	0
Estimated Base Oil Blend Viscosity, mm <sup>2</sup> /s	5.66	6.65	6.89
DI Additive Package, wt%	16.9	14.69 + 1 TBN booster	14.69
Viscosity Modifier, wt%	4.35	2.0	6.31
Pour Point Depressant, wt%	0.40	0.40	0.40

Ursa®, OLOA®, and PARATONE® are registered trademarks owned by Chevron Intellectual Property L.L.C.

10 Chevron 220R , Chevron 600R, and Chevron 110RLV are API Group II base oils from Chevron Corporation. Chevron 220R and Chevron 600R had viscosity indexes from 102 to 109. Chevron 110RLV had a viscosity index from 110 to 119. The Detergent Inhibitor (DI) Additive Packages used were either used alone or with the addition of a TBN booster. The TBN booster had a TBN from 50 to 62 mg KOH/g by ASTM D2896-11. The TBN booster contributed the following to the lubricating oil composition: 0.5 wt% non-borated dispersant  
 15 as described in U.S. Pat. No. 7,745,541, 0.394 wt% diphenyl amine antioxidant, 0.75 wt% borated succinimide dispersant, 0.03 wt% heavy overbased magnesium sulfonate detergent, and 0.07 wt% diluent oil. The TBN booster, when used, was used in an amount to raise the TBN by about 1.0 base number by ASTM D2896-11, but it did not increase the sulfated ash above 1.00 in the lubricating oil composition. In this example the total amount of the TBN  
 20 booster used was 1.744 wt%

The Detergent Inhibitor (DI) Additive Packages used in the base oil blends of this example were heavy duty diesel engine oil additives designed to meet or exceed the API Service Category CJ-4 in the SAE 15W-40 viscosity grade when blended with Group II base oils.

- 5 The Viscosity Modifiers that were used were Lubrizol® 7075F or PARATONE® 8011, which are shear stable non-dispersant olefin copolymer viscosity modifiers.

The pour point depressant that was used was a polyalkylmethacrylate (PAMA), Viscoplex™ 1-604, a trademarked pour point depressant from Degussa of Germany.

- 10 Key properties of these three different blends are summarized in Table 2.

Table 2

	SAE 10W-30	SAE 15W-30	SAE 15W-40
	Chevron Ursa® Super Plus EC 10W-30		Chevron Ursa® Super Plus EC 15W-40
Kinematic Viscosity at 100°C, mm <sup>2</sup> /s, ASTM D445-12	12.0	12.0	15.4
TBN, ASTM D2896-11	8.5	9.0	8.0
Sulfated Ash, Wt%, ASTM D874-13a	1.00	1.00	1.00
HTHS at 150°C, mPa·s, ASTM D5481-13	3.60	3.60	3.90

**Example 2:** Performance Tests for Oxidation Stability

- 15 The lubricating oil compositions described in Example 1 were tested in a number of oxidation tests as shown in Table 3. Where more than one result is shown, these are replicated tests.

Table 3

Oxidation Test	Method	SAE 10W-30	SAE 15W-30	SAE 15W-40
Pressurized Differential Scanning Calorimeter (PDSC), minutes	CEC L-85-99	91.3, 91.5	>120	119.6, >120
Caterpillar Micro-Oxidation	See below	71.1, 77.3	357.6, 370.7	269, 269.3

Oxidation Test	Method	SAE 10W-30	SAE 15W-30	SAE 15W-40
Test, minutes				
Moderately High Temperature Thermo-Oxidation Engine Test (TEOST MHT), mg total deposit	ASTM D7097-09	40.2, 37.7	10, 11.2	19.4, 19.1

5

TEOST and MHT are registered trademarks of the Tannas Co. The European Automobile Manufacturers' Association (ACEA) represents the 15 Europe-based car, van, truck and bus makers: BMW Group, Daimler, DAF, Fiat, Ford of Europe, General Motors Europe, Hyundai Motor Europe, Iveco, Jaguar Land Rover, PSA Peugeot Citroën, Renault, Toyota Motor Europe, Volkswagen Group, Volvo Cars, Volvo Group. The Coordinating European Council's CEC L-85-T-99 pressurized differential scanning calorimeter (PDSC) test was developed in Europe for the ACEA specifications for heavy duty diesel oils. This test differentiates between base oils and additives, and indicates synergies between antioxidants. The PDSC results can correlate with other oxidation tests.

