Specification Handbook

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Specification Handbook

This handbook, compiled by Afton Chemical, is a collection of widely used Industry Specifications. We aim to provide a single source for specifications for Engine Oils, Industrial, Driveline and Off Road, together with the associated bench, rig and engine test procedures.

Afton Chemical hopes you find this handbook a useful reference tool and source of information. The handbook is also available electronically from our website, **www.aftonchemical.com** and on Afton's **Spec-Stik™**, a portable memory stick that will allow you to access the information when and wherever you want.

If you require information about our products and services please contact your local Afton Chemical representative.

www.aftonchemical.com

Afton Chemical have been working in the lubricant additives marketplace for over 90 years. During that time we have developed a unique way of doing things that gives our customers so much more than our leading-edge chemistry.

What makes us so different is the special way we involve ourselves in our customers' businesses in order to help them achieve their goals.

We do this through a combination of the innovative solutions we develop, and the passion and integrity our people bring to our style of working.

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Viscosity

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Viscosity

SAE Viscosity Grades For Engine Oils (1) (2)

January 2009

SAE Viscosity Grade	Low Temperature (°C) Cranking Viscosity(3), mPa·s Max	Low Temperature (°C) Pumping Viscosity(4), mPa·s Max with No Yield Stress(4)	Low-Shear-Rate Kinematic Viscosity(5) (mm^2/s) at 100°C Min.	Low-Shear-Rate Kinematic Viscosity(5) (mm^2/s) at 100°C Max.	High-Shear-Rate Viscosity(6) (mPa·s) at 150°C Min.
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	-	-
25W	13 000 at -10	60 000 at -15	9.3	-	-
20	-	-	5.6	< 9.3	2.6
30	-	-	9.3	< 12.5	2.9
40	-	-	12.5	< 16.3	3.5 (0W-40, 5W-40, and 10W-40 grades)
40	-	-	12.5	< 16.3	3.7 (15W-40, 20W-40, 25W-40, 40 grades)
50	-	-	16.3	< 21.9	3.7
60	-	-	21.9	< 26.1	3.7

Note:

(1) -1 mPa·s = 1 cP; 1 mm^2/s = 1 cSt

(2) All values, with the exception of the low-temperature cranking viscosity, are critical specifications as defined by ASTM D3244 (See text, Section 3).

(3) ASTM D5293: Cranking viscosity - The non-critical specification protocol in ASTM D3244 shall be applied with a P value of 0.95.

(4) ASTM D4684: Note that the presence of any yield stress detectable by this method constitutes a failure regardless of viscosity.

(5) ASTM D445.

(6) ASTM D4683, CEC L-36-A-90 (ASTM D4741), or ASTM D5481.

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ISO Viscosity Grade Conversions

ISO Viscosity Grade	Mid-point Kinematic Viscosity	Kinematic Viscosity Limits cSt at 40°C (104°F)		ASTM, Saybolt Viscosity Number	Saybolt Viscosity SUS 100°F (37.8°C)	
		Min.	Max.		Min.	Max.
2	2.2	1.98	2.42	32	34.0	35.5
3	3.2	2.88	3.52	36	36.5	38.2
5	4.6	4.14	5.06	40	39.9	42.7
7	6.8	6.12	7.48	50	45.7	50.3
10	10	9.00	11.0	60	55.5	62.8
15	15	13.5	16.5	75	72	83
22	22	19.8	24.2	105	96	115
32	32	28.8	35.2	150	135	164
46	46	41.4	50.6	215	191	234
68	68	61.2	74.8	315	280	345
100	100	90.0	110	465	410	500
150	150	135	165	700	615	750
220	220	198	242	1000	900	1110
320	320	288	352	1500	1310	1600
460	460	414	506	2150	1880	2300
680	680	612	748	3150	2800	3400
1000	1000	900	1100	4650	4100	5000
1500	1500	1350	1650	7000	6100	7500

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Viscosity Ranges for AGMA Lubricant Numbers

Rust and Oxidation Inhibited Gear Oils	Viscosity Range	Equivalent ISO Grade	Extreme Pressure Gear Lubricants
AGMA Lubricant No.	**cSt (mm^2/s) at 40°C**		**AGMA Lubricant No.**
1	41.4 to 50.6	46	
2	61.2 to 74.8	68	2 EP
3	90 to 110	100	3 EP
4	135 to 165	150	4 EP
5	198 to 242	220	5 EP
6	288 to 352	320	6 EP
7 Compounded	414 to 506	460	7 EP
8 Compounded	612 to 748	680	8 EP
8A Compounded	900 to 1100	1000	8A EP

Note:
Viscosity ranges for AGMA Lubricant Numbers will henceforth be identical with those of the ASTM system
Oils compounded with 3% to 10% fatty or synthetic fatty oils.

SAE J306 Automotive Gear Viscosity Classifications

Axle and Manual Transmission Lubricant Viscosity Classifications

		70W	75W	80W	85W	80	85	90	110	140	190	250
Viscosity at 100°C	min, mm^2/s	4.1	4.1	7.0	11.0	7.0	11.0	13.5	18.5	24.0	32.5	41.0
	max, mm^2/s	No requirement				11.0	13.5	18.5	24.0	32.5	41.0	No req
Viscosity of 150,000 mPa·s, max. temp °C		-55	-40	-26	-12	No requirement						
20 hr. KRL Shear (CRC L-45-T-93), KV100 after Shear, mm^2/s, min.		4.1	4.1	7.0	11.0	7.0	11.0	13.5	18.5	24.0	32.5	41.0

SAE J2360 Specifications

		75W	80W-90	85W-140
Viscosity at 100°C	min, mm^2/s	4.1	13.5	24.0
	max, mm^2/s	-	18.5	32.5
Viscosity of 150,000 mPa·s, max. temp °C		-40	-26	-12
Channel Point, min, °C		-45	-35	-20
Flash Point, min, °C		150	165	180

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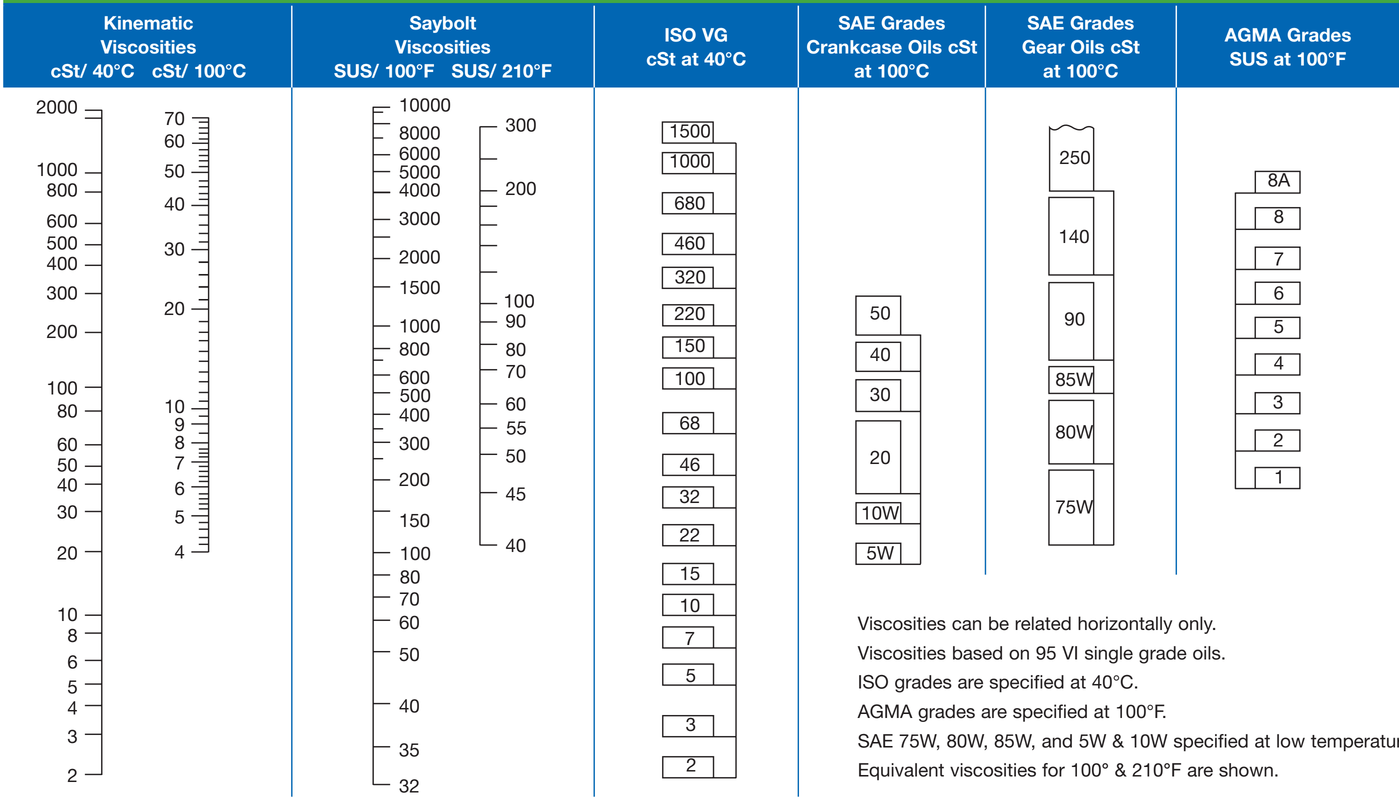
Comparison of Viscosity Classifications

Approximate Equivalents



Viscosities can be related horizontally only.
Viscosities based on 95 VI single grade oils.
ISO grades are specified at 40°C.
AGMA grades are specified at 100°F.
SAE 75W, 80W, 85W, and 5W & 10W specified at low temperature.
Equivalent viscosities for 100° & 210°F are shown.

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Viscosity Equivalents at Same Temperature

Approximate Equivalents

Kinematic (Centistokes)	Saybolt Universal (Seconds)	Redwood No.1 (Seconds)	Engler (Degrees)	Saybolt Furol (Seconds)	Redwood No.2 (Seconds)	Kinematic (Centistokes)	Saybolt Universal (Seconds)	Redwood No.1 (Seconds)	Engler (Degrees)	Saybolt Furol (Seconds)	Redwood No.2 (Seconds)
1.8	32	30.8	1.14	-	-	96.8	450	397	12.8	47.0	-
2.7	35	32.2	1.18	-	-	102.2	475	419	13.5	49	-
4.2	40	36.2	1.32	-	-	107.6	500	441	14.2	51	-
5.8	45	40.6	1.46	-	-	118.4	550	485	15.6	56	-
7.4	50	44.9	1.60	-	-	129.2	600	529	17.0	61	-
8.9	55	49.1	1.75	-	-	140.3	650	573	18.5	66	-
10.3	60	53.5	1.88	-	-	151	700	617	19.8	71	-
11.7	65	57.9	2.02	-	-	162	750	661	21.3	76	-
13.0	70	62.3	2.15	-	-	173	800	705	22.7	81	-
14.3	75	67.6	2.31	-	-	183	850	749	24.2	86	-
15.6	80	71.0	2.42	-	-	194	900	793	25.6	91	-
16.8	85	75.1	2.55	-	-	205	950	837	27.0	96	-
18.1	90	79.6	2.68	-	-	215	1,000	882	28.4	100	-
19.2	95	84.2	2.81	-	-	259	1,200	1,058	34.1	121	104
20.4	100	88.4	2.95	-	-	302	1,400	1,234	39.8	141	122
22.8	110	97.1	3.21	-	-	345	1,600	1,411	45.5	160	138
25.0	120	105.9	3.49	-	-	388	1,800	1,587	51	180	153
27.4	130	114.8	3.77	-	-	432	2,000	1,763	57	200	170
29.6	140	123.6	4.04	-	-	541	2,500	2,204	71	250	215
31.8	150	132.4	4.32	-	-	650	3,000	2,646	85	300	255
34.0	160	141.1	4.59	-	-	758	3,500	3,087	99	350	300
36.0	170	150.0	4.88	-	-	866	4,000	3,526	114	400	345
38.4	180	158.8	5.15	-	-	974	4,500	3,967	128	450	390
40.6	190	167.5	5.44	-	-	1,082	5,000	4,408	142	500	435
42.8	200	176.4	5.72	23.0	-	1,190	5,500	4,849	156	550	475
47.2	220	194.0	6.28	25.3	-	1,300	6,000	5,290	170	600	515
51.8	240	212	6.85	27.0	-	1,405	6,500	5,730	185	650	580
55.9	260	229	7.38	28.7	-	1,515	7,000	6,171	199	700	600
60.2	280	247	7.95	30.5	-	1,625	7,500	6,612	213	750	645
64.5	300	265	8.51	32.5	-	1,730	8,000	7,053	227	800	690
69.9	325	287	9.24	35.0	-	1,840	8,500	7,494	242	850	730
75.3	350	309	9.95	37.2	-	1,950	9,000	7,934	256	900	770
80.7	375	331	10.70	39.5	-	2,055	9,500	8,375	270	950	815
86.1	400	353	11.40	42.0	-	2,165	10,000	8,816	284	1,000	855
91.5	425	375	12.10	44.2	-						

