2nd VegOil

Demonstration of 2nd Generation Vegetable Oil Fuels in Advanced Engines

Workpackage WP4

Engine Oil Development

Deliverable N° 4.2:

Conclusions from Engine lubricant Bench Marking

Version: 1

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1 Engine Lubricant Analysis

An ACEA E9 engine lubricant (ref: section 2) was supplied to the relevant laboratories to conduct their bench marking exercises (ref: Work Package 4, Deliverable 4.1). Used engine lubricant samples were provided to Lubrizol by John Deere and LVK-TUM from these bench marking exercises for chemical and physical analysis.

The used engine lubricant samples were analysed for Total Base Number (TBN by method D2896), Kinematic Viscosity (tested at 40^{o}C and 100^{o}C by method D7279), Total Acid Number (TAN by method D664), wear metals and engine lubricant additive depletion, measured by Inductive Coupled Plasma (ICP) and percentage soot measured by Thermogravimetic Analysis (TGA).

The analytical data (ref: Table 1) from the used oil engine lubricant samples was compared against the analytical data from the fresh engine lubricant. No significant degradation of the ACEA E9 engine lubricant was noted. It is therefore concluded that the ACEA E9 lubricant is suitable to be assessed in the field trial element of the 2nd VegOil project.

Table 1 Analytical Data from ACEA E9 Engine Lubricant (Fresh Lubricant and Used Lubricant from Bench Marking Exercise)

Chemical Identity	E9 Fresh Oil	ACEA E9 (OS240946 - Drain Oil) John Deere Bench Test	LVK-TUM 2ND VEG OIL (ACEA E9) 09.02.2009	LVK-TUM 2ND VEG OIL (ACEA E9) 23.04.2009
Sample Details	**Fresh Oil**	**Bench Test Sample**	**Engine Running in Sample**	**Before Veb Oil Adaption**
OS Number	OS240946	OS246257	OS247779	OS247780
D2896 Total Base Number				
TBN mg KOH/g	8.4	8.35	8.79	8.73
D7279_Kinematic Viscosity				
KV HOUILLON 40 cSt		106	116	112
KV HOUILLON 100 cSt	16.2	14.1	15.4	14.95
KV HOUILLON VI		135	139	138
D664 Total Acid Number				
TAN BUFFER mg KOH/g		3.49	2.21	2.87
ICP/AES ANALYSIS				
BA ppm	<0.001	0	18	2
CA ppm	2295	2399	2366	2359
CU ppm	<0.001	5	3	2
FE ppm	<0.001	12	8	7
MG ppm	<0.001	6	22	11
NA ppm	<0.001	2	4	0
P ppm	1073	1088	1036	1045
S ppm	3518	3964	4660	4397
SI ppm	<0.001	32	5	5
ZN ppm	1227	1189	1183	1172
SOOT measured by TGA				
CARBON %wt	0.0	0.15	1.0	1.0

2 Engine Lubricants Selection for 2nd VegOil Project

The engine lubricants chosen to be researched as part of the 2nd VegOil project are:

- OS240946 = a lubricant which is capable of meeting the ACEA E9-2008 specification
- OS241936 = a lubricant which is capable of meeting the ACEA E7-2008 specification

The ACEA 2008 nomenclature and specifications for E7 and E9 lubricants is detailed in Appendix A. Appendix A reproduces the ACEA 2008 specifications which are available from the ACEA website (http://www.acea.be)

Appendix A

ACEA 2008 European Oil Sequences

A C E A
European
Automobile
Manufacturers
Association

ACEA EUROPEAN OIL SEQUENCES

2008

SERVICE FILL OILS FOR GASOLINE ENGINES LIGHT DUTY DIESEL ENGINES ENGINES WITH AFTER TREATMENT DEVICES and HEAVY DUTY DIESEL ENGINES

Laboratory tests for gasoline and light duty diesel engine oils,
Engine tests for gasoline and light duty diesel engine oils,
Laboratory tests for engine with after treatment devices,
Engine tests for engine with after treatment devices.
Laboratory tests for heavy duty diesel engine oils,
Engine tests for heavy duty diesel engine oils,

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ACEA	ACEA 2008 EUROPEAN OIL SEQUENCES FOR SERVICE-FILL OILS	Dec. 2008

This document details the ACEA 2008 European Oil Sequences for Service-fill Oils for Gasoline engines, for Light Duty Diesel engines, for Gasoline & Diesel engines with after treatment devices and for Heavy Duty Diesel engines. These sequences define the minimum quality level of a product for presentation to ACEA members. Performance parameters other than those covered by the tests shown or more stringent limits may be indicated by individual member companies.

These sequences will replace the ACEA 2007 sequences as a means of defining engine lubricant quality from 22nd December 2008.

CONDITIONS FOR USE OF PERFORMANCE CLAIMS AGAINST THE ACEA OIL SEQUENCES

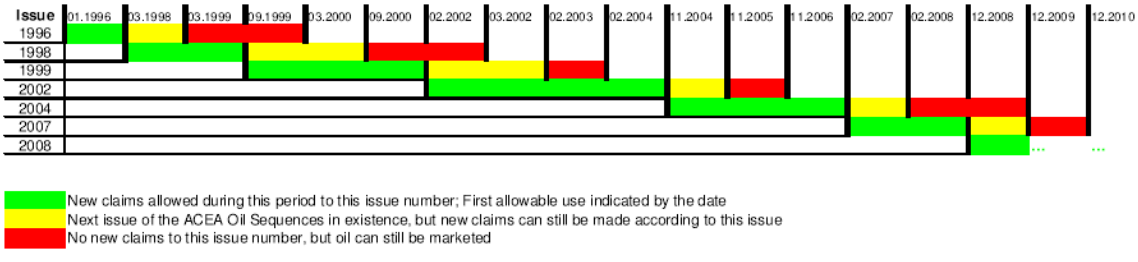
ACEA requires that any claims for Oil performance to meet these sequences must be based on credible data and controlled tests in accredited test laboratories.