10

15

Notably, this 15W-30 lubricating oil composition has met all the requirements for API CJ-4, API SM, Cummins CES 20081, Volvo VDS-4, Mack Trucks (Volvo) EO-O Premium Plus 2007, Renault Trucks (Volvo) RLD-3, and Caterpillar ECF-3. The oxidative stability of this SAE 15W-30 lubricating oil composition was outstanding.

20

**Example 3: Shear Stability Tests**

The lubricating oil compositions described in Example 1 were tested in two different shear stability tests. The percent viscosity losses obtained in these tests are shown in Table 4.

Table 4

Test	Method	SAE 10W-30	SAE 15W-30	SAE 15W-40
Shear Stability	ASTM			
PVL30	D7109-12	0.86	0.45	1.55
PVL90		1.01	0.57	4.27
KRL % Viscosity Loss	CEC-L-45-99	20.38	12.45	28.85

- 5 The KRL shear stability test was performed in a taper roller bearing rig, according to the CEC-L-45-99 test method that published May 28, 2014. All three lubricating oil compositions provided acceptable shear stability performance, but the SAE 15W-30 lubricating oil composition provided improved results in both shear stability tests.

**Example 4:** Performance Tests for Engine Wear

The lubricating oil compositions described in Example 1 were tested in three different engine tests, as shown in Table 4.

Table 5

Engine Test	Method	SAE 10W-30	SAE 15W-30	SAE 15W-40
Cummins ISB	ASTM D7484-13a			
Avg. Slider Tappet Wt. Loss, mg		77.1	65	91
Avg. Cam Lobe Wear, $\mu\text{m}$		39.6	26	49
Avg. Crosshead Wt. Loss, mg		2.7	5.1	2.4
Sequence IIIG	ASTM D7320-13			
KV40 Increase at 40°C, %		Not tested	76	71
Avg. Piston Skirt Varnish, rating			10	9.5
Weighted Piston Deposit Rating			6	4.9
Avg. Cam and Lifter Wear, $\mu\text{m}$			11	22
Hot Stuck Rings			None	None
Oil Consumption, liters			3	2.3
Sequence IVA	ASTM D6891-13a			
Avg. Cam Wear, $\mu\text{m}$		Not tested	2	11

All three lubricating oil compositions provided acceptable engine performance, but the SAE 15W-30 lubricating oil composition provided improved wear results in the Cummins ISB and Sequence IVA engine tests.

5           The transitional term "comprising", which is synonymous with "including," "containing," or  
"characterized by," is inclusive or open-ended and does not exclude additional, unrecited  
elements or method steps. The transitional phrase "consisting of" excludes any element, step, or  
ingredient not specified in the claim. The transitional phrase "consisting essentially of" limits the  
scope of a claim to the specified materials or steps "and those that do not materially affect the  
10 basic and novel characteristic(s)" of the claimed invention.

For the purposes of this specification and appended claims, unless otherwise indicated, all  
numbers expressing quantities, percentages or proportions, and other numerical values used in  
the specification and claims, are to be understood as being modified in all instances by the term  
"about." Furthermore, all ranges disclosed herein are inclusive of the endpoints and are  
15 independently combinable. Whenever a numerical range with a lower limit and an upper limit  
are disclosed, any number falling within the range is also specifically disclosed. Unless  
otherwise specified, all percentages are in weight percent.

Any term, abbreviation or shorthand not defined is understood to have the ordinary  
meaning used by a person skilled in the art at the time the application is filed. The singular  
20 forms "a," "an," and "the," include plural references unless expressly and unequivocally limited  
to one instance.

All of the publications, patents and patent applications cited in this application are herein  
incorporated by reference in their entirety to the same extent as if the disclosure of each  
individual publication, patent application or patent was specifically and individually indicated to  
25 be incorporated by reference in its entirety.