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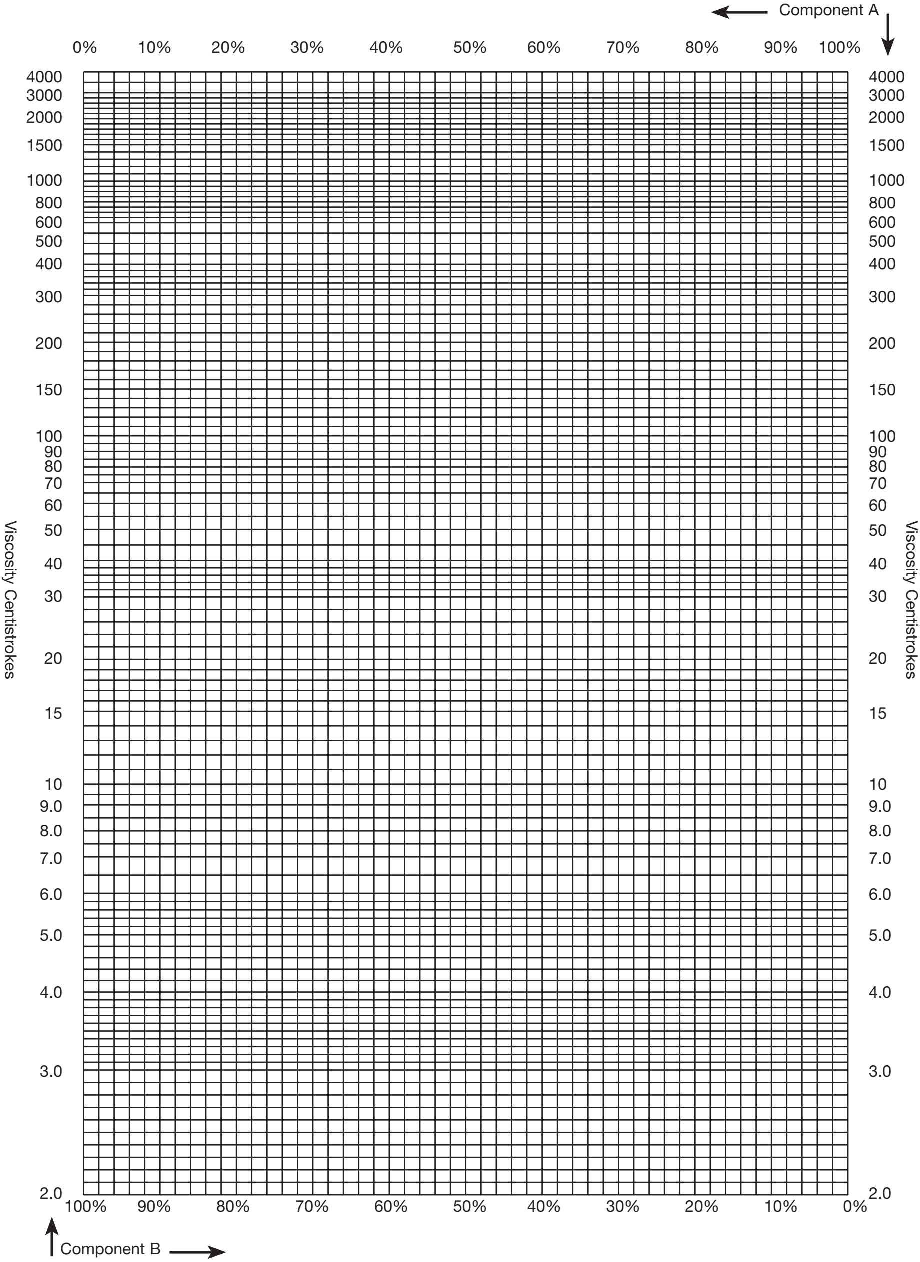
Two Components Viscosity Blending (cSt)



Base Stock Viscosities

Approximate Equivalents

	Neutrals			
	40°C		100°C	
	cSt	SUS	cSt	SUS
70N	13.3	70.8	3.0	37.0
80N	15.6	80.3	3.35	37.3
90N	18.0	89.0	3.4	37.5
100N	21.5	104.0	4.0	39.0
140N	30.7	144.0	4.5	41.0
150N	31.6	148.0	4.9	42.4
160N	33.7	158.0	5.2	43.3
170N	34.0	159.0	5.4	44.0
180N	38.5	181.0	5.7	44.9
200N	44.5	204.0	6.2	46.0
250N	56.1	257.0	6.5	47.0
300N	61.3	285.0	7.0	49.0
315N	70.0	315.0	7.9	52.0
330N	70.9	328.0	8.4	53.7
350N	76.0	358.0	8.8	55.0
400N	86.0	398.6	9.8	58.0
450N	98.0	454.0	10.5	61.0
500N	107.0	496.0	11.0	64.0
600N	130.4	604.0	12.1	66.0
650N	141.0	665.0	13.8	71.0
700N	151.0	668.0	14.0	73.0

	Brights			
	40°C		100°C	
	cSt	SUS	cSt	SUS
135 Brt	413.2	1875.0	28.6	135.0
145 Brt	523.3	2425.0	30.9	145.0
150 Brt	568.0	2632.0	33.0	155.0
160 Brt	600.0	2800.0	35.2	166.0
175 Brt	616.0	2855.0	36.0	169.7
185 Brt	654.7	3034.0	37.6	177.0
225 Brt	1030.0	4800.0	49.3	229.0

Conversion Factors

1 yd	= 0.9144 m
1 m	= 1.0936 yd
1 ft	= 0.3048 m
1 m	= 3.28 ft
1 in	= 2.54 cm
1 cm	= 0.3937 in
1 mile	= 1.6093 km
1 km	= 0.6214 mile
1 sq yd	= 0.8361 sq m
1 sq m	= 1.1960 sq yd
1 sq in	= 6.452 sq cm
1 sq cm	= 0.155 sq in
1 cu in	= 16.3872 cc
1 cc	= 0.0610 cu in
1 cu ft	= 0.02832 cu m
1 cu m	= 35.314 cu ft
1 cu yd	= 0.7646 cu m
1 cu m	= 1.3079 cu yd
1 imp gall	= 4.54596 litre
1 litre	= 0.21998 imp gall
1 imp gall	= 1.201 US gall
1 litre	= 1.76 pints
1 oz	= 28.3495 g
1 g	= 0.03527 oz
1 lb	= 453.59 g
1 kg	= 2.20462 lbs
1 g/litre	= 0.16035 oz/imp gall
1 oz/imp gall	= 6.236 g/litre
1 g/litre	= 0.01002 lb/imp gall
1 lb/imp gall	= 99.8003 g/litre
°C	= (°F - 32) x 5/9
°F	= (°C x 9/5) + 32
API gravity, deg	= (141.5/sp.gr. at 60/60°F) - 131.5

$$\text{\% volume of additive} = \frac{\text{\% weight of additive} \times \text{density of finished oil}}{\text{density of additive}}$$

(typical finished oil density = 0.88 g/ml)

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Engine Oils

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API Service Classifications

"S" Service

"S" Service - (Service Stations, Garages, New Car Dealers, etc.)

The following descriptions of the categories in the API Engine Service Classification System are intended as guides to aid in the selection of proper engine oils for significantly different engine service conditions. The performance requirements for these categories are technically described in SAE J183-June 1991, Engine Oil Performance and Engine Service Classification (except for SH).

SA **Formerly for Utility Gasoline and Diesel Engine Service**

Service typical of older engines operated under such mild conditions that the protection afforded by compounded oils is not required. This category should not be used in any engine unless specifically recommended by the equipment manufacturer.

SB **For Minimum Duty Gasoline Engine Service**

Service typical of older gasoline engines operated under such mild conditions that only minimum protection afforded by compounding is desired. Oils designed for this service have been used since the 1930s and provide only antiscuff capability and resistance to oil oxidation and bearing corrosion. They should not be used in any engine unless specifically recommended by the equipment manufacturer.

SC **For 1964 Gasoline Engine Warranty Maintenance Service**

Service typical of gasoline engines in 1964 through 1967 models of passenger cars and some trucks operating under engine manufacturers' warranties in effect during those model years. Oils designed for this service provide control of high and low temperature deposits, wear, rust and corrosion in gasoline engines.

SD **For Gasoline Engine Warranty Maintenance Service**

Service typical of gasoline engines in 1968 through 1970 models of passenger cars and some trucks operating under engine manufacturers' warranties in effect during those model years. Also may apply to certain 1971 and/or later models as specified (or recommended) in the owners' manuals. Oils designed for this service provide more protection against high and low temperature engine deposits, wear, rust and corrosion in gasoline engines than oils which are satisfactory for API Engine Service Category SC and may be used when API Engine Service Category SC is recommended.

SE **For 1972 Gasoline Engine Warranty Service**

Service typical of gasoline engines in passenger cars and some trucks beginning with 1972 and certain 1971 models operating under engine manufacturers' warranties. Oils designed for this service provide more protection against oil oxidation, high temperature engine deposits, rust and corrosion in gasoline engines than oils which are satisfactory for API Engine Service Categories SD or SC and may be used when either of these classifications is recommended.

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"S" Service

SF

For 1980 Gasoline Engine Warranty Maintenance Service

Service typical of gasoline engines in passenger cars and some trucks beginning with the 1980 model year operating under manufacturers' recommended maintenance procedures. Oils developed for this service provide increased oxidation stability and improved anti-wear performance relative to oils which meet the minimum requirements for API Service Category SE. The oils also provide protection against engine deposits, rust and corrosion. Oils meeting API Service Classification SF may be used where API Service Categories SE, SD or SC are recommended.

Oils meeting the performance requirements measured in the following gasoline engine tests: The IID gasoline engine test has been correlated with vehicles used in short-trip service prior to 1978, particularly with regard to rusting. The IIID gasoline engine test has been correlated with vehicles used in high temperature service prior to 1978, particularly with regard to oil thickening and valve train wear. The V-D gasoline engine test has been correlated with vehicles used in stop-and-go service prior to 1978, particularly with regard to varnish, sludge and valve train wear. The L-38 gasoline engine test requirement provides a measurement of copper-lead bearing weight loss under high-temperature operating conditions.

SG

For 1989 Gasoline Engine Warranty Maintenance Service

Service typical of gasoline engine in passenger cars, vans and light trucks beginning with the 1989 model year operating under manufacturers' recommended maintenance procedures. Category SG quality oils include the performance properties of API service category CC. (Certain manufacturers of gasoline engines require oils also meeting API Category CD).

Oils developed for this service provide improved control of engine deposits, oil oxidation and engine wear relative to oils developed for previous categories. These oils also provide protection against rust and corrosion. Oils meeting API Service Category SG may be used where API Service Categories SF, SF/CC, SE or SE/CC are recommended.

Oils meeting the performance requirements measured in the following gasoline and diesel engine tests:

- The IID gasoline engine test has been correlated with vehicles used in short-trip service prior to 1978, particularly with regard to rusting.
- The IIIE gasoline engine test has been correlated with vehicles used in high-temperature service prior to 1988, particularly with regard to oil thickening and valve train wear.
- The VE gasoline engine test has been correlated with vehicles used in stop-and-go service prior to 1988, particularly with regard to sludge and valve train wear.
- The L-38 gasoline engine test requirement provides a measurement of copper-lead bearing weight loss and piston varnish under high temperature operating conditions.
- The 1-H2 diesel engine test requirement provides a measurement of high-temperature deposits.

"S" Service

SH **For 1992 Gasoline Engine Warranty Maintenance Service**

Category SH covers the performance requirements of SG oils tested to the latest CMA protocol on engine testing. In addition, SH oils must meet various bench test requirements including volatility, filterability and foaming tests.

SJ **For 1997 Gasoline Engine Warranty Maintenance Service**

API Service Category SJ was adopted for use in describing engine oils available in 1996. These oils are for use in service typical of gasoline engines in current and earlier passenger-car, sport utility vehicle, van, and light truck operations under vehicle manufacturers' recommended maintenance procedures. Engine oils that meet API Service Category SJ designation may be used where API Service Category SH and earlier Categories have been recommended. Engine oils that meet the API Service Category SJ designation have been tested in accordance with the CMA Code, may use the API Base Oil Interchangeability Guidelines and the API Guidelines for SAE Viscosity-Grade Engine Testing. Engine oils that meet these requirements may display API Service Category SJ in the upper portion of the API Service Symbol.

SL **For 2001 Gasoline Engine Warranty Maintenance Service**

API Service Category SL was adopted for use in describing engine oils available in 2001. These oils are for use in service typical of gasoline engines in current and earlier passenger cars, sport utility vehicles, vans, and light-duty trucks operating under vehicle manufacturers' recommended maintenance procedures. Engine oils that meet API Service Category SL designation may be used where API Service Category SJ and earlier Categories have been recommended. Engine oils that meet the API Service Category SL designation have been tested in accordance with the ACC Code and may use the API Base Oil Interchangeability Guidelines and the API Guidelines for SAE Viscosity-Grade Engine Testing. First licence date was July 1, 2001, engine oils that meet these requirements may display API Service Category SL in the upper portion of the API Service Symbol.

SM For all automotive engines currently in use. Introduced in 2004, SM oils are designed to provide improved oxidation resistance, improved deposit protection, better wear protection, and better low-temperature performance over the life of the oil. Some SM oils may also meet the latest ILSAC specifications and/or quality as Energy Conserving. Suitable for use where API SJ or SL have been recommended. The first license date for API SM was November 30th 2004. Engine oil that meet these requirements may display API Service Category SM in the upper portion of the API Service Symbol.

SN API Service Category SN was adopted for use in describing engine oils available in 2011. These oils are for use in service typical of gasoline engines in current and earlier passenger cars, sport utility vehicles, vans, and light-duty trucks operating under vehicle manufacturers' recommended maintenance procedures. Vehicle owners and operators should follow their vehicle manufacturer's recommendations on engine oil viscosity and performance standard.

Engine oils that meet the API Service Category SN designation may be used where API Service Category SM and earlier S categories have been recommended. Engine oils that meet the API Service Category SN designation have been tested in accordance with the ACC Code and may use the API Base Oil Interchangeability Guidelines and the API Guidelines for SAE Viscosity-Grade Engine Testing. Starting October 1, 2010, oils that have passed the tests for API Service Category SN and are properly licensed by API may display API Service SN in the upper portion of the API Service Symbol.