ACEA requires that engine performance testing used to support a claim of compliance with these ACEA sequences should be generated according to the European Engine Lubricants Quality Management System (EELQMS), but ACEA reserves the right to define alternatives in exceptional cases.
EELQMS which is described in the ATIEL Code of Practice[1], addresses product development testing and product performance documentation, and involves the registration of all candidate and reference oil testing and defines the compliance process. Compliance with the ATIEL Code of Practice is mandatory for any claim to meet the requirements of the 2008 issue of the ACEA sequences. Therefore ACEA requires that claims against the ACEA oil sequences can only be made by oil companies or oil distributors who have signed the EELQMS oil marketers' Letter of Conformance (for details: www.atiel.org).

The ACEA oil sequences are underlying a constant development. Replacement tests and other changes required by the European automobile manufacturers are integrated and new issues are published on a regular basis. As new editions are published older editions have to be withdrawn. Validities of new and old editions are overlapping for limited periods of time as shown in the following table and graph.

Issue year of full document	First allowable use	All new claims by	withdrawn
1996	1st January 1996	1st March 1997	1st March 2000
1998	1st March 1998	1st March 1999	1st March 2002
1999	1st September 1999	1st September 2000	1st February 2004
2002	1st February 2002	1st February 2003	1st November 2006
2004	1st November 2004	1st November 2005	31st December 2009
2007	1st February 2007	1st February 2008	22nd December 2010
2008	22nd December 2008	22nd December 2009	

First allowable use means that claims cannot be made against the specification before the date indicated.
All new claims by means that from this date onward all claims for new oil formulations must be according to the latest ACEA release. Until that date new claims can also be made according to the previous ACEA release. (For example until 1st February 2008, oil marketers can make claims against the ACEA 2004 release even though the 2007 release is active. After 1st February 2008, any new oil claims must be according to the ACEA 2007 sequences.)
Withdrawn means that no claims can be made against the issue after the date indicated.



[1] The ATIEL Code of Practice is the sole property of ATIEL and is available from ATIEL (Association Technique de l'Industrie Européenne des Lubrifiants), Boulevard du Souverain 165, B-1160 Brussels, Belgium.

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The marketer of an oil claiming ACEA performance requirements is responsible for all aspects of product liability.

Where limits are shown relative to a reference oil, then these must be compared to the last valid Reference Result on that test stand prior to the candidate and using the same hardware. Further details will be in the ATIEL Code of Practice.

Where claims are made that Oil performance meets the requirements of the ACEA sequences (e.g. product literature, packaging, labels) they must specify the ACEA Class and Category (see Nomenclature & ACEA Process for definitions).

The categories A2 and B2 are not included in this edition of the ACEA European Oil Sequences because they are unsuitable for some of the current engines and will be unsuitable for many future engines. Misuse may cause engine damage. However, the use of A2/B2 oils for older engines (where owner's or workshop's literature recommends this use) is still appropriate and can be done according to the categories A2-96 Issue 3 and B2-98-Issue 2.

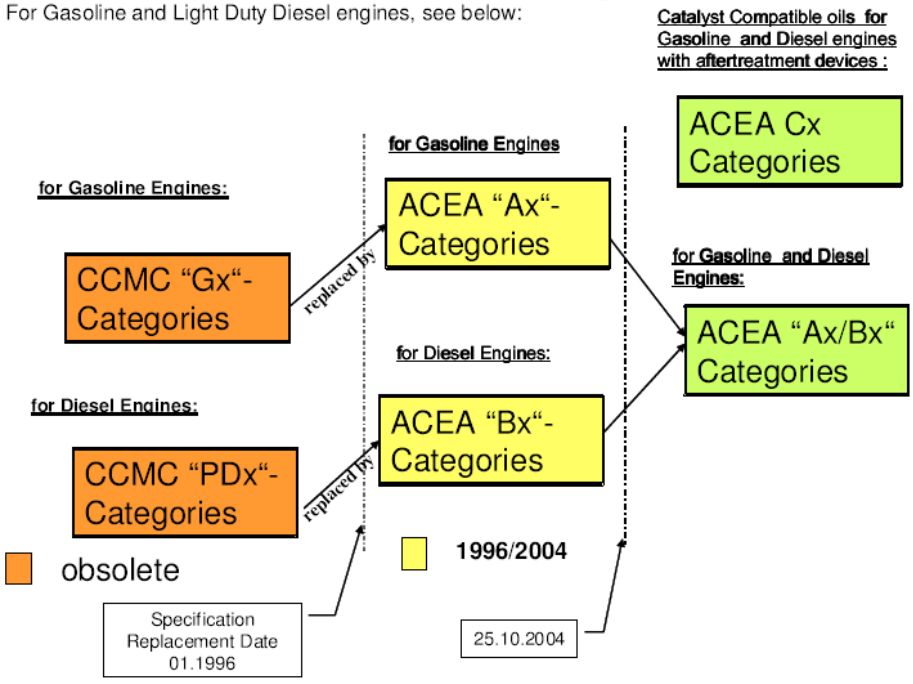
REPLACEMENT of CCMC sequences

The chart below shows the evolution of the engine oil specifications commonly developed by the European Automobile manufacturers. CCMC (Comité des Constructeurs du Marché Commun) was the forerunner organisation to ACEA.

In January 1996 the CCMC European Oil Sequences became obsolete and were replaced by the ACEA European Oil Sequences. This is true for light duty engine oils as well as heavy duty engine oils. CCMC European Oil Sequences are not supported any more by ACEA.

With the 2004 release of the ACEA European Oil Sequences the A and B categories have been combined to the respective A/B categories. At the same time, a new set of categories has been introduced with the intention to create specifications for engine oils being suitable for the latest and future aftertreatment systems for Gasoline and Diesel engines. These categories are designated as Cx-categories.