This written description uses examples to disclose the invention, including the best  
mode, and also to enable any person skilled in the art to make and use the invention. Many  
modifications of the exemplary embodiments of the invention disclosed above will readily occur  
to those skilled in the art. Accordingly, the invention is to be construed as including all structure  
30 and methods that fall within the scope of the appended claims. Unless otherwise specified, the  
recitation of a genus of elements, materials or other components, from which an individual  
component or mixture of components can be selected, is intended to include all possible sub-  
generic combinations of the listed components and mixtures thereof.

The invention illustratively disclosed herein suitably may be practiced in the absence of  
35 any element which is not specifically disclosed herein.

## 5 IT IS CLAIMED:

## 1. A lubricating oil composition, comprising:

a. a first Group II base oil having a first kinematic viscosity at 100°C from 5.0 to 8.0 mm<sup>2</sup>/s;

10 b. a second Group II base oil having a second kinematic viscosity at 100°C from 10 to 14 mm<sup>2</sup>/s;

c. a detergent inhibitor additive package designed to meet an API CJ-4 service category; and

15 d. 0.50 to 4.95 wt % of a viscosity modifier; wherein the lubricating oil composition has a SAE 15W-30 viscosity grade by SAE J300, a TBN by ASTM D2896-11 from 8.55 to 11.00 mg KOH/g; and wherein the lubricating oil composition provides an Induction Time in a Caterpillar Micro-Oxidation Test from 270 to 450 minutes.

2. The lubricating oil composition of claim 1, additionally comprising a TBN booster.

20 3. The lubricating oil composition of claim 1, wherein the first Group II base oil has a first viscosity index less than 110 and the second Group II base oil has a second viscosity index less than 110.

4. The lubricating oil composition of claim 1, wherein the first Group II base oil has the first kinematic viscosity at 100°C from 6.2 to 7.0 mm<sup>2</sup>/s and the second Group II base oil has the second kinematic viscosity at 100°C from 11.0 to 13.0 mm<sup>2</sup>/s.

25 5. The lubricating oil composition of claim 1, wherein no trim stock is used to bring the lubricating oil composition to the 15W-30 viscosity grade.

6. The lubricating oil composition of claim 1, wherein the lubricating oil composition has a sulfated ash from 0.65 to 1.00 wt%.

30 7. The lubricating oil composition of claim 1, wherein the lubricating oil composition provides 5 to 16 mg total deposits in a Moderately High Temperature Thermo-Oxidation Engine Test as determined by ASTM D7097-09.

- 5 8. The lubricating oil composition of claim 1, wherein the lubricating oil composition provides a percent change in viscosity at 100°C in the KRL Shear Stability Test, performed according to CEC-L-45-99, less than 20%.
9. A process for making a lubricating oil composition, comprising:
- 10 a. blending a first Group II base oil having a kinematic viscosity at 100°C from 5.0 to 8.0 mm<sup>2</sup>/s with a second Group II base oil having a second kinematic viscosity at 100°C from 10 to 14 mm<sup>2</sup>/s to make a blended base oil mixture having a blended base oil kinematic viscosity at 100°C from 6.0 mm<sup>2</sup>/s to 7.3 mm<sup>2</sup>/s; and
- b. adding to the blended base oil mixture:
- 15 i. a detergent inhibitor additive package designed to meet an API CJ-4 service category; and
- ii. 0.5 to 4.95 wt% of a viscosity modifier to make the lubricating oil composition; wherein the lubricating oil composition has an SAE 15W-30 viscosity grade by SAE J300, a TBN from 8.55 to 11.00 mg KOH/g by ASTM D2896-11; and wherein the lubricating oil composition provides an Induction Time in a Caterpillar
- 20 Micro-Oxidation Test from 270 to 450 minutes.
10. The process of claim 9, wherein the first Group II base oil has a first viscosity index less than 110 and the second Group II base oil has a second viscosity index less than 110.
11. The process of claim 9, wherein no trim stock is blended into the blended base oil mixture or added to the blended base oil mixture.
- 25 12. The process of claim 9, wherein the adding to the blended base oil mixture is done such that the lubricating oil composition comprises 70 to 85 wt% of the first Group II base oil and from 2.0 to 6.5 wt% of the second Group II base oil.
13. The process of claim 9, additionally comprising adding a TBN booster to the blended base oil mixture.
- 30 14. The process of claim 9, wherein the adding to the blended base oil mixture is done such that the lubricating oil composition has a sulfated ash of 0.65 to 1.00 wt%.