API Gasoline Engine Performance Criteria

	Test	Primary Performance Criteria	Limits	
SA	None	None		
			L-4	**L-38**
SB	L-4 or L-38	Bearing Weight Loss, mg. max.	500	500
	Sequence IV	Cam Scuffing	None	
		Lifter Scuff Rating, max.	2	
SC	Sequences IIA and IIIA	Cam and Lifter Scuffing	None	
		Avg. Cam plus Lifter Wear, in. max.	0.0025	
		Avg. Rust Rating, min.	8.2	
		Avg. Sludge Rating, min.	9.5	
		Avg. Varnish Rating, min.	9.7	
	Sequence IV	Cam Scuffing	None	
		Lifter Scuff Rating, max.	2	
	Sequence V	Total Engine Sludge Rating, min.	40	
		Avg. Piston Skirt Varnish Rating, min.	7.0	
		Total Engine Varnish Rating, min.	35	
		Avg. Intake Valve Tip Wear, in. max.	0.0020	
		Ring Sticking	None	
		Oil Ring Clogging, %. max.	20	
		Oil Screen Plugging, %. max.	20	
	L-38	Bearing Weight Loss, mg. max.	50	
	L-1 (0.95% min. sulphur fuel)	Top Groove Filling, % vol. max. Second Groove and Below	25 Clean	
SD	Sequences IIB and IIIB	Cam and Lifter Scuffing	None	
		Avg. Cam and Lifter Wear, in. max.	0.0030	
		Avg. Rust Rating, min.	8.8	
		Avg. Sludge Rating, min.	9.6	
		Avg. Varnish Rating, min.	9.6	
	Sequence IV	Cam Scuffing	None	
		Lifter Scuff Rating, max.	1	
	Sequence VB	Total Engine Sludge Rating, min.	42.5	
		Avg. Piston Skirt Varnish Rating, min.	8.0	
		Total Engine Varnish Rating, min.	37.5	
		Avg. Intake Valve Tip Wear, in. max.	0.0015	
		Oil Ring Clogging, %. max.	5	
		Oil Screen Plugging, %. max.	5	
	L-38	Bearing Weight Loss, mg. max.	40	
			L-1	1-H
	L-1(0.95% min. S. fuel) or 1-H	Top Groove Filling, % vol. max.	25	30
		Second Groove and Below	-	Clean
		Weighted Total Demerits	-	140
	Falcon	Avg. Engine Rust Rating, min.	9	

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API Gasoline Engine Performance Criteria

	Test	Primary Performance Criteria	Limits	
SE	Sequence IIC or IID		**IIC**	**IID**
		Avg. Engine Rust Rating, min.	8.4	8.5
		Lifter Sticking	None	None
	Sequence IIIC or IIID		**IIIC**	**IIID**
		Viscosity Increase at 100°F. and 40 test hrs, %. max.	400	-
		Viscosity Increase at 40°C. and 40 test hrs, %. max.	-	375
		Avg. Piston Skirt Varnish Rating, min.	9.3	9.1
		Ring Land Face Varnish Rating, min.	6.0	4.0
		Avg. Sludge Rating, min.	9.2	9.2
		Ring Sticking	None	None
		Lifter Sticking	None	None
		Cam & Lifter Scuffing	None	None
		Cam & Lifter Wear, in. average	0.0010	0.0040
		Cam & Lifter Wear, in. max.	0.0020	0.0100
	Sequence VC or VD		**VC**	**VD**
		Avg. Engine Sludge Rating, min.	8.7	9.2
		Avg. Piston Skirt Varnish Rating, min.	7.9	6.4
		Avg. Engine Varnish Rating, min.	8.0	6.3
		Oil Ring Clogging, %. max.	5	10
		Oil Screen Plugging, %. max.	5	10
		Compression Ring Sticking	None	None
		Cam Wear, in. avg.	-	0.0020*
		Cam Wear, in. max.	-	0.0040*
	CRC L-38	Bearing Weight Loss, mg. max.	40	
SF	Sequence IID	Avg. Engine Rust Rating, min.	8.5	
		Lifter Sticking	None	
	Sequence IIID	Viscosity Increase at 40°C. and 64 test hrs, %. max.	375	
		Avg. Piston Skirt Varnish Rating, min.	9.2	
		Ring Land Face Varnish Rating, min.	4.8	
		Avg. Sludge Rating, min.	9.2	
		Ring Sticking	None	
		Lifter Sticking	None	
		Cam & Lifter Scuffing	None	
		Cam & Lifter Wear, in. avg.	0.0040	
		Cam & Lifter Wear, in. max.	0.0080	
	Sequence VD	Avg. Engine Sludge Rating, min.	9.4	
		Avg. Piston Skirt Varnish Rating, min.	6.7	
		Avg. Engine Varnish Rating, min.	6.6	
		Oil Ring Clogging, %. max.	10	
		Oil Screen Plugging, %. max.	7.5	
		Compression Ring Sticking	None	
		Cam Wear, in. avg.	0.0010	
		Cam Wear, in. max.	0.0025	
	CRC L-38	Bearing Weight Loss, mg. max.	40	

Note:
* Suggested performance - not pass/fail limit.

API Gasoline Engine Performance Criteria

	Test	Primary Performance Criteria			Limits
SG	Sequence IID	Avg. Engine Rust Rating, min.			8.5
		Lifter Sticking			None
	Sequence IIIE	Viscosity Increase at 40°C. and 64 test hrs, %. max.			375
		Avg. Piston Skirt Varnish Rating, min.			8.9
		Avg. Sludge Rating, min.			9.2
		Ring Land Face Varnish Rating, min.			3.5
		Ring Sticking			None
		Lifter Sticking			None
		Cam & Lifter Scuffing			None
		Cam & Lifter Wear, mm. average			30
		Cam & Lifter Wear, mm. max.			64
	Sequence VE	Avg. Engine Sludge Rating, min.			9.0
		Rocker Arm Cover Sludge Rating, min.			7.0
		Avg. Piston Skirt Varnish Rating, min.			6.5
		Avg. Engine Varnish Rating, min.			5.0
		Oil Ring Clogging, %. max.			15
		Oil Screen Plugging, %. max.			20
		Compression Ring Sticking			None
		Cam Wear, mm. average			122
		Cam Wear, mm. max.			381
	CRC L-38	Bearing Weight Loss, mg. max.			40
	1H2	Top Groove Filling, % vol. max.			45
		Weighted Total Demerits			140
SH	Sequence IID	API SG limits apply Tested according to CMA Code of Practice			
	Sequence IIIE or IIIF or IIIG				
	Sequence VE or IVA + VG				
	CRC L-38				
	SAE (J300)	**5W30**	**10W30**	**15W40**	**All Others**
	CEC-L-40-A-93/ L-40-T-87 (NOACK), %	25 max.	20 max.	18 max.	-
	Phosphorus, % m.	0.12 max.	0.12 max.	-	-
	Flash Point (ASTM D92), °C.	200 min.	205 min.	215 min.	-
	Foaming (Tendency/Stability)				
	Sequence I, max.	10/0	10/0	10/0	-
	Sequence II, max.	50/0	50/0	50/0	-
	Sequence III, max.	10/0	10/0	10/0	-
	Sequence IV	Report	Report	Report	-
	Homogeneity/Miscibility	Pass	Pass	Pass	-
	GM EOFT Filterability, Flow Reduction, %	50 max.	50 max.	-	-

API Gasoline Engine Performance Criteria

	Test	Primary Performance Criteria	
SJ	BRT	Average gray value, min.	100
	Sequence IIIF	Viscosity increase, % max.	325
		Avg. piston skirt varnish, min.	8.5
		Weighted piston deposit, min.	3.2
		Avg. cam-plus-lifter wear µm. max.	20
		Hot stuck rings	None
	Sequence VG (1)	Avg. engine sludge rating, min.	7.8
		Rocker arm cover sludge rating, min.	8.0
		Avg. piston skirt varnish rating, min.	7.5
		Avg. engine varnish rating, min.	8.9
		Oil screen clogging, % max.	20
		Hot stuck compression rings	None
	Sequence IVA (1)	Avg. cam wear µm. max.	120
	Sequence VIII (2)	Bearing weight loss, mg max.	26.4
		Sheer stability	Stay-in-grade
	SAE (J300)	**0W-20, 5W-20, 5W-30, 10W-30**	**All Others**
	CEC-L-40-A-93/ L-40-T-87 (NOACK), %	22 max.	20 max.
	Phosphorus, % m.	0.10 max.	-
	Flash Point (ASTM D92), °C.	200 min. 205 min. (10W-30)	-
	Foaming (Tendency/Stability)		
	Sequence I, max.	10/0	10/0
	Sequence II, max.	50/0	50/0
	Sequence III, max.	10/0	10/0
	High Temp. (ASTM D6082),	200/50	200/50
	Homogeneity/Miscibility	Pass	Pass
	GM EOFT Filterability, Flow Reduction, %	50 max.	50 max.
	High Temp. Deposits (TEOST) mg.	60 max.	60 max.
	Gelation Index	12 max.	-

Note:

(1) Sequence IVA + VG in lieu of Sequence VE.

(2) Sequence VIII to API SL limits may be used.

API Gasoline Engine Performance Criteria

	Test	Primary Performance Criteria	Limits
SL	ASTM Ball Rust Test	Avg. Grey Value, min.	100
	Sequence IIIF (2)	Viscosity Increase (KV 40°C), %. max.	275
		Avg. Piston Skirt Varnish, min.	9.0
		Weighted Piston Demerit Rating, min.	4.0
		Hot Stuck Piston Rings	None
		Avg. Cam and Lifter Wear, µm. max.	20
		Oil Consumption	5.2
		Low Temp. Viscosity	Report (1)
	Sequence VE (3)	Cam Wear Average µm. max.	127
		Cam Wear Average µm. max.	380
	Sequence IVA	Avg. Cam Wear µm, max.	120
	Sequence VG	Avg. Engine Sludge Rating, min.	7.8
		Rocker Cover Sludge Rating, min.	8.0
		Average Engine Varnish Rating, min.	8.9
		Average Piston Skirt Varnish, min.	7.5
		Oil Screen Clogging, max.	20
		Hot Stuck Compression Ring	None
		Cold Stuck Rings	Rate & Report
		Oil Screen Debris (%)	Rate & Report
		Oil Ring Clogging	Rate & Report
	SAE (J300)	**0W-20, SW-20, SW-30, 10W-30**	**All Others**
	Volatility Loss ASTM D5800, %. max.	15	15
	Volatility Loss at 37 °C ASTM D6417, %. max.	10	10
	Sequence VIII	Bearing % wt. Loss, mg. max.	26.4
	Phosphorus, % m.	0.10 max.	-
	Flash Point (ASTM D92), °C.	200 min. 205 min. (10W-30)	-
	Foaming (Tendency/Stability)		
	Sequence I, max.	10/0	10/0
	Sequence II, max.	50/0	50/0
	Sequence III, max.	10/0	10/0
	High Temp. (ASTM D6082), max.	100/0	100/0
	Homogeneity/Miscibility	Pass	Pass
	GM EOFT Filterability, Flow Reduction, %. max.	50	50
	High Temp. Deposits (TEOST) mg. max.	45	45
	Gelation Index, max.	12	-
	Shear Stability - Seq. VIII 10 hr. Stripped KV100°C.	Stay-in-grade	Stay-in-grade

Note:

(1) The 80 hr test sample shall be evaluated by test method D4684 (MRV TP-1) at the temperature indicated by the low-temperature grade of oil as determined on the 80 hr sample by test method D5293 (CCS Viscosity).

(2) Sequence IIIG at API SM performance accepted as alternative to Sequence IIIF.

(3) Not required for oils containing a minimum of 0.08% phosphorus in the form of ZDDP.

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API Gasoline Engine Performance Criteria

	Test	Primary Performance Criteria	Limits	
			SAE 0W-20, SAE 5W-20 SAE 0W-30, SAE 5W-30, SAE 10W-30	All Others
SM	ASTM Ball Rust Test	Avg. Grey Value, min	100	100
	Sequence IIIG	Viscosity Increase (KV 40˚C), %, max.	150	150
		Weighted Piston Demerit rating, min.	3.5	3.5
		Hot Stuck Piston Rings	None	None
		Avg. Cam and Lifter Wear, μm, max.	60	60
		Oil Consumption	Report	Report
	Sequence IIIGA	Used oil MRV (1)	Pass	-
	Sequence IVA	Avg. Cam Wear μm, max	90	90
	Sequence VG	Avg. Engine Sludge rating, min.	7.8	7.8
		Rocker Cover Sludge rating, min.	8.0	8.0
		Average Engine Varnish rating, min.	8.9	8.9
		Average Piston Skirt Varnish, min.	7.5	7.5
		Oil Screen Clogging, max.	20	20
		Hot Stuck Compression Ring	None	None
		Cold Stuck Rings	Rate & Report	Rate & Report
		Oil Screen Debris (%)	Rate & Report	Rate & Report
		Oil Ring Clogging	Rate & Report	Rate & Report
	Sequence VIII	Bearing Weight Loss, mg, max.	26	26

Note:
(1) To be measured at 5˚C greater than that specified by SAE J300 for the viscosity grade of the oil.

API Gasoline Engine Performance Criteria

Bench Tests	Primary Performance Criteria	Limits	
		SAE 0W-20, SAE 5W-20 SAE 0W-30, SAE 5W-30, SAE 10W-30	All Others
SM	Phosphorus % mass, max.(2)	0.08(3)	-
	Phosphorus % mass, min.(2)	0.06(3)	0.06 (3)
	or D2622, sulphur mass, max.(2)	0.5(3)	-
	SAE 0W-20, 0W-30, 5W-20, 5W-30, SAE 10W-30	0.7(3)	-
	Flash Point (ASTM D92), ˚C	200 min. 205 min. (10W-30)	-
	Foaming (Tendency / Stability)		
	Sequence I, max.	10/0	10/0
	Sequence II, max.	50/0	50/0
	Sequence III, max.	10/0	10/0
	High Temp. (ASTM D6082), max.	100/0	100/0
	Homogeneity / Miscibility	Pass	Pass
	GM EOFT Filterability Flow reduction, %, max.	50	50
	EOWTT, % flow reduction, max.		
	with 0.6% H_2O	50	50
	with 1.0% H_2O	50	50
	with 2.0% H_2O	50	50
	with 3.0% H_2O	50	50
	High temp. deposits (TEOST) mg, max	35	45
	Gelation Index, max.(4)	12	-
	Shear Stability - Seq. VIII 10 hr. Stripped KV 100˚C	Stay-in-grade	Stay-in-grade
	Volatility Loss ASTM D5800, %, max.	15	15
	Volatility Loss at 37˚C ASTM D6417, %, max.	10	10

Note:

(2) For all viscosity grades: If CF-4, CG-4, CH-4 and/or CI-4 categories precede the "S" category and there is no API Certification Mark, the limits for phosphorus, sulphur, and the TEOST MHT do not apply. Note that these oils have been formulated primarily for diesel engines and may not provide all of the performance requirements consistent with vehicle manufacturers' recommendations for gasoline-fueled engines.