For Heavy Duty Diesel engines, the CCMC Dx categories were replaced by the ACEA Ex categories as of 1 January 1996. The CCMC Dx categories then became obsolete and are no longer supported by ACEA.
For Gasoline and Light Duty Diesel engines, see below:



X= 1, 2, 3, 4 or 5 depending of categories

ACEA	ACEA 2008 EUROPEAN OIL SEQUENCES FOR SERVICE-FILL OILS	Dec. 2008

The ACEA 2008 European Oil Sequences for Service-fill Oils comprise 3 sets (classes) of sequences: one for Gasoline and Light Duty Diesel engines; one specifically for Gasoline and Light Duty Diesel engines with after treatment devices and one for Heavy Duty Diesel engines. Within each of these sets there are categories which reflect different performance requirements - four (A1/B1, A3/B3, A3/B4 & A5/B5) for gasoline and light duty diesel engines; four (C1, C2, C3, C4) specifically for engines with after treatment devices, and four (E4, E6, E7, E9) for heavy duty diesel engines. Typical applications for each sequence are described below for guidance only. Specific applications of each sequence are the responsibility of individual engine manufacturers for their own vehicles / engines.

The sequences define the minimum quality level of a product for self-certification to EELQMS and presentation to ACEA members. Performance parameters other than those covered by the tests shown or more stringent limits may be indicated by individual ACEA member companies.

NOMENCLATURE & ACEA PROCESS:

Each set of sequences is designated for consumer use by a 2 part code comprising a letter to define the CLASS (e.g. C), and a number to define the CATEGORY (e.g. C1).

In addition, for industry use, each sequence has a two-digit number to identify the YEAR of implementation of that severity level (e.g. A1 / B1-04).

The CLASS indicates oil intended for a general type of engine - currently A / B = gasoline and light duty diesel engines; C = catalyst compatible oils for gasoline and diesel engines with after treatment devices. Other classes may be added in future if, for example, Natural Gas engines prove to require oil characteristics which cannot readily be incorporated into existing classes.

The CATEGORY indicates oils for different purposes or applications within that general class, related to some aspect or aspects of the performance level of the oil. Typical applications for each sequence are described below for guidance only. Specific applications of each sequence are the responsibility of the individual motor manufacturer for their own vehicles and engines. Oils within a category may also meet the requirements of another category, but some engines may only be satisfied by oils of one category within a class.

The YEAR numbers for ACEA Sequence is intended only for industry use and indicates the year of implementation of that severity level for the particular category. A new year number will indicate, for example, that a new test, parameter or limit has been incorporated in the category to meet new / upgraded performance requirements whilst remaining compatible with existing applications. An update must always satisfy the applications of the previous issue. If this is not the case, then a new category is required.

An administrative ISSUE Number is added for industry use where it is necessary to update the technical requirements of a sequence without the intention to increase severity (e.g. when a CEC test engine is updated to the latest version whilst maintaining equivalent severity; or where a severity shift in the test requires modification of the specified limits.).

ACEA	ACEA 2008 EUROPEAN OIL SEQUENCES FOR SERVICE-FILL OILS	Dec. 2008

Where claims are made that Oil performance meets the requirements of the ACEA sequences (e.g. product literature, packaging, labels) they must specify the ACEA Class and Category (see Nomenclature & ACEA Process for definitions).

«Consumer Language»:

A/B : gasoline and diesel engine oils

A1/B1 Stable, stay-in-grade oil intended for use at extended drain intervals in gasoline engines and car & light van diesel engines specifically designed to be capable of using low friction low viscosity oils with a high temperature / high shear rate viscosity of 2.6 mPa*s for xW/20 and 2.9 to 3.5 mPa.s for all other viscosity grades. These oils are unsuitable for use in some engines. Consult owner manual or handbook if in doubt.

A3/B3 Stable, stay-in-grade oil intended for use in high performance gasoline engines and car & light van diesel engines and/or for extended drain intervals where specified by the engine manufacturer, and/or for year-round use of low viscosity oils, and/or for severe operating conditions as defined by the engine manufacturer.

A3/B4 Stable, stay-in-grade oil intended for use in high performance gasoline and direct injection diesel engines, but also suitable for applications described under A3/B3.

A5/B5 Stable, stay-in-grade oil intended for use at extended drain intervals in high performance gasoline engines and car & light van diesel engines designed to be capable of using low friction low viscosity oils with a High temperature / High shear rate (HTHS) viscosity of 2.9 to 3.5 mPa.s. These oils are unsuitable for use in some engines. Consult owner manual or handbook if in doubt.

C : Catalyst compatibility oils

C1 Stable, stay-in-grade oil intended for use as catalyst compatible oil in vehicles with DPF and TWC in high performance car and light van diesel and gasoline engines requiring low friction, low viscosity, low SAPS oils with a minimum HTHS viscosity of 2.9 mPa.s. These oils will increase the DPF and TWC life and maintain the vehicles fuel economy.

Warning: these oils have the lowest SAPS limits and are unsuitable for use in some engines. Consult owner manual or handbook if in doubt.

C2 Stable, stay-in-grade oil intended for use as catalyst compatible oil in vehicles with DPF and TWC in high performance car and light van diesel and gasoline engines designed to be capable of using low friction, low viscosity oils with a minimum HTHS viscosity of 2.9mPa.s. These oils will increase the DPF and TWC life and maintain the vehicles fuel economy.

Warning: these oils are unsuitable for use in some engines. Consult owner manual or handbook if in doubt.

C3 Stable, stay-in-grade oil intended for use as catalyst compatible oil in vehicles with DPF and TWC in high performance car and light van diesel and gasoline engines, with a minimum HTHS viscosity of 3.5mPa.s. These oils will increase the DPF and TWC life.

Warning: these oils are unsuitable for use in some engines. Consult owner manual or handbook if in doubt.

C4 Stable, stay-in-grade oil intended for use as catalyst compatible oil in vehicles with DPF and TWC in high performance car and light van diesel and gasoline engines requiring low SAPS oil with a minimum HTHS viscosity of 3.5mPa.s. These oils will increase the DPF and TWC life.

Warning: these oils are unsuitable for use in some engines. Consult owner manual or handbook if in doubt.