- 5        15. The process of claim 9, wherein the blended base oil kinematic viscosity at 100°C is from 6.50 mm<sup>2</sup>/s to 6.80 mm<sup>2</sup>/s.
16. A method of operating an engine, comprising lubricating the engine with the lubricating oil composition of claim 1, wherein operating the engine with the lubricating oil composition provides one or more of:
- 10        a) an average cam lobe wear in a Cummins ISB test from 20 to 45 μm;
- b) an average cam and lifter wear in a Sequence IIIG test from 5 to 20 μm;
- c) a cam wear average in a Sequence IVA test from 1 to 10 μm; and
- d) 5 to 16 mg total deposits in a Moderately High Temperature Thermo-Oxidation Engine Test by ASTM D7097-09.

**AMENDED CLAIMS**  
**received by the International Bureau on 26 August 2015 (26.08.2015)**

IT IS CLAIMED:

1. A lubricating oil composition, comprising:
  - a. a first Group II base oil having a first kinematic viscosity at 100°C from 5.0 to 8.0 mm<sup>2</sup>/s;
  - b. a second Group II base oil having a second kinematic viscosity at 100°C from 10 to 14 mm<sup>2</sup>/s;
  - c. a detergent inhibitor additive package designed to meet an API CJ-4 service category;
  - d. a TBN booster comprising 15 to 30 wt% of diphenyl amine antioxidant, 20 to 40 wt% of an ashless non-borated dispersant, 35 to 50 wt% of an ashless borated dispersant, and and 0.5 to 3 wt% of a magnesium sulfonate detergent; and
  - e. 0.50 to 4.95 wt % of a viscosity modifier; wherein the lubricating oil composition has a SAE 15W-30 viscosity grade by SAE J300, a TBN by ASTM D2896-11 from 8.55 to 11.00 mg KOH/g; and wherein the lubricating oil composition provides an Induction Time in a Caterpillar Micro-Oxidation Test from 270 to 450 minutes.
2. (cancelled)
3. The lubricating oil composition of claim 1, wherein the first Group II base oil has a first viscosity index less than 110 and the second Group II base oil has a second viscosity index less than 110.
4. The lubricating oil composition of claim 1, wherein the first Group II base oil has the first kinematic viscosity at 100°C from 6.2 to 7.0 mm<sup>2</sup>/s and the

- second Group II base oil has the second kinematic viscosity at 100°C from 11.0 to 13.0 mm<sup>2</sup>/s.
5. The lubricating oil composition of claim 3, wherein no trim stock having a viscosity index greater than or equal to 110 is used to bring the lubricating oil composition to the 15W-30 viscosity grade.
  6. The lubricating oil composition of claim 1, wherein the lubricating oil composition has a sulfated ash from 0.65 to 1.00 wt%.
  7. The lubricating oil composition of claim 1, wherein the lubricating oil composition provides 5 to 16 mg total deposits in a Moderately High Temperature Thermo-Oxidation Engine Oil Simulation Test (TEOST MHT) as determined by ASTM D7097-09.
  8. The lubricating oil composition of claim 1, wherein the lubricating oil composition provides a percent change in viscosity at 100°C in the KRL Shear Stability Test, performed according to CEC-L-45-99, less than 20%.
  9. A process for making a lubricating oil composition, comprising:
    - a. blending a first Group II base oil having a kinematic viscosity at 100°C from 5.0 to 8.0 mm<sup>2</sup>/s with a second Group II base oil having a second kinematic viscosity at 100°C from 10 to 14 mm<sup>2</sup>/s to make a blended base oil mixture having a blended base oil kinematic viscosity at 100°C from 6.0 mm<sup>2</sup>/s to 7.3 mm<sup>2</sup>/s; and
    - b. adding to the blended base oil mixture:
      - i. a detergent inhibitor additive package designed to meet an API CJ-4 service category;
      - ii. 0.50 to 3.50 wt% of a TBN booster comprising 15 to 30 wt% of a diphenyl amine antioxidant, 20 to 40 wt% of an ashless non-borated