(3) This is a non-critical specification as described in ASTM D3244.

(4) To be evaluated from -5˚C to temperature at which 40,000 cP is attained or -40˚C, or 2˚C below the appropriate MRV TP-1 temperature (defined by SAE J300), whichever occurs first.

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API Gasoline Engine Performance Criteria

	Engine Tests	Primary Performance Criteria	Limits	
			SAE 0W-20, 5W-20, 0W-30, 5W-30, 10W-30	All Others
SN	Sequence IIIG (ASTM D7320)	Kinematic viscosity increase @ 40°C, %, max.	150	
		Average Weighted Piston Deposits, merits, min.	4.0	
		Hot Stuck Rings	None	
		Average Cam plus Lifter Wear, μm, max.	60	
	Sequence IVA (ASTM D6891)	Average Cam Wear (7 positions average), μm, max.	90	
	Sequence VG (ASTM D6593)	Average Engine Sludge, merits, min.	8.0	
		Average Rocker Cover Sludge, merits, min.	8.3	
		Average Engine Varnish, merits, min.	8.9	
		Average Piston Skirt Varnish, merits, min.	7.5	
		Oil Screen Sludge, % area, max.	15	
		Oil Screen Debris, % area	Rate & Report	
		Hot Stuck Compression Rings	none	
		Cold Stuck Rings	Rate & Report	
		Oil Ring Clogging, % area	Rate & Report	
	Sequence VID (ASTM D7589)	SAE xW-20 Viscosity grade		
		FEI SUM	2.6% min.	
		FEI 2	1.2% min. after 100 hrs. aging	
		SAE xW-30 viscosity grade		
		FEI SUM	1.9% min.	
		FEI 2	0.9% min. after 100 hrs. aging	
		SAE 10W-30 and all others viscosity grades not listed above:		
		FEI SUM	1.5% min.	
		FEI 2	0.6% min. after 100 hrs. aging	
	Sequence VIII (ASTM D6709)	Bearing weight loss, mg, max.	26	

API Gasoline Engine Performance Criteria

	Bench Test and Measured Parameters	Primary Performance Criteria	Limits	
			SAE 0W-20, 5W-20, 0W-30, 5W-30, 10W-30	All Others
SN	Aged oil Low Temp Viscosity, ASTM Sequence IIIGA test, ASTM D7320	Measure CCS viscosity of the EOT Sequence IIIGA sample at the CCS temperature corresponding to original viscosity grade	(1) a) b) c)	
	Aged oil Low Temperature Viscosity, ROBO Test, ASTM D7528	Measure CCS viscosity of the EOT ROBO sample at the CCS temperature corresponding to original viscosity grade	(2) a) b) c)	
	Sequence IIIGB, ASTM D7320	Phosphorous volatility, % min.	79	
	Ball Rust Test, ASTM D6557	Average gray value, % min.	100	
	Evaporation loss, ASTM D5800	1 hr at 250°C, max. (3)	15.0	
	Simulated distillation, ASTM D6417	% max at 371°C	10	
	EOFT, ASTM D6795	Maximum Flow reduction, %	50	
	EOWTT, ASTM D6794	with 0.6% H_2O, maximum flow reduction, %	50	
		with 1.0% H_2O, maximum flow reduction, %	50	
		with 2.0% H_2O, maximum flow reduction, %	50	
		with 3.0% H_2O, maximum flow reduction, %	50	
	Phosporous content, ASTM D4951	% mass	≥ 0.06 and ≤ 0.08	≥ 0.06
	Sulphur content, ASTM D4951 or D2622	0W-XX, 5W-XX, % mass max.	0.5	
		10W-30, % mass, max.	0.6	
		All other grades, % mass max.	0.6	
	Fresh Oil Foaming Characteristics ASTM D892 (option A)		Tendency/ Stability (after 10 min)	Tendency/ Stability (after 10 min)
		Sequence I, ml max.	10/0	10/0
		Sequence II, ml max.	50/0	50/0
		Sequence III, ml max.	10/0	10/0

Note:

(1) a) If CCS Viscosity measured is less than or equal to the maximum CCS viscosity for the original viscosity grade, run ASTM D4684 (MRV TP-1) at the MRV temperature specified in SAE J300 for the original viscosity grade.
b) If CCS Viscosity measured is higher than the maximum viscosity specified for the original grade in J300, run ASTM D4684 (MRV TP-1) at 5°C higher temperature (i.e at MRV temperature specified in SAE J300 for the next higher viscosity (grade).
c) The EOT IIIGA sample must show no yield stress in the D4684 test and its D4684 viscosity must be below the maximum specified in SAE J300 for the original viscosity grade or the next higher viscosity grade, depending on the CCS viscosity as outlined in a) or b) above.

(2) a) Same as above.
b) Same as above.
c) The EOT ROBO sample must show no yield stress in the D4684 test and its D4684 viscosity must be below the maximum specified in SAE J300 for the original viscosity grade or the next higher viscosity grade, depending on the CCS viscosity as outlined in a) or b) above.

(3) Calculated conversions specified in D5800 are allowed.

API Gasoline Engine Performance Criteria

	Bench Test and Measured Parameters	Primary Performance Criteria	Limits: SAE 0W-20, 5W-20, 0W-30, 5W-30, 10W-30	Limits: All Others
SN	Fresh Oil High Temperature Foaming Characteristics, ASTM D6082 (Option A)	ml, max.	Tendency/ Stability (after 10 min) 100/0	Tendency/ Stability (after 10 min) 100/0
	Homogeneity and Miscibility, ASTM D6922	Shall remain homogeneous and, when mixed with ASTM Test Monitoring Centre (TMC) reference oils, shall remain miscible	Pass	
	Shear stability, Sequence VIII, ASTM D6709	10 hr stripped KV @ 100°C	Kinematic viscosity must remain in original SAE viscosity grade	
	High Temperature Deposits, TEOST MHT, ASTM D7097	Deposit weight, mg, max.	35	45
	Gelation Index, ASTM D5133 (4)	Max.	12	-
	Emulsion Retention, ASTM D7563	0°C, 24 hrs	No water separation	
		25°C, 24 hrs	No water separation	

Elastomer Compatibility

Candidate oil for elastomer compatibility shall be performed using the five Standard Reference Elastomers (SREs) referenced herein and defined in SAE J2643. Candidate oil testing shall be performed according to ASTM D7216 Annex A2. The post-candidate-oil-immersion elastomers shall conform to the specification limits detailed herein.

Elastomer Material (SAE J2643)	Test Procedure	Material property	Units	Limits
Polyacrylate Rubber (ACM-1)	ASTM D471	Volume	% Δ	-5, 9
	ASTM D2240	Hardness	pts	-10, 10
	ASTM D412	Tensile Strength	% Δ	-40, 40
Hydrogenated Nitrile Rubber (HNBR-1)	ASTM D471	Volume	% Δ	-5, 10
	ASTM D2240	Hardness	pts	-10, 5
	ASTM D412	Tensile Strength	% Δ	-20, 15
Silicone Rubber (VMQ-1)	ASTM D471	Volume	% Δ	-5, 40
	ASTM D2240	Hardness	pts	-30, 10
	ASTM D412	Tensile Strength	% Δ	-50, 5
Fluorocarbon Rubber (FKM-1)	ASTM D471	Volume	% Δ	-2, 3
	ASTM D2240	Hardness	pts	-6, 6
	ASTM D412	Tensile Strength	% Δ	-65, 10
Ethylene Acrylic Rubber (AEM-1)	ASTM D471	Volume	% Δ	-5, 30
	ASTM D2240	Hardness	pts	-20, 10
	ASTM D412	Tensile Strength	% Δ	-30, 30

Note:

(4) To be evaluated from -5°C to temperature at which 40,000 cP is attained or -40°C, or 2°C below the appropriate MRV TP-1 temperature (defined by SAE J300), whichever occurs first.

ILSAC Specifications: GF-1

Test		Limits
Viscosity Requirements		As defined by SAE J300
Engine Test Requirements	Sequence IID, Sequence IIIE, Sequence VE, CRC L-38	API SG Limits apply. Tested according to CMA Code of Practice
Bench Test Requirements	HTHS Viscosity at 150°C. and $10^6 s^{-1}$	2.9 min. (for all viscosity grades)
	Volatility Sim. dis. (ASTM D2887) or Evaporative Loss (CEC-L-40-T-87)	
	SAE 0W and 5W multigrades	20% max. at 371°C. 25% max. 1 hr. at 250°C.
	All other SAE viscosity grades	17% max. at 371°C. 20% max. 1 hr. at 250°C.
	GM EOFT Filterability	50% max. flow reduction
	Foaming (Tendency/Stability) ASTM D892 (Option A)	
	Sequence I, max.	10/0
	Sequence II, max.	50/0
	Sequence III, max.	10/0
	Sequence IV, max.	Report & Report
	Flash Point	
	ASTM D92 or	185°C. min.
	ASTM D93	200°C. min.
	Shear Stability	
	L-38 10 hr stripped viscosity	Must stay-in-grade
	Homogeneity and Miscibility	
	Federal test method 791B, method 3470	Shall remain homogeneous and when mixed with SAE reference oils, shall remain miscible
Additional Requirements	Sequence VI, EFEI	2.7% min.
	Catalyst Compatibility	
	Phosphorus Content, % wt.	0.12% max.
	SAE J300 Low Temperature Viscosity, mPa.s	
	Cranking	3500 max. at -20°C.
	Pumping	30000 max. at -25°C.

ILSAC Specifications: GF-2

ILSAC GF-2 is applicable to SAE viscosity grades 0W-XX, 5W-XX and 10W-XX grades only. Oils can be licensed with the API Engine Oil Licensing and Certification System (EOLCS) from 15 October 1996.

The Sequence VI fuel economy engine test from ILSAC GF-1 is replaced with the Sequence VI-A. Three categories of fuel economy improvement are possible with ILSAC GF-2.

ILSAC GF-2 oils have a phosphorus limitation of 0.10% maximum compared with 0.12% maximum for GF-1.

Test		Limits
Viscosity Requirements	SAE 0W-XX, 5W-XX, 10W-XX	As defined by SAE J300
Engine Test Requirements	Sequence IID, Sequence IIIE, Sequence VE, CRC L-38	API SG Limits apply. Tested according to CMA Code of Practice
Bench Test Requirements	CEC-L-40-A-93/L-40-T-87 (NOACK), %	22 max.
	Phosphorus, % m.	0.10 max.
	Flash Point (ASTM D92), °C.	200 min.
	Foaming (Tendency/Stability)	
	D892 Sequence I, max.	10/0
	D892 Sequence II, max.	50/0
	D892 Sequence III, max.	10/0
	D6082 High temp. (ASTM D1392), max.	200/50
	Homogeneity/Miscibility	Pass
	GM EOFT Filterability	
	Flow reduction, %	50 max.
	GM EOFT Modified	
	0.6/1.0% water	Rate & Report
	2.0/3.0% water	Rate & Report
	High Temp. Deposits (TEOST)	
	Deposit % wt. mg.	60 max.
	Gelation Index	12.0 max.
Additional Requirements	Sequence VI-A Fuel Economy	
	SAE 0W-20, 5W-20	1.4% min.
	Other SAE 0W-X, 5W-X	1.1% min.
	SAE 10W-X	0.5% min.

ILSAC Specifications: GF-3

ILSAC GF-3 is applicable to SAE viscosity grades 0W-XX, 5W-XX and 10W-XX grades only. Oils can be licensed with the API Engine Oil Licensing and Certification System (EOLCS) from 15 October 1996.

The Sequence VI-A fuel economy engine test from ILSAC GF-2 is replaced with the Sequence VI-B. Three categories of fuel economy improvement are possible with ILSAC GF-3.

ILSAC GF-3 oils maintain a phosphorus limitation of 0.10% maximum established in ILSAC GF-2 to maintain acceptable catalyst protection.

Test		Limits		
Viscosity Requirements	SAE 0W-XX, 5W-XX, 10W-XX	As defined by SAE J300		
Engine Test Requirements	Sequence IIIF, Sequence IVA, Sequence VG, Sequence VIII, BRT	API SL Limits apply. Tested according to ACC Code of Practice		
Bench Test Requirements	Evaporation Loss (ASTM D5800)	15% max. 1 hr at 250ºC.		
	Simulated Distillation (ASTM D6417)	10% max. at 371ºC.		
	Phosphorus, % m.	0.10 max.		
	Foaming Tendency/Stability (Option A)			
	Sequence I, max.	10/0		
	Sequence II, max.	50/0		
	Sequence III, max.	10/0		
	High temp. (ASTM D6082), max.	100/0		
	Homogeneity/Miscibility	Pass		
	GM EOFT Filterability			
	Flow reduction, %	50 max.		
	GM EOFT Modified (EOWTT) (1)			
	0.6/1.0% water	50 max.		
	2.0/3.0% water	50 max.		
	High Temp. Deposits (TEOST-MHT-4)			
	Deposit % wt. mg.	45 max.		
	Gelation Index	12.0 max.		
Additional Requirements	Sequence VI-B Fuel Economy	FE1 (16 hr)	FE2 (96 hr)	Sum FE1/FE2
	SAE 0W-20, 5W-20	2.0 min	1.7 min.	-
	Other SAE 0W-30, 5W-30	1.6 min.	1.3 min.	3.0 min.
	SAE 10W-30 & all other viscosity grades	0.9 min.	0.6 min.	1.6 min.