SAPS : Sulphated Ash, Phosphorus, Sulphur
DPF : Diesel Particulate Filter
TWC : Three way catalyst
HTHS : High temperature / High shear rate viscosity

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E : Heavy Duty Diesel engine oils

E4 Stable, stay-in-grade oil providing excellent control of piston cleanliness, wear, soot handling and lubricant stability. It is recommended for highly rated diesel engines meeting Euro I, Euro II, Euro III, Euro IV and Euro V emission requirements and running under very severe conditions, e.g. significantly extended oil drain intervals according to the manufacturer's recommendations. It is suitable for engines without particulate filters, and for some EGR engines and some engines fitted with SCR NOx reduction systems. However, recommendations may differ between engine manufacturers so Driver Manuals and/or Dealers shall be consulted if in doubt.

E6 Stable, stay-in-grade oil providing excellent control of piston cleanliness, wear, soot handling and lubricant stability. It is recommended for highly rated diesel engines meeting Euro I, Euro II, Euro III, Euro IV and Euro V emission requirements and running under very severe conditions, e.g. significantly extended oil drain intervals according to the manufacturer's recommendations. It is suitable for EGR engines, with or without particulate filters, and for engines fitted with SCR NO_x reduction systems. E6 quality is strongly recommended for engines fitted with particulate filters and is designed for use in combination with low sulphur diesel fuel. However, recommendations may differ between engine manufacturers so Driver Manuals and/or Dealers shall be consulted if in doubt.

E7 Stable, stay-in-grade oil providing effective control with respect to piston cleanliness and bore polishing. It further provides excellent wear control, soot handling and lubricant stability. It is recommended for highly rated diesel engines meeting Euro I, Euro II, Euro III, Euro IV and Euro V emission requirements and running under severe conditions, e.g. extended oil drain intervals according to the manufacturer's recommendations. It is suitable for engines without particulate filters, and for most EGR engines and most engines fitted with SCR NOx reduction systems. However, recommendations may differ between engine manufacturers so Driver Manuals and/or Dealers shall be consulted if in doubt.

E9 Stable, stay-in-grade oil providing effective control with respect to piston cleanliness and bore polishing. It further provides excellent wear control, soot handling and lubricant stability. It is recommended for highly rated diesel engines meeting Euro I, Euro II, Euro III, Euro IV and Euro V emission requirements and running under severe conditions, e.g. extended oil drain intervals according to the manufacturer's recommendations. It is suitable for engines with or without particulate filters, and for most EGR engines and for most engines fitted with SCR NO_x reduction systems. E9 is strongly recommended for engines fitted with particulate filters and is designed for use in combination with low sulphur diesel fuel. However, recommendations may differ between engine manufacturers so Drivers Manuals and/or Dealers should be consulted if in doubt

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Performance parameters other than those covered by the tests shown or more stringent limits may be indicated by individual member companies.

REQUIREMENT	TEST METHOD	PROPERTIES	UNIT	LIMITS			
				A1 / B1-08	**A3 / B3-08**	**A3 / B4-08**	**A5 / B5-08**
1. LABORATORY TESTS							
1.1 Viscosity grades		SAE J300 Latest active issue		No restriction except as defined by shear stability and HT/HS requirements. Manufacturers may indicate specific viscosity requirements related to ambient temperature.			
1.2 Shear stability	CEC L -014-93 or ASTM D6278	100°C Viscosity after 30 cycles	mm^2/s	Xw-20 stay in grade xW30 ≥ 9.3 xW40 ≥ 12.0	All grades to be stay in grade	All grades to be stay in grade	All grades to be stay in grade
1.3 Viscosity at high temp. & high shear rate	CEC L-036-90 (2nd Edition) (Ravenfield)	Viscosity at 150°C and $10^6\ s^{-1}$ shear rate	mPa.s	≥ 2.9 and ≤ 3.5; Xw-20: 2.6. min	≥ 3.5	≥ 3.5	≥ 2.9 and ≤ 3.5
1.4 Evaporative loss	CEC L-040-93 (Noack)	Max. weight loss after 1 h at 250°C	%	≤ 15	≤ 13	≤ 13	≤ 13
1.5 TBN	ASTM D 2896		mgKOH/g	≥ 8.0	≥ 8.0	≥ 8.0	≥ 8.0
1.6 Sulphated ash	ASTM D874		% m/m	≤ 1.3 (see note 2)	≤ 1.5 (see note 2)	≤ 1.6 (see note 2)	≤ 1.6 (see note 2)
				NOTE: the following sections apply to all sequences			
1.7 Sulphur (see note 1)	ASTM D5185		% m/m	Report			
1.8 Phosphorus (see note 1)	ASTM D5185		% m/m	Report			
1.9 Chlorine	ASTM D6443		ppm m/m	Report			
1.10 Oil / elastomer compatibility	CEC L-039-96 (see note 3)	Max. variation of characteristics after immersion for 7 days in fresh oil without pre-ageing			Elastomer type		
				RE1	RE2-99	RE3-04	RE4	AEM (VAMAC)
		Hardness DIDC	points	-1/+5	-5/+8	-22/+1	-5/+5	As per Daimler
		Tensile strength	%	-40/+10	-15/+18	-30/+10	-20/+10	
		Elongation at rupture	%	-50/+10	-35/+10	-20/+10	-50/+10	
		Volume variation	%	-1/+5	-7/+5	-1/+22	-5/+5	
1.11 Foaming tendency	ASTM D892 without option A	Tendency - stability	ml	Sequence I (24°C) 10 - nil Sequence II (94°C) 50 - nil Sequence III (24°C) 10 - nil			
1.12 High temperature foaming tendency	ASTM D6082 High temperature foam test	Tendency - stability	ml	Sequence IV (150°C) 100 - nil			