dispersant, 35 to 50 wt% of an ashless borated dispersant, and 0.5 to 3 wt% of a magnesium sulfonate detergent; and

iii. 0.5 to 4.95 wt% of a viscosity modifier to make the lubricating oil composition; wherein the lubricating oil composition has an SAE 15W-30 viscosity grade by SAE J300, a TBN from 8.55 to 11.00 mg KOH/g by ASTM D2896-11; and wherein the lubricating oil composition provides an Induction Time in a Caterpillar Micro-Oxidation Test from 270 to 450 minutes.

10. The process of claim 9, wherein the first Group II base oil has a first viscosity index less than 110 and the second Group II base oil has a second viscosity index less than 110.
11. The process of claim 10, wherein no trim stock having a viscosity index greater than or equal to 110 is blended into the blended base oil mixture or added to the blended base oil mixture.
12. The process of claim 9, wherein the adding to the blended base oil mixture is done such that the lubricating oil composition comprises 70 to 85 wt% of the first Group II base oil and from 2.0 to 6.5 wt% of the second Group II base oil.
13. (cancelled)
14. The process of claim 9, wherein the adding to the blended base oil mixture is done such that the lubricating oil composition has a sulfated ash of 0.65 to 1.00 wt%.
15. The process of claim 9, wherein the blended base oil kinematic viscosity at 100°C is from 6.50 mm<sup>2</sup>/s to 6.80 mm<sup>2</sup>/s.

16. A method of operating an engine, comprising lubricating the engine with the lubricating oil composition of claim 1, wherein operating the engine with the lubricating oil composition provides one or more of:

a) an average cam lobe wear in a Cummins ISB test from 20 to 45  $\mu\text{m}$ ;

b) an average cam and lifter wear in a Sequence III G test from 5 to 20  $\mu\text{m}$ ;

c) a cam wear average in a Sequence IVA test from 1 to 10  $\mu\text{m}$ ; or

d) 5 to 16 mg total deposits in a Moderately High Temperature Thermo-Oxidation Engine Oil Simulation Test (TEOST MHT) by ASTM D7097-09.

17. A method of operating an engine, comprising lubricating the engine with the lubricating oil composition made by the process of claim 9, wherein operating the engine with the lubricating oil composition provides one or more of:

a) an average cam lobe wear in a Cummins ISB test from 20 to 45  $\mu\text{m}$ ;

b) an average cam and lifter wear in a Sequence III G test from 5 to 20  $\mu\text{m}$ ;

c) a cam wear average in a Sequence IVA test from 1 to 10  $\mu\text{m}$ ; or

d) 5 to 16 mg total deposits in a Moderately High Temperature Thermo-Oxidation Engine Oil Simulation Test (TEOST MHT) by ASTM D7097-09.

INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2015/016264

A. CLASSIFICATION OF SUBJECT MATTER  
 INV. C10M169/04 C10M171/02  
 ADD. C10N20/02 C10N30/04 C10N30/10 C10N40/25  
 According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED  
 Minimum documentation searched (classification system followed by classification symbols)  
 C10M C10N  
 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
 EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents :

<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&amp;" document member of the same patent family</p>
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Date of the actual completion of the international search <b>17 June 2015</b>	Date of mailing of the international search report <b>06/07/2015</b>
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer <b>Keipert, Olaf</b>
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A	WO 2012/080441 A1 (SHELL INT RESEARCH [NL]; WEDLOCK DAVID JOHN [GB]) 21 June 2012 (2012-06-21) examples -----	1-16
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