Note:

(1) Test formulation with highest additive (DI/VI) concentration.
Read across results to all other base oil/viscosity grade formulations using same or lower concentration of identical additive (DI/VI) combination.
Each different DI/VI combination must be tested.

ILSAC Specifications: GF-4

ILSAC GF-4 is applicable to SAE viscosity grades 0W-XX, 5W-XX and 10W-XX grades only. Oils can be licensed with the API Engine Oil Licensing and Certification System (EOLCS) from 14 January 2004.

Three categories of fuel economy improvement are possible with ILSAC GF-4.

ILSAC GF-4 oils have a phosphorus limitation of 0.08% maximum compared with 0.10% maximum for GF-3 and a sulphur limit dependent on the viscosity grade, to maintain acceptable catalyst protection.

Test		Limits
Viscosity Requirements	SAE 0W-XX, 5W-XX, 10W-XX	As defined by SAE J300
Engine Test Requirements	Sequence IIIG	
	Kinematic Viscosity Increase @ 40°C, %	150 max.
	Average Weighted Piston Deposits, merits	3.5 min.
	Hot Stuck Rings	none
	Average Cam plus Lifter Wear, μm	60 max.
	Sequence IIIGA Evaluate the EOT oil from the ASTM Sequence IIIGA test with ASTM D4684 (MRV TP-1)	The D4684 viscosity of the EOT sample must meet the requirements of the original grade or the next higher grade.
	Sequence VG	
	Average Engine Sludge, merits	7.8 min.
	Average Rocker Cover Sludge, merits	8.0 min.
	Average Engine Varnish, merits	8.9 min.
	Average Piston Skirt Varnish, merits	7.5 min.
	Oil Screen Sludge, % area	20 max.
	Oil Screen Debris, % area	Rate & Report
	Hot Stuck Compression Rings	None
	Cold Stuck Rings	Rate & Report
	Oil Ring Clogging, % area	Rate & Report
	Follower Pin Wear, cyl #8, avg, μm	Rate & Report (1)
	Ring Gap Increase, cyl #1 & #8, avg, μm	Rate & Report (1)
	Sequence IVA	
	Average Cam Wear (7 position average), μm	90 maximum
	Sequence VIII	
	Bearing Weight Loss, mg	26 maximum
	Sequence VIB (2)	
	SAE 0W-20 and 5W-20 viscosity grades:	2.3% FEI 1 min. after 16 hrs. aging 2.0% FEI 2 min. after 96 hrs. aging
	SAE 0W-30 and 5W-30 viscosity grades:	1.8% FEI 1 min. after 16 hrs. aging 1.5% FEI 2 min. after 96 hrs. aging
	SAE 10W-30 and all other viscosity grades not listed above	1.1% FEI 1 min. after 16 hrs. aging 0.8% FEI 2 min. after 96 hrs. aging

Note:

(1) ASTM Surveillance Panel will review statistics annually.

(2) All FEI 1 and FEI 2 values determined relative to ASTM Reference Oil BC.

Afton CHEMICAL

ILSAC Specifications: GF-4

Test		Limits	
Bench Test Requirements	Evaporation Loss (ASTM D5800)	15% max. 1 hr at 250°C	
	Simulated Distillation (ASTM D6417)	10% max. at 371°C	
	Phosphorous, % mass	0.06 min. - 0.08 max.	
	Sulphur, % mass,		
	SAE 0W and 5W multigrades	0.5% max.	
	SAE 10W multigrades	0.7% max.	
	Shear Stability, Sequence VIII (ASTM D6709)	Kinematic viscosity must remain in original SAE viscosity	
	10 hr stripped KV @ 100°C		
	Ball Rust test (ASTM D6557)		
	Average Grey value	100 min.	
	Foaming (Tendency/Stability)		
	Sequence I, max.	10/0	
	Sequence II, max.	50/0	
	Sequence III, max.	10/0	
	High temp. (ASTM D6082), max.	100/0	
	Homogeneity/Miscibility	Pass	
	GM EOFT Filterability		
	Flow reduction, %	50 max.	
	GM EOFT Modified (EOWTT) (3)		
	0.6/1.0% water	50 max.	
	2.0/3.0% water	50 max.	
	High Temp. deposits (TEOST MHT-4)		
	Deposit wt. mg.	35 max.	
Additional Requirements	Sequence VI-B Fuel Economy (2)	FE1 (16 hr)	FE2 (96 hr)
	SAE 0W-20, 5W-20	2.3 min.	2.0 min.
	SAE 0W-30, 5W-30	1.8 min.	1.5 min.
	SAE 10W-30 & all other viscosity grades	1.1 min.	0.8 min.

Note:

(2) All FEI 1 and FEI 2 values determined relative to ASTM Reference Oil BC.

(3) Test formulation with highest additive (DI/VI) concentration.
Read across results to all other base oil/viscosity grade formulations using same or lower concentration of identical additive (DI/VI) combination.
Each different DI/VI combination must be tested.

ILSAC Specifications: GF-5

Test	Performance Criteria	Limits
Viscosity requirements	SAE 0W-XX, 5W-XX, 10W-XX	As defined by SAE J300
Gelation Index	ASTM D5133 To be evaluated from -5°C at which 40,000 cP is attained or -40°C, or 2°C below the appropriate MRV TP-1 temperature (defined by SAE J300), whichever occurs first	
Engine Test Requirements	Sequence IIIG (ASTM D7320)	
	Kinematic viscosity increase @ 40°C, %	150 max.
	Average Weighted Piston Deposits, merits	4.0 min.
	Hot Stuck Rings	none
	Average Cam plus Lifter Wear, µm	60 max.
	Sequence VG (ASTM D6593)	
	Average Engine Sludge, merits	8.0 min.
	Average Rocker Cover Sludge, merits	8.3 min.
	Average Engine Varnish, merits	8.9 min.
	Average Piston Skirt Varnish, merits	7.5 min.
	Oil Screen Sludge, % area	15 max.
	Oil Screen Debris, % area	Rate & Report
	Hot Stuck Compression Rings	none
	Cold Stuck Rings	Rate & Report
	Oil Ring Clogging, % area	Rate & Report
	Sequence IVA (ASTM D6891)	
	Average Cam Wear (7 positions average), µm	90 max.
	Sequence VIII (ASTM D6709)	
	Bearing weigth loss, mg	26 max.
	Sequence VID (ASTM D7589)	
	SAE xW-20 Viscosity grade	
	FEI SUM	2.6% min.
	FEI 2	1.2% min. after 100 hrs.
	SAE xW-30 viscosity grade	
	FEI SUM	1.9% min.
	FEI 2	0.9% min. after 100 hrs.
	SAE 10W-30 and all others viscosity grades not listed above:	
	FEI SUM	1.5% min.
	FEI 2	0.6% min. after 100 hrs.
	Catalyst compatibility	
	Phosphorus Content, ASTM D4951	0.08% (mass) max.
	Phosphorus Volatility ASTM D7320 (Sequence IIIGB, Phosphorus retention)	79% min
	Sulphur content, ASTM D4951 or D2622	
	SAE 0W-XX, 5W-XX	0.5% (mass) max.
	SAE 10W-30	0.6% (mass) max.
	Wear	
	Phosphorous content, ASTM D4951	0.06% (mass) min.

Afton CHEMICAL

ILSAC Specifications: GF-5

Test	Performance Criteria	Limits	
Engine Test Requirements	Volatility		
	Evaporation loss, ASTM D5800	15% max 1 hr at 250°C (1)	
	Simulated distillation, ASTM D6417	10% max at 371°C	
	High Temperature Deposits, TEOST MHT-4 ASTM D7097		
	Deposit weight, mg	35 max	
	High Temperature Deposits, TEOST 33C, ASTM D6335		
	Total deposit weight, mg	30 max (2)	
	Filterability		
	EOWTT, ASTM D6794		
	with 0.6% H2O	50% maximum flow reduction	
	with 1.0% H2O	50% maximum flow reduction	
	with 2.0% H2O	50% maximum flow reduction	
	with 3.0% H2O	50% maximum flow reduction	
	EOFT, ASTM D6795	50% maximum flow reduction	
	Fresh Oil Foaming Characteristics (ASTM D6082 option A and excluding paragraph 11)	Tendency	Stability (after 1 min settling period)
	Sequence I	10 ml max	0 ml max
	Sequence II	50 ml max	0 ml max
	Sequence III	10 ml max	0 ml max
	Fresh Oil High Temperature Foaming Characteristics, ASTM D6082 (Option A)	Tendency	Stability (after 1 min settling period)
		100ml max	0 ml max
	Aged oil Low Temperature Viscosity, ROBO Test, ASTM D7528		
	Measure CCS viscosity of the EOT ROBO sample at the CCS temperature corresponding to original viscosity grade	See (3) a) b) c)	

Note:

(1) Calculated conversions specified in D5800 are allowed.

(2) No TEOST 33C limit for SAE 0W-20.

(3) a) If CCS Viscosity measured is less than or equal to the maximum CCS viscosity for the original viscosity grade, run ASTM D4684 (MRV TP-1) at the MRV temperature specified in SAE J300 for the original viscosity grade

b) If CCS Viscosity measured is higher than the maximum viscosity specified for the original grade in J300, run ASTM D4684 (MRV TP-1) at 5°C higher temperature (i.e at MRV temperature specified in SAE J300 for the next higher viscosity grade).

c) The EOT ROBO sample must show no yield stress in the D4684 test and its D4684 viscosity must be below the maximum specified in SAE J300 for the original viscosity grade or the next higher viscosity grade, depending on the CCS viscosity as outlined in a) or b) above.

ILSAC Specifications: GF-5

Test	Performance Criteria	Limits
	Aged oil Low Temperature Viscosity, ASTM Sequence IIIGA test, ASTM D7320	
	Measure CCS viscosity of the EOT Sequence IIIGA sample at the CCS temperature corresponding to original viscosity grade	See (4) a) b) c)
	Shear stability, Sequence VIII, ASTM D6709	
	10 hr stripped KV @ 100°C	Kinematic viscosity must remain in original SAE viscosity grade
	Homogeneity and Miscibility, ASTM D6922	Shall remain homogeneous and, when mixed with ASTM Test Monitoring Center (TMC) reference oils, shall remain miscible
	Engine Rusting, Ball Rust Test, ASTM D6557	
	Average gray value	100 min
	Emulsion Retention, ASTM D7563	
	0°C, 24 hrs	No water separation
	25°C, 24 hrs	No water separation

Elastomer compatibility

Candidate oil for elastomer compatibility shall be performed using the five Standard Reference Elastomers (SREs) referenced herein and defined in SAE J2643. Candidate oil testing shall be performed according to ASTM D7216 Annex A2. The post-candidate-oil-immersion elastomers shall conform to the specification limits detailed herein.

Elastomer Material (SAE J2643)	Test Procedure	Material property	Units	Limits
Polyacrylate Rubber (ACM-1)	ASTM D471	Volume	% Δ	-5, 9
	ASTM D2240	Hardness	pts	-10, 10
	ASTM D412	Tensile Strength	% Δ	-40, 40
Hydrogenated Nitrile Rubber (HNBR-1)	ASTM D471	Volume	% Δ	-5, 10
	ASTM D2240	Hardness	pts	-10, 5v
	ASTM D412	Tensile Strength	% Δ	-20, 15
Silicone Rubber (VMQ-1)	ASTM D471	Volume	% Δ	-5, 40
	ASTM D2240	Hardness	pts	-30, 10
	ASTM D412	Tensile Strength	% Δ	-50, 5
Fluorocarbon Rubber (FKM-1)	ASTM D471	Volume	% Δ	-2, 3
	ASTM D2240	Hardness	pts	-6, 6
	ASTM D412	Tensile Strength	% Δ	-65, 10

Note:

(4) a) If CCS Viscosity measured is less than or equal to the maximum CCS viscosity for the original viscosity grade, run ASTM D4684 (MRV TP-1) at the MRV temperature specified in SAE J300 for the original viscosity grade.

b) If CCS Viscosity measured is higher than the maximum viscosity specified for the original grade in J300, run ASTM D4684 (MRV TP-1) at 5°C higher temperature (i.e at MRV temperature specified in SAE J300 for the next higher viscosity grade).

c) The EOT IIIGA sample must show no yield stress in the D4684 test and its D4684 viscosity must be below the maximum specified in SAE J300 for the original viscosity grade or the next higher viscosity grade, depending on the CCS viscosity as outlined in a) or b) above.

API Commercial Classifications

"C" Commercial

"C" Commercial - (Fleets, Contractors, Farmers, etc.)

CA

For Light Duty Diesel Engine Service

Service typical of diesel engine operated in mild to moderate duty with high-quality fuels and occasionally has included gasoline engines in mild service. Oils designed for this service provide protection from bearing corrosion and from ring belt deposits in some naturally aspirated diesel engines when using fuels of such quality that they impose no unusual requirements for wear and deposit protection. They were widely used in the late 1940s and 1950s but should not be used in any engine unless specifically recommended by the equipment manufacturer.

CB

For Moderate Duty Diesel Engine Service

Service typical of diesel engines operated in mild to moderate duty, but with lower-quality fuels which necessitate more protection for wear and deposits. Occasionally has included gasoline engines in mild service. Oils designed for this service provide necessary protection from bearing corrosion and from ring belt deposits in some naturally aspirated diesel engines with higher sulphur fuels. Oils designed for this service were introduced in 1949.

CC

For Moderate Duty Diesel and Gasoline Engine Service

Service typical of many naturally aspirated diesel engines operated in moderate to severe-duty service and certain heavy-duty gasoline engines. Oils designed for this service provide protection from high temperature deposits and bearing corrosion and low temperature deposits in gasoline engines. These oils were introduced in 1961.

CD

For Severe Duty Diesel Engine Service

Service typical of certain naturally aspirated, turbocharged or supercharged diesel engines where highly effective control of wear and deposits is vital, or when using fuels of a wide quality range including high sulphur fuels. Oils designed for this service were introduced in 1955 and provide protection from bearing corrosion and from high temperature deposits in these diesel engines.