ACEA	ACEA 2008 EUROPEAN OIL SEQUENCE FOR SERVICE-FILL OILS FOR GASOLINE and DIESEL ENGINES	Dec. 2008

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REQUIREMENT	TEST METHOD	PROPERTIES	UNIT	LIMITS			
				A1 / B1-08	A3 / B3-08	A3 / B4-08	A5 / B5-08
2. ENGINE TESTS							
2.1 High temperature deposits Ring sticking Oil thickening	CEC L-088-02 (TU5JP-L4) 72 Hour test	Ring sticking (each part)	Merit	≥ 9.0	≥ 9.0	≥ 9.0	≥ 9.0
		Piston varnish (6 elements, average of 4 pistons)	Merit	≥ RL 216	≥ RL 216	≥ RL 216	≥ RL 216
		Absolute viscosity increase at 40°C between min and max values during test	mm^2/s	≤ 0.8 x RL216	≤ 0.8 x RL216	≤ 0.8 x RL216	≤ 0.8 x RL216
		Oil consumption	kg/test	Report	Report	Report	Report
2.2 Low temperature sludge	ASTM D6593-00 (Sequence VG) Under protocol & requirements for API (See Note 4)	Average engine sludge	merit	≥ 7.8	≥ 7.8	≥ 7.8	≥ 7.8
		Rocker cover sludge	merit	≥ 8.0	≥ 8.0	≥ 8.0	≥ 8.0
		Average Piston skirt varnish	merit	≥ 7.5	≥ 7.5	≥ 7.5	≥ 7.5
		Average engine varnish	merit	≥ 8.9	≥ 8.9	≥ 8.9	≥ 8.9
		Comp. ring (hot stuck)		none	none	none	none
		Oil screen clogging	%	≤ 20	≤ 20	≤ 20	≤ 20
2.3 Valve train scuffing wear	CEC L-038-94 (TU3M)	Cam wear, average	µm	≤ 10	≤ 10	≤ 10	≤ 10
		Cam wear, max.	µm	≤ 15	≤ 15	≤ 15	≤ 15
		Pad merit (Ave. of 8 pads)	merit	≥ 7.5	≥ 7.5	≥ 7.5	≥ 7.5
2.4 Black sludge	CEC L-053-95 (M111)	Engine sludge, average	merit	≥ RL 140	≥ RL 140 + 4σ or ≥ 9.0	≥ RL 140 + 4σ or ≥ 9.0	≥ RL 140 + 4σ or ≥ 9.0
2.5 Fuel economy See Note (5)	CEC L-054-96 (M111)	Fuel economy improvement vs. Reference oil RL191 (15W-40)	%	≥ 2.5	–	–	≥ 2.5
2.6 Medium temperature dispersivity	CEC L-093-04 (DV4TD)	Absolute viscosity increase at 100°C and 6 % soot	mm2/s	≤ 0.60 x RL223 result	≤ 0.60 x RL223 result	≤ 0.60 x RL223 result	≤ 0.60 x RL223 result
		Piston merit	merit	≥ (RL223 – 2,5pts)	≥ (RL223 – 2,5pts)	≥ (RL223 – 2,5pts)	≥ (RL223 – 2,5pts)
2.7 Wear See notes (6)	CEC L–099-08 (OM646LA)	Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 140	≤ 140	≤ 120	≤ 120
		Cam wear inlet (avg. max. wear 8 c.); (8)	µm	≤ 110	≤ 110	≤ 100	≤ 100
		Cylinder wear (avg. 4 cyl.); s. note (8)	µm	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
		Bore polishing (13 mm) - max. value of 4 cylinders; s. note (8)	%	≤ 3.5	≤ 3.5	≤ 3.0	≤ 3.0
		Tappet wear inlet (avg. max. wear 8 cams)	µm	report	report	report	report
		Tappet wear outlet (avg. max. wear 8cams)	µm	report	report	report	report
		Piston cleanliness (avg. 4 pistons)	merits	report	report	report	report
		Engine sludge avg.	merits	report	report	report	report

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Performance parameters other than those covered by the tests shown or more stringent limits may be indicated by individual member companies.

REQUIREMENT	TEST METHOD	PROPERTIES	UNIT	LIMITS			
				A1 / B1-08	A3 / B3-08	A3 / B4-08	A5 / B5-08
2. ENGINE TESTS CONTINUED							
2.8	CEC L-078-99	Piston cleanliness	merit	≥ RL206	≥ RL206	≥ RL206	≥ RL206
DI diesel	(VW TDI)			minus	minus		
Piston				4 points	4 points		
cleanliness &		Ring sticking (Rings 1 & 2)					
Ring sticking		Average of all 8 rings	ASF	≤ 1.2	≤ 1.2	≤ 1.0	≤ 1.0
See notes (9)		Max. for any 1st ring	ASF	≤ 2.5	≤ 2.5	≤ 1.0	≤ 1.0
		Max. for any 2nd ring	ASF	0.0	0.0	0.0	0.0
		EOT TBN (ISO 3771); s. note (7 & 8)	mgKOH /g	≥ 4.0	≥ 4.0	≥ 4.0	≥ 4.0
		EOT TAN (ASTM D 664); s. note (7)	mgKOH /g	Report	Report	Report	Report

(1) The internal standard method has to be used.
(2) Maximum limits, Values take into account method and production's tolerances
(3) Use either complete Daimler requirements (VDA 675301, 7 days +/- 2h, 4 materials (NBR: NBR34 DIN 53538 T3 (100 °C +/- 2°C); FPM: AK6 (150 °C +/- 2°C); ACM: E7503 (150 °C +/- 2°C); AEM: D 8948/200.1 (150 °C +/- 2°C)) + RE3, or complete requirements according to 1.10 above + Daimler requirements for AEM
(4) The limits shown are based upon those applied in U.S. market requirements. ACEA will continuously review the situation to ensure that these limits are appropriate for European vehicles and lubricants.
(5) ACEA considers the CEC L-54-T-96 test the only valid comparator against which claims of lubricant fuel economy improvement should be made.
(6) For A1/B1 claims OM 602A passing results obtained before the end of 2008 can be used instead of OM 646LA results.
(7) Test report has to give measured values before & after the test, all measurements to be taken in the same lab.
(8) These parameters are not yet official CEC parameters.
(9) Test results from tests performed before the publishing of the 2008 ACEA oil sequences are allowed to be used without passing the EOT TBN criteria and reporting EOT TAN values.

ACEA	ACEA 2008 EUROPEAN OIL SEQUENCE FOR SERVICE-FILL OILS FOR GASOLINE and DIESEL ENGINES WITH AFTER TREATMENT DEVICES	Dec. 2008

This sequence defines the minimum quality level of a product for self-certification to EELQMS and for presentation to ACEA members.
Performance parameters other than those covered by the tests shown or more stringent limits may be indicated by individual member companies.