Oil meeting the performance requirements measure in the following diesel and gasoline engine tests: The 1-G2 diesel engine test has been correlated with indirect injection engines used in heavy-duty operation, particularly with regard to piston and ring groove deposits. The L-38 gasoline engine test requirement provides a measurement of copper-lead bearing weight loss and piston varnish under high-temperature operating conditions.

API Commercial Classifications

"C" Commercial

CD-II

For Severe Duty two-Stroke Diesel Engine Service

Service typical of two-stroke cycled engines requiring highly efficient control over wear and deposits. Oils designed for this service also meet the performance requirements of API service category CD.

Oils meeting the performance requirements measured in the following diesel and gasoline engine tests: The 1-G2 diesel engine test has been correlated with indirect injection engines used in heavy-duty operation, particularly with regard to piston and ring groove deposits. The 6V-53T diesel engine test has been correlated with vehicles equipped with two-stroke cycle diesel engines in high-speed operation prior to 1985, particularly with regard to ring and liner distress. The L-38 gasoline engine test requirement provides a measurement of copper-lead bearing weight loss and piston varnish under high-temperature operating conditions.

CE

For High Performance Diesel Engine Service

Service typical of many turbocharged or supercharged high performance diesel engines, operated under both low speed - high load and high speed - high load conditions. Oils designed for this service have been available since 1984 and provide improved control of oil consumption, oil thickening and piston assembly deposits and wear relative to the performance potential offered by oils designed for Category CD Service.

Oils meeting the performance requirements of the following diesel and gasoline engine tests: The 1-G2 diesel engine test has been correlated with indirect injection engines used in heavy-duty service, particularly with regard to piston and ring groove deposits. The T-6, T-7 and NTC-400 are direct injection diesel engine tests. The T-6 has been correlated with vehicles equipped with engines used in high-speed operation prior to 1980, particularly with regard to deposits, oil consumption and wear. The T-7 test has been correlated with vehicles equipped with engines used in lugging operation prior to 1984, particularly with regard to oil thickening. The NTC-400 diesel engine test has been correlated with vehicles equipped with engines in highway operation prior to 1983, particularly with regard to oil consumption, deposits and wear. The L-38 gasoline engine test requirement provides a measurement of copper-lead bearing weight loss under high-temperature operating conditions.

API Commercial Classifications

"C" Commercial

CF

For Indirect Injected Diesel Engine Service

API Service Category CF denotes service typical of indirect injected diesel engines, and other diesel engines which use a broad range of fuel types including those using fuel with higher sulphur content, for example, over 0.5% wt. Effective control of piston deposits, wear and copper - containing bearing corrosion is essential for these engines which may be naturally aspirated, turbocharged or supercharged. Oils designated for this service have been in existence since 1994. Oils designated for this service may also be used when API service category CD is recommended.

CF-2

For Two-Stroke Cycle Diesel Engine Service

API Service category CF-2 denotes service typical of two-stroke cycle engines requiring highly effective control over cylinder and ring-face scuffing and deposits. Oils designated for this service have been in existence since 1994 and may also be used when API Service Category CD-II is recommended. These oils do not necessarily meet the requirements of CF or CF-4 unless passing test requirements for these categories.

CF-4

For High Performance Diesel Engine Service

This category was adopted in 1990 and describes oils for use in high speed, four-stroke diesel engines. API CF-4 oils exceed the requirements of the CE category, providing improved control of oil consumption and piston deposits.

Oils meeting the performance requirements in the following diesel and gasoline engine tests:

The T-6, T-7, NTC 400 and L-38 engines: See API CE Category for explanation.

The 1K diesel engine test, which has been correlated with direct injection engines used in heavy-duty service prior to 1990, particularly with regard to piston and ring groove deposits. It has been demonstrated that the 1K test, in combination with test method D5968, the bench corrosion test, can be substituted for the NTC-400 test as an acceptable means to demonstrate performance against this category.

Test method D6483, the T-9 diesel engine test can be used as an alternate for the T-6 test and its limits.

Test method D5967, the F8A version, and its limits can be used as an alternate for the T-7 test and its limits.

API Commercial Classifications

“C” Commercial

CG-4

For Severe Duty Diesel Engine Service

API Service Category CG-4 describes oils for use in high speed four stroke-cycle diesel engines used on both heavy-duty on-highway (less than 0.05% wt. sulphur fuel) and off highway (less than 0.5% wt. sulphur fuel) applications. CG-4 oils provide effective control over high temperature piston deposits, wear, corrosion, foaming, oxidation stability and soot accumulation. These oils are especially effective in engines designed to meet 1994 exhaust emission standards and may also be used in engines requiring API Service Categories CD, CE and CF-4. Oils designated for this service have been in existence since 1994.

CH-4

For 1998 Severe Duty Diesel Engine Service

API Service Category CH-4 describes oils for use in high-speed, four-stroke diesel engines designed to meet 1998 exhaust emissions standards as well as for previous model years. CH-4 oils are specifically compounded for use with diesel fuels ranging in sulphur content up to 0.5 percent weight.

These oils are especially effective to sustain engine durability even under adverse applications that may stress wear control, high temperature stability, and soot handling properties. In addition, optimum protection is provided against non-ferrous corrosion, oxidative and insoluble thickening, foaming, and viscosity loss due to shear. These oils also have the performance capability to afford a more flexible approach to oil drain intervals in accordance with the recommendations of the individual engine builders for their specific engines.

CH-4 oils are superior in performance to those meeting API CF-4 and API CG-4 and can effectively lubricate engines calling for those API Service Categories.

CI-4

For 2004 Severe Duty Diesel Engine Service

API Service Category CI-4 describes oils for use in high-speed, four-stroke cycle diesel engines designed to meet 2004 exhaust emission standards implemented in 2002. These oils are intended for use in all applications with diesel fuels ranging in sulphur content up to 0.5% weight.

These oils are specifically formulated to sustain engine durability where Exhaust Gas Recirculation (EGR) is used and the impact of these oils on other supplemental exhaust emission devices has not been determined. Optimum protection is provided against corrosive and soot-related wear tendencies, piston deposits, degradation of low- and high-temperature viscometric properties due to soot accumulation, oxidative thickening, loss of oil consumption control, foaming, degradation of seal materials, and viscosity loss due to shear.

Engine oils that meet the API Service Category CI-4 designation have been tested in accordance with the ACC Code and may use the API Base Oil Interchangeability Guidelines and the API Guidelines for SAE Viscocity-Grade Engine Testing.

CI-4 oils are superior in performance to those meeting API CH-4, CG-4, and CF-4 and may be used in engines calling for those API Service Categories.

CJ-4 Diesel Engine Service

API Service Category CJ-4 describes oils for use in high-speed four-stroke cycle diesel engines designed to meet 2007 model year on-highway exhaust emission standards as well as for previous model years.

These oils are compounded for use in all applications with diesel fuels ranging in sulphur content up to 500ppm (0.05% by weight). However, the use of these oils with greater than 15ppm (0.0015% by weight) sulphur fuel may impact after treatment system durability and/or oil drain interval.

These oils are especially effective at sustaining emission control system durability where particulate filters and other advanced after treatment systems are used. Optimum protection is provided for control of catalyst poisoning, particulate filter blocking, engine wear, piston deposits, low- and high-temperature stability, soot handling properties, oxidative thickening, foaming, and viscosity loss due to shear.

Engine oils that meet the API Service Category CJ-4 designation have been tested in accordance with the ACC Code and may use the API Base Oil Interchangeability Guidelines and the API Guidelines for SAE Viscosity-Grade Engine Testing.

API CJ-4 oils exceed the performance criteria of API CI-4 with CI-4 PLUS, CI-4, CH-4, CG-4 and CF-4 and can effectively lubricate engines calling for those API Service Categories. When using CJ-4 oil with higher than 15 ppm sulphur fuel, consult the engine manufacturer for service interval.

The first licence date for API CJ-4 will be October 15, 2006.

Effective May 1, 2006, marketers may license products meeting API CJ-4 requirements as API CI-4 with CI-4 PLUS, CI-4, CH-4, CG-4, and CF-4.

API Diesel Engine Performance Criteria

	Test	Primary Performance Criteria	Limits	
			L-4	**L-38**
CA	L-4 or L-38	Bearing Weight Loss, mg. max.	120-135	50
		Piston Skirt Varnish Rating, min.	9.0	9.0
	L-1 (0.35% min. sulphur fuel)	Top Groove Filling, % vol. max.	25	
		Second Groove and below	Essentially clean	
CB	L-4 or L-38	Same as CA		
	L-1 (0.95% min. sulphur fuel)	Same as CA, except Top Groove Filling, % vol. max.	30	
CC	L-38	Bearing Weight Loss, mg. max.	50	
		Piston Skirt Varnish Rating, min.	9.0	
			LTD	**Mod LTD**
	LTD or Modified LTD	Piston Skirt Varnish Rating, min.	7.5	7.5
		Total Engine Varnish Rating, min.	-	42
		Total Engine Sludge Rating, min.	35	42
		Oil Ring Plugging, %. max.	25	10
		Oil Screen Clogging, %. max.	25	10
			IIC	**IID**
	IIC or IID	Avg. Engine Rust Rating, min.	7.6	7.7
	1-H2	Top Groove Fill, % vol. max.	45	
		Weighted Total Demerits, max.	140	
		Ring Side Clearance Loss, in. max.	0.0005	
CD	1-G2	Top Groove Fill, % vol. max.	80	
		Weighted Total Demerits, max.	300	
		Ring Side Clearance Loss, in. max.	0.0005	
	L-38	Bearing Weight Loss, mg. max.	50	
		Piston Skirt Varnish Rating, min.	9.0	
CD-II	I-G2	Top Groove Fill, % vol. max.	80	
		Weighted Total Demerits, max.	300	
		Ring Side Clearance Loss, in. max.	0.0005	
	L-38	Bearing Weight Loss, mg. max.	50	
		Piston Varnish Rating, min.	9.0	
	6V-53T	Piston Area		
		Weighted Total Demerits, avg. max.	400	
		Hot Stuck Rings	None	
		2 and 3 Ring Face Distress avg. Demerits, max.	13	
		Liner and Head Area		
		Liner Distress, avg. % Area, max.	12	
		Valve Distress	None	

API Diesel Engine Performance Criteria

	Test	Primary Performance Criteria	Limits
CE	1G2	Top Groove Fill, % vol. max.	80
		Weighted Total Demerits, max.	300
		Ring Side Clearance loss, in. max.	0.0005
	L-38	Bearing Weight Loss, mg. max.	50
	T-6	Merit Rating, min.	90
	T-7	Avg. Rate of Viscosity increase during last 50 hrs, cSt. 100°C/hr. max.	0.040
	NTC-400	Oil Consumption	Candidate oil consumption second order regression curve must fall completely below the published mean plus one standard deviation curve for the applicable reference oil
		Camshaft Roller Follower Pin Wear average, max. mm. (in).	0.051 (0.002)
		Crown Land (Top Land) Deposits, % area covered with heavy carbon, average, max.	25
		Piston Deposits, Third Ring Land, total CRC demerits for all 6 pistons, max.	40

API Diesel Engine Performance Criteria

	Test	Primary Performance Criteria	Number of Test Runs		
			1	**2**	**3**
CF	1M-PC	Top Groove Filling (TGF), % vol. max.	70	70	70
		Weighted Total Demerits (WTD), max.	240	240	240
		Ring Side Clearance Loss, mm. max.	0.013	0.013	0.013
		Piston Ring Sticking	None	None	None
		Piston, Ring and Liner Scuffing	None	None	None
	Seq. VIII	Bearing Weight Loss, mg. max.	29.3	31.9	33.0
CF-2	1M-PC	Weighted Total Demerits (WTD), max.	100	100	100
	6V-92TA	Cylinder Line Scuffing, %. max.	45.0	48.0	50.0
		Port Plugging, %. max.			
		Average	2	2	2
		Single Cylinder	5	5	5
		Piston Ring Face Distress Demerits, max.			
		No. 1 (Fire Ring)	0.23	0.24	0.26
		Avg. No. 2 & 3	0.20	0.21	0.22
	Seq. VIII	Bearing Weight Loss, mg. max.	29.3	31.9	33.0
CF-4	1-K	A 1-K test programme with a minimum of two tests, acceptable to the limits shown in the columns to the right, is required to demonstrate performance for this category	**Number of Test Runs**		
			2	**3**	**4**
		Weighted Demerits (WDK), max.	332	339	342
		Top Groove Carbon Fill (TGF), % vol. max.	24	26	27
		Top Land Heavy Carbon (TLHC), %. max.	4	4	5
		Avg. Oil Consumption, g/kW-h. (0-252 hrs.) max.	0.5	0.5	0.5
		Final Oil Consumption, g/kW-h. (228-252 hrs.) max.	0.27	0.27	0.27
		Scuffing, (piston-rings-liner)	None	None	None
			Limits (1 test)		
	T6	Merit Rating (*), min.	90		
	or T10 (D6987)	or Top Piston Ring % wt. loss, avg. mg. max.	180		
		Linear Wear, µm. max.	47		
	T7	Average rate of KV inc. during last 50 hrs. max.	0.040		
	or T8A (D5967)	or Average rate of KV inc. 100-150 hrs. max.	0.20		
	Seq. VIII	Bearing Weight Loss, mg. max.	33		
	CBT (D5968)	Copper, mg/kg. (ppm) increase, max.	20		
		Lead, mg/kg. (ppm) increase, max.	60		
		Tin, mg/kg. (ppm) increase, max.	Report		
		Copper Corrosion, max.	3		

Note:
* Requires greater than zero unit on all individual rating.