REQUIREMENT	TEST METHOD	PROPERTIES	UNIT	LIMITS			
				C1-08	C2-08	C3-08	C4-08
1. LABORATORY TESTS							
1.1 Viscosity grades		SAE J300 Latest active issue		No restriction except as defined by shear stability and HT/HS requirements. Manufacturers may indicate specific viscosity requirements related to ambient temperature.			
1.2 Shear stability	CEC L-014-93 or ASTM D6278	100°C Viscosity after 30 cycles	mm^2/s	All grades to be stay in grade	All grades to be stay in grade	All grades to be stay in grade	All grades to be stay in grade
1.3 Viscosity at high temp. & high shear rate	CEC L-036-90 (2nd Edition) (Ravenfield)	Viscosity at 150°C and $10^6\ s^{-1}$ shear rate	mPa.s	≥ 2.9	≥ 2.9	≥ 3.5	≥ 3.5
1.4 Evaporative loss	CEC L-040-93 (Noack)	Max. weight loss after 1 h at 250°C	%	≤ 13	≤ 13	≤ 13	≤ 11
1.5 Sulphur	ASTM D5185	(see note 1)	% m/m	≤ 0.2	≤ 0.3	≤ 0.3	≤ 0.2
1.6 Phosphorus	ASTM D5185	(see note 1)	% m/m	≤ 0.05 (2)	≥ 0.070 ≤0.090 (2)	≥ 0.070 ≤0.090 (2)	≤ 0.090 (2)
1.7 Sulphated ash	ASTM D874		% m/m	≤ 0.5 (see note 2)	≤ 0.8 (see note 2)	≤ 0.8 (see note 2)	≤ 0.5 (see note 2)
1.8 Chlorine	ASTM D6443		ppm m/m	Report	Report	Report	Report
1.9 TBN	ASTM D 2896		mg KOH / g			≥ 6.0	≥ 6.0
				NOTE: The following sections apply to all sequences			
1.10 Oil / elastomer compatibility	CEC L-039-96 (see note 3)	Max. variation of characteristics after immersion for 7 days in fresh oil without pre-ageing		Elastomer type			
				RE1	RE2-99	RE3-04	RE4	AEM VAMAC
		Hardness DIDC	points	-1/+5	-5/+8	-22/ +1	-5/+5	As per Daimler
		Tensile strength	%	-40/+10	-15/+18	-30/+10	-20/+10	
		Elongation at rupture	%	-50/+10	-35/+10	-20/+10	-50/+10	
		Volume variation	%	-1/+5	-7/+5	-1/+22	-5/+5	
1.11 Foaming tendency	ASTM D892 without option A	Tendency - stability	ml	Sequence I (24°C) 10 - nil Sequence II (94°C) 50 - nil Sequence III (24°C) 10 - nil			
1.12 High temperature foaming tendency	ASTM D6082 High temperature foam test	Tendency - stability	ml	Sequence IV (150°C) 100 - nil			

ACEA	ACEA 2008 EUROPEAN OIL SEQUENCE FOR SERVICE-FILL OILS FOR GASOLINE and DIESEL ENGINES WITH AFTER TREATMENT DEVICES	Dec. 2008

This sequence defines the minimum quality level of a product for self-certification to EELQMS and for presentation to ACEA members.
Performance parameters other than those covered by the tests shown or more stringent limits may be indicated by individual member companies.

REQUIREMENT	TEST METHOD	PROPERTIES	UNIT	LIMITS			
				C1-08	C2-08	C3-08	C4-08
2. ENGINE TESTS							
2.1 High temperature deposits Ring sticking Oil thickening	CEC L-088-T-02 (TU5JP-L4) 72 Hour test	Ring sticking (each part)	Merit	≥ 9.0	≥ 9.0	≥ 9.0	≥ 9.0
		Piston varnish (6 elements, average of 4 pistons)	Merit	≥ RL 216	≥ RL 216	≥ RL 216	≥ RL 216
		Absolute viscosity increase at 40°C between min and max values during test	mm^2/s	≤ 0.8 x RL216	≤ 0.8 x RL216	≤ 0.8 x RL216	≤ 0.8 x RL216
		Oil consumption	kg/test	Report	Report	Report	Report
2.2 Low temperature sludge	ASTM D6593-00 (Sequence VG) Under protocol & requirements for API (See Note 4)	Average engine sludge	merit	≥ 7.8	≥ 7.8	≥ 7.8	≥ 7.8
		Rocker cover sludge	merit	≥ 8.0	≥ 8.0	≥ 8.0	≥ 8.0
		Average Piston skirt varnish	merit	≥ 7.5	≥ 7.5	≥ 7.5	≥ 7.5
		Average engine varnish	merit	≥ 8.9	≥ 8.9	≥ 8.9	≥ 8.9
		Comp. ring (hot stuck)		none	none	none	none
		Oil screen clogging	%	≤ 20	≤ 20	≤ 20	≤ 20
2.3 Valve train scuffing wear	CEC L-038-94 (TU3M)	Cam wear, average	µm	≤ 10	≤ 10	≤ 10	≤ 10
		Cam wear, max.	µm	≤ 15	≤ 15	≤ 15	≤ 15
		Pad merit (Ave. of 8 pads)	merit	≥ 7.5	≥ 7.5	≥ 7.5	≥ 7.5
2.4 Black sludge	CEC L-53-95 (M111)	Engine sludge, average	merit	≥ RL 140 + 4σ or ≥ 9.0	≥ RL 140 + 4σ or ≥ 9.0	≥ RL 140 + 4σ or ≥ 9.0	≥ RL 140 + 4σ or ≥ 9.0
2.5 Fuel economy See Note (5)	CEC L-54-96 (M111)	Fuel economy improvement vs. Reference oil RL191 (15W-40)	%	≥ 3.0	≥ 2.5	≥ 1.0 (for Xw30 grades)	≥ 1.0 (for Xw30 grades)
2.6 Medium temperature dispersivity	CEC L-093-04 (DV4TD)	Absolute viscosity increase at 100°C and 6 % soot	s	≤ 0.60 x RL223 result	≤ 0.60 x RL223 result	≤ 0.60 x RL223 result	≤ 0.60 x RL223 result
		Piston merit	merit	≥ (RL223 – 2,5pts)	≥ (RL223 – 2,5pts)	≥ (RL223 – 2,5pts)	≥ (RL223 – 2,5pts)
2.7 Wear See notes (6)	CEC L-099-08 (OM646LA)	Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 120	≤ 120	≤ 120	≤ 120
		Cam wear inlet (avg. max. wear 8 c.); (9)	µm	≤ 100	report, note(8)	≤ 100	≤ 100
		Cylinder wear (avg. 4 cyl.); s. note (9)	µm	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
		Bore polishing (13 mm) - max. value of 4 cylinders; s. note (9)	%	≤ 3.0	≤ 3.0	≤ 3.0	≤ 3.0
		Tappet wear inlet (avg. max. wear 8cams)	µm	report	report	report	report
		Tappet wear outlet (avg. max. wear 8cams)	µm	report	report	report	report
		Piston cleanliness (avg. 4 pistons)	merits	report	report	report	report
		Engine sludge avg.	merits	report	report	report	report

ACEA	ACEA 2008 EUROPEAN OIL SEQUENCE FOR SERVICE-FILL OILS FOR GASOLINE and DIESEL ENGINES WITH AFTER TREATMENT DEVICES	Dec. 2008

This sequence defines the minimum quality level of a product for self-certification to EELQMS and for presentation to ACEA members.
Performance parameters other than those covered by the tests shown or more stringent limits may be indicated by individual member companies.

REQUIREMENT	TEST METHOD	PROPERTIES	UNIT	LIMITS			
				C1-08	C2-08	C3-08	C4-08
2. ENGINE TESTS CONTINUED							
2.8 DI diesel Piston cleanliness & Ring sticking See notes (10)	CEC L-078-99 (VW TDI)	Piston cleanliness	merit	≥ RL206	≥ RL206	≥ RL206	≥ RL206
		Ring sticking (Rings 1 & 2)					
		Average of all 8 rings	ASF	≤ 1.0	≤ 1.2	≤ 1.0	≤ 1.0
		Max. for any 1st ring	ASF	≤ 1.0	≤ 2.5	≤ 1.0	≤ 1.0
		Max. for any 2nd ring	ASF	0.0	0.0	0.0	0.0
		EOT TBN (ISO 3771) and EOT TAN (ASTM D 664); s. note (7)	mgKOH /g	report	report	report	report

(1) The internal standard method has to be used.
(2) Maximum limits, Values take into account method and production's tolerances
(3) Use either complete Daimler requirements (VDA 675301, 7 days +/- 2h, 4 materials (NBR: NBR34 DIN 53538 T3 (100 °C +/- 2°C); FPM: AK6 (150 °C +/- 2°C); ACM: E7503 (150 °C +/- 2°C); AEM: D 8948/200.1 (150 °C +/- 2°C)) + RE3, or complete requirements according to 1.10 above + Daimler requirements for AEM
(4) The limits shown are based upon those applied in U.S. market requirements. ACEA will continuously review the situation to ensure that these limits are appropriate for European vehicles and lubricants.
(5) ACEA considers the CEC L-54-T-96 test the only valid comparator against which claims of lubricant fuel economy improvement should be made.
(6) Limits for C1 might be revised if needed. For C1 claims OM 602A passing results obtained before the end of 2008 can be used instead of OM 646LA results.
(7) Test report has to give measured values before & after the test, all measurements to be taken in the same lab.
(8) Limit under definition.
(9) These parameters are not yet official CEC parameters.
(10) Test results from tests performed before the publishing of the 2008 ACEA oil sequences are allowed to be used without reporting EOT TBN & TAN.

ACEA	ACEA 2008 EUROPEAN OIL SEQUENCE FOR SERVICE-FILL OILS FOR HEAVY DUTY DIESEL ENGINES	Dec. 2008

This sequence defines the minimum quality level of a product for self-certification to EELQMS and for presentation to ACEA members.
Performance parameters other than those covered by the tests shown or more stringent limits may be indicated by individual member companies.

REQUIREMENTS	TEST METHOD	PROPERTIES	UNIT	LIMITS			
				E4-08	**E6-08**	**E7-08**	**E9-08**
1. LABORATORY TESTS							
1.1 Viscosity		SAE J300 Latest Active Issue		No restriction except as defined by shear stability and HT/HS requirements. Manufacturers may indicate specific viscosity requirements related to ambient temperature.			
1.2 Shear stability	CEC L-014-93 or ASTM D6278	Viscosity after 30 cycles measured at 100°C.	mm^2/s	Stay in grade			
	ASTM D6278	Viscosity after 90 cycles measured at 100°C	mm^2/s		Stay in grade		
1.3 Viscosity High Temperature High Shear Rate	CEC L-036-90 (2nd Edition) (Ravenfield)	Viscosity at 150°C and $10^6\ s^{-1}$ Shear rate	mPa.s	≥ 3.5			
1.4 Evaporative Loss	CEC L-040-93 (Noack)	Max. weight loss after 1 h at 250°C	%	≤ 13			
1.5 Sulphated Ash	ASTM D874		% m/m	≤ 2.0	≤ 1.0	≤ 2.0	≤ 1.0
1.6 Phosphorus (Note 1)	ASTM D5185+		% m/m		≤ 0.08		≤ 0.12
1.7 Sulphur (Note 1)	ASTM D5185+		% m/m		≤ 0.3		≤ 0.4
1.8 Oil Elastomer Compatibility (Note 2)	CEC L-039-96	Max. variation of characteristics after immersion for 7 days in fresh oil without pre-ageing		RE1	Elastomer type RE2-99	RE3-04	RE4	AEM (VAMAC) As per Daimler
		Hardness DIDC	points	-1/+5	-5/+8	-25/+1	-5/+5	
		Tensile strength	%	-50/+10	-15/+18	-45/+10	-20/+10	
		Elongation rupture	%	-60/+10	-35/+10	-20/+10	-50/+10	
		Volume variation	%	-1/+5	-7/+5	-1/+30	-5/+5	
1.9 Foaming Tendency	ASTM D892 without option A	Tendency – stability	ml ml ml	Sequence I (24°C) 10 – nil Sequence II (94°C) 50 – nil Sequence III (24°C) 10 – nil				Seq I 10/0 Seq II 20/0 Seq III 10/0
1.10 High temperature foaming tendency	ASTM D6082	Tendency - stability	ml	Sequence IV (150°C) 200-50				
1.11 Oxidation	CEC L-085-99 (PDSC)	Oxidation induction time	min	R&R	R&R	≥ 65	≥ 65	
1.12 Corrosion	ASTM D 6594	Copper increase Lead increase Copper strip rating	ppm ppm max	R&R R&R R&R	R&R R&R R&R	R&R ≤ 100 R&R	≤ 20 ≤ 100 3	
1.13 Turbocharger performance (Note 3)								
1.14 TBN	ASTM D2896		mg KOH/g	≥12	≥ 7	≥ 9 (Note 4)	≥7	