API Diesel Engine Performance Criteria

	Test	Primary Performance Criteria	Number of Test Runs		
			1	2	3
CG-4	1N	WDN (Weighted Demerits-1N), avg. max.	286.2	311.7	323.0
		TGF (Top Groove Fill), % vol. avg. max.	20	23	25
		TLHC (Top Land Heavy Carbon), % avg. max.	3	4	5
		Oil Consumption, g/kW-h. avg. max.	0.5	0.5	0.5
		Scuffing, Piston-Rings-Liner			
		Number of Tests Allowed	None	None	None
		Stuck Rings	None	None	None
	T-8	Viscosity Increase at 3.8% soot, cSt. avg. max.	11.5	12.5	13.0
		Filter Plugging, Differential Pressure, kPa. avg. max.	138	138	138
		Oil Consumption, g/kW-h. avg. max.	0.304	0.304	0.304
	Seq. IIIF or	60 hr viscosity (at 40°C)	325	349	360
	IIIG	Kinematic viscosity % increase @ 40°C, max	150	173	184
	Seq. VIII	Bearing Weight Loss, mg. avg. max.	29.3	31.9	33.0
		Used Oil Viscosity, cSt. greater than SAE J300 lower limit for Grade, avg. min.	0.5	0.5	0.5
	RFWT	Wear, µm. (mils), avg. max.	11.4 (0.45)	12.4 (0.49)	12.7 (0.50)
	Foam Option A not allowed	Foaming/Settling, ml. max.			
		Sequence I	10/0		
		Sequence II	20/0		
		Sequence III	10/0		
	Bench Corrosion Test	ppm. Increase, max.			
		Copper	20		
		Lead	60		
		Tin	50		
		Copper Corrosion, max. D130	3		

Note:
Limits do not apply to monograde oils.

API Diesel Engine Performance Criteria

	Test	Primary Performance Criteria	Number of Test Runs 1	2	3
CH-4	1P	WDP (Weighted Demerits - 1P), max.	350	378	390
		TGC (Top Groove carbon), %, vol. max.	36	39	41
		TLC (Top land Carbon), %, max.	40	46	49
		Avg. Oil Consumption, 0-360 hrs.	11.0 max./test		
		Final oil Consumption, 336-360 hrs.	10.0 max./test		
	M-11[1]	Crosshead Weight Loss, 4.5% soot, mg, max.	6.5	7.5	8.0
		Sludge, min.	8.7	8.6	8.5
		Differential Pressure/Oil Filter, kPa, max.	79	93	100
	T-9 [2]	Avg. Liner wear, µm, max.	25.4	26.6	27.1
		Top Ring Weight Loss, mg, max.	120	136	144
		Increase in Lead Content, ppm, max.	25	32	36
	T8-E	Viscosity Increase, 3.8% soot cSt, max.	11.5	12.5	13.0
		Relative Viscosity, 4.8% soot, max.	2.1	2.2	2.3
	1K	WDK (Weighted Demerits - 1K), max.	332	347	353
		TGF (Top Groove Fill), % vol, max.	24	27	29
		TLHC (Top Land Heavy Carbon), %, max.	4	5	5
		Oil Consumption, g/bhp-hr, max.	0.5	0.5	0.5
		Piston, Ring and Liner Scuffing	None	None	None
	RFWT	Pin Wear, mils, max.	0.30	0.33	0.36
	D6984 (Sequence IIIF)	60 hr viscosity at 40°C, increase from 10 min sample, %, max.	295	295 (MTAC)	295 (MTAC)
	or Sequence IIIG	Kinematic viscosity, % increase at 40°C, max.	150	150 (MTAC)	150 (MTAC)
	D892 (Option A not allowed)	Foaming/Settling, mL, max.			
		Sequence I	10/0		
		Sequence II	20/0		
		Sequence III	10/0		
	D5800 or	% volatility loss at 250°C, max.	SAE 10W-30 20	SAE 15W-40 18	
	D6417	% volatility loss at 371°C, max.	17	15	
	D6278	Kinematic viscosity after shearing, cSt min.	SAE XW-30 9.3	SAE XW-40 12.5	
	EOAT	Aeration Volume, %, max.	8.0	8.0	8.0
	Bench Corrosion	Copper, ppm, Increase, max.	20	20	20
		Lead, ppm, Increase, max.	120	120	120
		Tin, ppm, Increase, max.	50	50	50
		Copper Corrosion, ASTM D130, max.	3	3	3

Note:

(1) Cummins ISM may be used as alternative for limits see ASTM D4485.

(2) Mack T-10 or Mack T-12 may be used as alternative for limits see ASTM D4485.

API Diesel Engine Performance Criteria

	Test	Primary Performance Criteria	Number of Test Runns 1	2	3
CI-4	D6923 (1R) or	Weighted demerits (WDP), max.	382	396	402
		Top groove carbon (TGC), demerits, max.	52	57	402
		Top land carbon (TLC), demerits, max.	31	35	36
		Initial oil consumption (IOC), (0-252 hrs.), g/h, average	13.1	13.1	13.1
	D6681 (1P)	Weighted demerits (WDP), max.	350	378	390
		Top groove carbon (TGC), demerits, max.	36	39	41
		Top land carbon (TLC), demerits, max.	40	46	49
		Average oil consumption, g/h (0-360 hrs.), max.	12.4	12.4	12.4
		Final oil consumption, g/h (312-360 hrs.), max.	14.6	14.6	14.6
		Piston, ring, and liner scuffing	none	none	none
	D6987 (T10) or D7422 (T12)	Merit rating, min.	1000	1000	1000
	D7468 (ISM)	Crosshead % wt. loss, mg, max.	7.5	7.8	7.9
		Oil filter differential pressure at 250 hrs, kPa, max	379	462	510
		Average engine sludge, CRC merits at EOT, min	8.1	8.0	8.0
	D5967 (T8-E)	Relative viscosity at 4.8% soot	1.8	1.9	2.0
	D6984 (Sequence IIIF)	kinematic viscosity (at 40˚C), % increase, max.	275	275 (MTAC)	275 (MTAC)
	or D7320 (Sequence IIIG)	Kinematic viscosity, % increase at 40˚C, max.	150	150 (MTAC)	150 (MTAC)
	D6750 (1K)	Weighted demerits (WDK), max.	332	347	353
		Top groove fill (TGF), %, max.	24	27	29
		Top land heavy carbon, (TLHC), %, max.	4	5	5
		Average oil consumption, g/kW-h, (0-252 hrs.), max	0.5	0.5	0.5
		Piston, ring and liner scuffing	none	none	none
	D5966 (RFWT)	Average pin wear, mils, max. or µm, max.	0.30 (7.6)	0.33 (8.4)	0.36 (9.1)
	D6894 (EOAT)	Aeration, volume %, max.	8.0	8.0	8.0
	D4683 (High temperature / High shear)	Viscosity after shear, mPa.s, min.	-	3.5	-
	D4684 (MRV TP-1)	The following limits are applied to SAE viscosity grades 0W, 5W, 10W and 15W: Viscosity of 75 hrs. used oil sample from T-10 test tested at -20˚C, mPa-s, max.		25,000	
		If yield stress is detected, use modified D4684 (external preheat), then mPa-s, max. and yield stress, Pa		25,000 <35	
	D5800 (NOACK)	Evaporative loss at 250˚C, %, max		15	

API Diesel Engine Performance Criteria

	Test	Primary Performance Criteria	Limits
CI-4	D6594 (135°C HTCBT)	Copper, mg/kg (ppm) increase, max.	20
		Lead, mg/kg (ppm) increase, max.	120
		Tin, mg/kg (ppm) increase, max.	50
		Copper strip rating, max.	3
	D6278	Kinematic viscosity after shearing, cSt, min.	SAE XW-30 / SAE XW-40 9.3 / 12.5
	D892	Foaming/settling, ml. max.	
		Sequence I	10/0
		Sequence II	20/0
		Sequence III	10/0

Elastomer Compatibility

Elastomer	Volume Change	Limits Hardness	Tensile Strength	Elongation
Nitrile	+5/-3	+7/-5	+10/-TMC 1006	+10/-TMC 1006
Silicone	+ TMC 1006/-3	+5/-TMC 1006	+10/-45	+20/-30
Polyacrylate	+5/-3	+8/-5	+18/-15	+10/-35
Fluoroelastomer	+5/-2	+7/-5	+10/-TMC 1006	+10/-TMC 1006

API Diesel Engine Performance Criteria

	Test	Primary Performance Criteria	Number of Test Runns 1	2	3
CJ-4	D7422 (T-12)	Merit rating, min.	1000	1000	1000
	D7468 (ISM)	Merit rating, min.	1000	1000	1000
		Top ring weight loss, mg, max.	100	100	100
	D7549 (C-13)	Merit rating, min.	1000	1000	1000
		Hot-stuck piston ring.	none	none	none
	D7156 (T-11)	TGA % Soot at 4.0 cSt increase, at 100˚C, min.	3.5	3.4	3.3
		TGA % Soot at 12.0 cSt increase, at 100˚C min.	6.0	5.9	5.9
		TGA % Soot at 15.0 cSt increase, at 100˚C min.	6.7	6.6	6.5
	D7484 (ISB)	Slider tappet weight loss, mg, average, max.	100	108	112
		Cam lobe wear, μm, average, max.	55	59	61
		Crosshead weight loss, mg, avg	Report	Report	Report
	D6750 (1N)	Weighted demerits (WDN), max.	286.2	311.7	323.0
		Top groove fill (TGF), %, max.	20	23	25
		Top land heavy carbon (TLHC), %, max.	3	4	5
		Oil consumption, g/kW-h, (0-252 hrs.), max.	0.5	0.5	0.5
		Piston, ring, and liner scuffing	none	none	none
		Piston ring sticking	none	none	none
	D5966 (RFWT)	Average pin wear, mils, max.	0.30	0.33	0.36
		(μm, max),	(7.6)	(8.4)	(9.1)
	D6984 (Seq. IIIF)	Kinematic viscosity (at 40˚C) % increase, max.	275	275 (MTAC)	275 (MTAC)
	Or, alternately, Sequence IIIG	Kinematic viscosity (at 40˚C), % increase, max.	150	150 (MTAC)	150 (MTAC)
	D6894 (EOAT)	Aeration, volume, %, max.	8.0	8.0 (MTAC)	8.0 (MTAC)
	D4683 (High temperature/ High shear)	Viscosity at 150˚C, mPa-s, min.	3.5		
	D6594 (135˚C HTCBT)	Copper, mg/kg (ppm) increase, max.	20		
		Lead, mg/kg (ppm) increase, max.	120		
		Copper strip rating, max.	3		
	D7109	Kinematic viscosity after 90 pass,	SAE XW-30 / SAE XW-40		
		shearing, cSt at 100˚C, min.	9.3 / 12.5		
	D5800 (NOACK)	Evaporative loss at 250˚C, %, max, (Viscosities other than SAE 10W-30)	13		
		Evaporative loss at 250˚C, %, max. (SAE 10W-30 viscosity)	15		
	D892	Foaming/settling, ml. max.			
		Sequence I	10/0		
		Sequence II	20/0		
		Sequence III	10/0		
	D6896 (MRV TP-1)	Viscosity of the 180 hr used oil drain sample from a T-11 test, tested at -20˚C mPa-s, max.	25,000		
		If yield stress is detected, use the modified test method (external preheat), then measure the viscosity, mPa-s, max.	25,000		
		Measure the yield stress, Pa	<35		

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API Diesel Engine Performance Criteria

	Test	Primary Performance Criteria		Limits	
CJ-4	D874	Sulfated ash, weight %, max.		1.0	
	D4951	Phosphorus, weight %, max.		0.12	
	D4951	Sulphur, weight %, max.		0.4	
	Seal Compatibility				
	Elastomer	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation at Break Change, %
	Nitrile (NBR)	(+5, -3)	(+7, -5)	(+10, -TMC 1006)	(+10, -TMC 1006)
	Silicone (VMQ)	(+TCM 1006, -3)	(+5, -TMC 1006)	(+10, -45)	(+20, -30)
	Polyacrylate (ACM)	(+5, -3)	(+8, -5)	(+18, -15)	(+10, -35)
	Fluoroelastomer (FKM)	(+5, -2)	(+7, -5)	(+10, -TMC 1006)	(+10, -TMC 1006)
	Vamac G (Seal Test)				
	Evaluate the Vamac G elastomer using the procedures specified in D7216 and Annex A10. Unadjusted specifications limits for Vamac G follow:				
	Volume Change %			+TMC 1006/-3	
	Hardness Change, Points			+5/-TMC 1006	
	Tensile Strength Change, %			+10/-TMC 1006	
	Elongation at Break Change, %			+10/-TMC 1006	

ACEA 2007 Service-Fill Oils For Gasoline And Diesel Engines

Requirements	Method	Properties	Unit	Limits			
				A1 / B1-04	A3 / B3-04	A3 / B4-04	A5 / B5-04
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.			
Shear stability	CEC-L-14-A-93 or ASTM D6278	100°C Viscosity after 30 cycles	mm^2/s	xW-20 stay in grade xW-30 ≥ 8.6 xW-40 ≥ 12.0	All grades to be Stay-in-grade	All grades to be Stay-in-grade	All grades to be Stay-in-grade
Viscosity at high temp. & high shear rate	CEC-L-36-A-90 (2nd Edition) (Ravenfield)	Viscosity at 150°C and $10^6 s^{-1}$ shear rate	mPa.s	max. 3.5. xW -20 2.6. min All others 2.9 min.	≥ 3.5	≥ 3.5	min 2.9 max. 3.5
Evaporative loss	CEC-L-40-A-93 (NOACK)	Max. weight loss after 1 hr at 250°C	%	≤ 15	≤ 13	≤ 13	≤ 13
NOTE: The following sections apply to all sequences							
Sulphated ash	ASTM D874		% m/m	≤ 1 .3 (1)	≤ 1.5 (1)	≤ 1.6 (1)	≤ 1.6 (1)
Sulphur	ASTM D5185	(2)	% m/m	Report			
Phosphorous	ASTM D5185	(2)	% m/m	Report			
Chlorine	ASTM D6443		ppm m/m	Report			

Requirements	Method	Properties	Unit	Elastomer type				
Oil / elastomer compatibility	CEC-L-39-T-96 (3)	Max variation of characteristics after immersion for 7 days in fresh oil without pre-aging		RE1	RE2-99	RE3-04	RE4	AEM VAMAC As per Daimler Chrysler
		Hardness DIDC	points	-1/+5	-5/+8	-22/+1	-5/+5	
		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	