ACEA	ACEA 2008 EUROPEAN OIL SEQUENCE FOR SERVICE-FILL OILS FOR HEAVY DUTY DIESEL ENGINES	Dec. 2008

This sequence defines the minimum quality level of a product for self-certification to EELQMS and for presentation to ACEA members.
Performance parameters other than those covered by the tests shown or more stringent limits may be indicated by individual member companies.

REQUIREMENTS	TEST METHOD	PROPERTIES	UNIT	LIMITS			
				E4-08	E6-08	E7-08	E9-08
2. ENGINE TESTS							
2.1 Wear	CEC L-099-08 (OM646LA)	Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 140 (Notes 5, 6)	≤ 140 (Notes 5, 6)	≤ 155 (Notes 5, 6)	≤ 155 (Notes 5, 6)
2.2 Soot in oil (Note 7)	ASTM D 5967 (Mack T-8E)	Test duration 300 h Relative viscosity at 4.8% soot 1 test/2 test/3 test average		≤ 2.1/2.2/2.3	≤ 2.1/2.2/2.3	≤ 2.1/2.2/2.3	
2.3 Soot in oil	Mack T11	Min TGA soot @ 4.0 cSt (100°C) Min TGA soot @ 12.0 cSt (100°C) Min TGA soot @ 15.0 cSt (100°C)	%				3.5/3.4/3.3 6.0/5.9/5.9 6.7/6.6/6.5
2.4 Bore polishing **Piston Cleanliness**	CEC L-101-08 (OM501LA)	Bore polishing, average Piston Cleanliness, average Oil consumption Engine sludge, average (Note 8)	% merit kg/test Merit	≤ 1.0 ≥ 26 ≤ 9 R&R (Notes 9,10)	≤ 1.0 ≥ 26 ≤ 9 R&R (Notes 9,10)	≤ 2.0 ≥ 17 ≤ 9 R&R (Notes 9,10)	≤ 2.0 ≥ 17 ≤ 9 R&R (Notes 9,10)
2.5. Soot induced wear	Cummins ISM	Merit Rocker pad average weight loss at 3.9 % soot 1 test/2 test/3 test average Oil filter diff.press @ 150h 1 test/ 2 test/3 test average Engine sludge 1 test/2 test/3 test average Adj. screw weight loss	 mg kPa merit mg			≤ 7.5/7.8/7.9 ≤55/67/74 ≥ 8.1/8.0/8.0 (Note 11)	≥1000 ≤ 7.1 ≤ 19 ≥ 8.7 ≤ 49
2.6. Wear (liner-ring-bearings)	Mack T12	Merit Avg.liner wear Average top ring weight loss End of test lead Delta lead 250-300 hrs Oil consumption (Phase II)	 µm mg ppm ppm g/hr		≥ 1000 ≤ 26 ≤ 117 ≤ 42 ≤ 18 ≤ 95 (Notes 12, 13)	≥ 1000 ≤ 26 ≤ 117 ≤ 42 ≤ 18 ≤ 95 (Notes 12, 13)	≥ 1000 ≤ 24 ≤ 105 ≤ 35 ≤ 15 ≤ 85

(1) The internal standard method has to be used.

(2) Use either the most recent complete Daimler requirements (VDA 675301, 7 days, 4 materials (NBR: NBR34 DIN 53538 T3 (100 °C); FPM: AK6 (150 °C); ACM: E7503 (150 °C); AEM: D 8948/200.1 (150 °C)) + RE3 according to requirement 1.8 above, or complete requirements according to 1.8 above + Daimler requirements for AEM.

(3) Should a test become available before the next document update, ACEA reserves the right to set performance limits providing adequate data is available.

(4) Values < 9.00 are not accepted.

(5) OM602A data can be used instead of OM646LA data providing it meets the requirements as specified in the 2007 ACEA sequences.

(6) Additional parameters may be included once approved by CEC.

(7) Mack T11 results obtained as part of an API CI-4, CI-4 plus or API CJ-4 approval program, can be used in place of Mack T8E.

(8) Bore polish, oil consumption and engine sludge are non-approved CEC parameters.

(9) OM441LA data can be used instead of OM501LA data providing it meets the requirements as specified in the 2007 ACEA sequences.

(10) Limits for the sludge parameter may be reconsidered when more data becomes available.

(11) Results from M11HST (ASTM D6838), at API CH-4, or M11EGR (ASTM D6975), at API CI-4 or CI-4 Plus, can be used in place of Cummins ISM.

(12) Merit number shall be calculated according to the API CI-4 specification

(13) Mack T10 results obtained as part of an API CI-4 or CI-4 plus approval program, can be used in place of Mack T12.

Appendix B

List of Acronyms

TAN – Total Acid Number
TBN – Total Base Number
ICP – Inductive Coupled Plasma
ACEA – European Automobile Manufactures Association
E7 – An engine lubricant which meets to ACEA E7 engine lubricant specification
E9 – An engine lubricant which meets to ACEA E7 engine lubricant specification
DPF – Diesel Particulate Filter