Requirements	Method	Properties	Unit	Limits
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
High temperature foaming tendency	ASTM D6082 High temperature foam test	Tendency - stability	ml	Sequence IV (150°C) 100 - nil

Note:
(1) Maximum limits. Values take into account method and production tolerances.
(2) The internal standard method has to be used.
(3) Use either complete DaimlerChrysler 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

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ACEA 2007 Service-Fill Oils For Gasoline And Diesel Engines - Engine Tests

Requirements	Method	Properties	Units	Limits			
				A1 / B1 -04	A3 / B3 -04	A3 / B4 -04	A5 / B5 -04
High temperature deposits Ring sticking Oil thickening	CEC-L-88-T-02 (TU5JP-L4) 72 hr test	Ring Sticking (each part)	merit, max.	9.0	9.0	9.0	9.0
		Piston Varnish (6 elements, average of 4 pistons)	merit, min.	RL 216	RL 216	RL 216	RL 216
		Absolute viscosity increase at 40°C between min. and max. values during test	mm^2/s, max.	RL 216	0.8 x RL 216	0.8 x RL 216	0.8 x RL 216
		Oil consumption	kg/test	Report	Report	Report	Report
Low temperature sludge	ASTM D6593-00 (Sequence VG) Under protocol & requirements for API (4)	Average engine sludge	merit, min.	7.8	7.8	7.8	7.8
		Rocker cover sludge	merit, min.	8.0	8.0	8.0	8.0
		Average piston skirt varnish	merit, min.	7.5	7.5	7.5	7.5
		Average engine varnish	merit, min.	8.9	8.9	8.9	8.9
		Compression ring (hot stuck)		none	none	none	none
		Oil screen clogging	%, max.	20	20	20	20
Valve train scuffing wear	CEC-L-38-A-94 (TU3M)	Average cam wear	µm, max.	10	10	10	10
		Cam wear	µm, max.	15	15	15	15
		Pad merit (avg. of 8 pads)	merit, min.	7.5	7.5	7.5	7.5
Black sludge	CEC-L-53-T-95 (M111)	Average engine sludge	merit, min.	RL 140	RL 140	RL 140	RL 140

Note:

(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.

ACEA 2007 Service-Fill Oils For Gasoline And Diesel Engines - Engine Tests

Requirements	Method	Properties	Units	Limits			
				A1 / B1 -04	A3 / B3 -04	A3 / B4 -04	A5 / B5 -04
Fuel economy [5]	CEC-L-54-T-96 (M111)	Fuel economy improvement vs. Reference oil RL191 (15W-40)	%, min.	2.5	-	-	2.5
Ring sticking and piston cleanliness	CEC-L-46-T-93 (VW 1.6 TC D) [6]	Ring sticking	merit, min.	RL 148	RL 148	-	-
		Piston cleanliness	merit, min.	RL 148	RL 148	-	-
Medium temperature dispersivity	CEC-L-093 (DV4TD) [7]	Absolute viscosity increase at 100°C and 6% soot	mm^2/s, max.	0.6 x RL223 result	0.6 x RL223 result	0.6 x RL223 result	0.06 x RL223 result
		Piston merit [8]	merit, min.	(RL223-2.5pts)	(RL223-2.5pts)	(RL223-2.5pts)	(RL223-2.5pts)

Note:

(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) The test according to CEC-L-78-T-99 may be run instead of CEC-L-46-T-93 for A1/B1 and A3/B3. The limits shall be as A3/B4.
(7) XUD11 BTE passing results obtained before the end of 2005 can be used instead of the DV4.
(8) Piston merit is not yet an official CEC barometer.

ACEA 2007 Service-Fill Oils For Gasoline And Diesel Engines

Requirements	Method	Properties	Units	Limits			
				A1 / B1 -04	A3 / B3 -04	A3 / B4 -04	A5 / B5 -04
Wear, Viscosity stability & Oil consumption	OM 602 A (9)	Average cam wear. (New tappet)	µm, max.	50.0	50.0	50.0	50.0
		Viscosity increase at 40°C	%, max.	90	90	90	90
		Bore polishing	%, max.	7.0	7.0	7.0	7.0
		Average cylinder wear	µm, max.	20.0	20.0	20.0	20.0
		Oil consumption	kg/test, max.	10.0	10.0	10.0	10.0
DI diesel Piston cleanliness & Ring sticking	CEC-L-78-T-99 (VW TDI)	Piston cleanliness	merit, min.	-	-	RL 206 - 3pts	RL 206
		Ring sticking (rings 1 & 2)					
		Average of all 8 rings	ASF, max.	-	-	1.2	1.2
		Max. for any 1st ring	ASF, max.	-	-	2.5	2.5
		Max. for any 2nd ring	ASF, max.	-	-	0.0	0.0

Note:

(9) OM 646 LA results at an equivalent performance level can be used as soon as the test becomes available as a CEC test. In the event of OM 602 A and OM 646 are not available, ACEA will define an alternative.

ACEA 2007 Service-Fill Oils For Gasoline And Diesel Engines With After Treatment Devices

Requirements	Method	Properties	Units	Limits			
				C1 -04	C2 -04	C3 -07	C4 -07
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.			
Shear stability	CEC-L-14-A-93 or ASTM D6278	100°C Viscosity after 30 cycles	mm^2/s	Stay-in-grade	Stay-in-grade	Stay-in-grade	Stay-in-grade
Viscosity at high temp. & high shear rate	CEC-L-36-A-90 (2nd Edition) (Ravenfield)	Viscosity at 150°C and $10^6\ s^{-1}$ shear rate	mPa.s, min.	2.9	2.9	3.5	3.5
Evaporative loss	CEC-L-40-A-93 (NOACK)	Max. weight loss after 1 hr at 250°C	%, max.	13	13	13	11
Sulphur	ASTM D5185	(1)	% m/m, max.	0.2	0.3	0.3	0.2
Phosphorus	ASTM D5185	(1)	% m/m, max.	0.05	0.070 - 0.090	0.070 - 0.090	0.090
Sulphated ash	ASTM D874		% m/m, max.	0.5 (2)	0.8 (2)	0.8 (2)	0.5 (2)
Chlorine	ASTM D6443		ppm - m/m.	Report	Report	Report	Report
TBN	ASTM D2896		mg KOH/g, min.	-	-	6	6

Note:
(1) The internal standard method has to be used.
(2) Maximum limits. Values take into account method and production tolerances OM 646 are not available, ACEA will define an alternative.

ACEA 2007 Service-Fill Oils For Gasoline And Diesel Engines With After Treatment Devices

Requirements	Method	Properties	Units	Limits				
				C1 -04	C2 -04	C3 -07	C4 -07	
NOTE: The following sections apply to all sequences								
Oil / elastomer compatibility [(3)]	CEC-L-39-T-96	Max. variation of characteristics after immersion for 7 days in fresh oil without pre-aging		Elastomer type				
				RE1	RE2-99	RE3-04	RE4	AEM VAMAC
		Hardness DIDC	points	-1/+5	-5/+8	-22/+1	-5/+5	As per Daimler Chrysler
		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	
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				
High temperature foaming tendency	ASTM D6082 High temperature foam test	Tendency - stability	ml	Sequence IV (150˚C) 100 - nil				

Note:

(3) Use either complete DaimlerChrysler 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 as above + DC requirements for AEM.

ACEA 2007 Service-Fill Oils For Gasoline And Diesel Engines With After Treatment Devices

Requirements	Method	Properties	Units	Limits			
				C1 -04	**C2** -04	**C3** -07	**C4** -07
High temperature deposits Ring sticking Oil thickening	CEC-L-88-T-02 (TU5JP-L4) 72 hr test	Ring sticking (each part)	merit, min.	9.0	9.0	9.0	9.0
		Piston varnish, (6 elements, average of 4 pistons)	merit, min.	RL 216	RL 216	RL 216	RL 216
		Absolute viscosity increase at 40°C between min and max values during test	mm^2/s, max.	0.8 x RL 216	0.8 x RL 216	0.8 x RL 216	0.8 x RL 216
		Oil consumption	kg/test	Report	Report	Report	Report
Low temperature sludge	ASTM D6593-00 (Sequence VG) Under protocol & requirements for API [4]	Average engine sludge	merit, min.	7.8	7.8	7.8	7.8
		Rocker cover sludge	merit, min.	8.0	8.0	8.0	8.0
		Average Piston skirt varnish	merit, min.	7.5	7.5	7.5	7.5
		Average engine varnish	merit, min.	8.9	8.9	8.9	8.9
		Comp. ring (hot stuck)		none	none	none	none
		Oil screen clogging	%, max.	20	20	20	20
Valve train scuffing wear	CEC-L-38-A-94 (TU3M)	Average cam wear	µm, max.	10	10	10	10
		Cam wear, max	µm, max.	15	15	15	15
		Pad merit (avg. of 8 pads)	merit, min.	7.5	7.5	7.5	7.5
Black sludge	CEC-L-53-T-95 (M111)	Average engine sludge	merit, min.	RL 140	RL 140	RL 140	RL 140 + 4 or > 9.0
Fuel economy [5]	CEC-L-54-T-96 (M111)	Fuel economy improvement vs. Reference oil RL 191 (15W-40)	%, min.	2.5	2.5	1.0 for xW-30 grade	1.0 for xW-30 grade

Note:

(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.

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ACEA 2007 Service-Fill Oils For Gasoline And Diesel Engines With After Treatment Devices

Requirements	Method	Properties	Units	Limits			
				C1 -04	C2 -04	C3 -07	C4 -07
Medium temperature dispersivity	CEC-L-093 (DV4TD)	Absolute viscosity increase at 100°C and 6% soot	mm^2/s, max.	0.60 x RL223 result	0.60 x RL223 result	0.60 x RL223 result	0.60 x RL223 result
		Piston merit (6)	merit, min.	(RL223 - 2.5pts)	(RL223 - 2.5pts)	(RL223 - 2.5pts)	(RL223 - 2.5pts)
DI diesel Piston cleanliness & Ring sticking	CEC-L-78-T-99 (VW DI)	Piston cleanliness	merit, min.	RL206	RL206	RL206	RL206
		Ring sticking (rings 1 & 2)					
		Average of all 8 rings	(ASF), max.	1.2	1.2	1.2	1.2
		Max. for any 1st ring	(ASF), max.	2.5	2.5	2.5	2.5
		Max. for any 2nd ring	(ASF), max.	0.0	0.0	0.0	0.0
Wear, Viscosity stability & Oil consumption	OM 602 A (7)	Average Cam wear	µm, max.	50.0	50.0	45.0	45.0
		Viscosity increase @ 40°C	%, max.	90	90	70.0	70.0
		Bore polishing	%, max.	7.0	7.0	4.5	4.5
		Average cylinder wear	µm, max.	20.0	20.0	15.0	15.0
		Oil consumption	kg/test, max.	10.0	10.0	10.0	10.0

Note:

(6) Piston merit is not yet an official CEC parameter.

(7) OM 646 LA results at an equivalent performance level can be used as soon as the test becomes available as CEC test. In the event of OM 602 A and OM 646 are not available, ACEA will define an alternative.

ACEA 2007 Service-Fill Oils For Heavy Duty Diesel Engines

Requirements	Method	Properties	Units	Limits			
				E2 -96 Issue 5	E4 -07	E6 -04 Issue 2	E7 -04 Issue 2
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.			
Shear stability	CEC-L-14-A-93 or ASTM D6278	Viscosity after 30 cycles measured at 100°C	mm^2/s, min.	xW-30 9.0 xW-40 12.0 xW-50 15.0 mono grades no req.	Stay-in-grade	-	
	ASTM D6278	Viscosity after 90 cycles measured at 100°C	mm^2/s	-	-	Stay-in-grade	
Viscosity, High temperature, High shear rate	CEC-L-36-A-90 (2^{nd} Edition) (Ravenfield)	Viscosity at 150°C and $10^6 s^{-1}$ Shear rate	mPa.s, min.	3.5			
Evaporative loss	CEC-L-40-A-93 (NOACK)	Max. weight loss after 1 hrs. at 250°C	%, max.	13			
Sulphated ash	ASTM D874		% m/m, max.	2.0	2.0	1.0	2.0
Phosphorous	ASTM D5185		% m/m,max.	-	-	0.08	-
Sulphur	ASTM D5185		% m/m, max.	-	-	0.3	-

ACEA 2007 Service-Fill Oils For Heavy Duty Diesel Engines

<table>
<tr><th>Requirements</th><th>Method</th><th>Properties</th><th>Units</th><th colspan="20">Limits</th></tr>
<tr><th></th><th></th><th></th><th></th><th colspan="5">E2 -96
Issue 5</th><th colspan="5">E4 -07</th><th colspan="5">E6 -04
Issue 2</th><th colspan="5">E7 -04
Issue 2</th></tr>
<tr><td rowspan="6">Oil elastomer compatibility [2]</td><td rowspan="6">CEC-L-39-T-96</td><td colspan="2"></td><td colspan="20">Elastomer Type</td></tr>
<tr><td colspan="2">Max. variation of characteristics after immersion for 7 days in fresh oil without pre-aging</td><td colspan="4">RE1</td><td colspan="4">RE2-99</td><td colspan="4">RE3-04</td><td colspan="4">RE4</td><td colspan="4">AEM VAMAC</td></tr>
<tr><td>Hardness DIDC</td><td>points</td><td colspan="4">-1/+5</td><td colspan="4">-5/+8</td><td colspan="4">-25/+1</td><td colspan="4">-5/+5</td><td colspan="4" rowspan="4">As per Daimler-Chrysler</td></tr>
<tr><td>Tensile strength</td><td>%</td><td colspan="4">-50/+10</td><td colspan="4">-15/+18</td><td colspan="4">-45/+10</td><td colspan="4">-20/+10</td></tr>
<tr><td>Elongation rupture</td><td>%</td><td colspan="4">-60/+10</td><td colspan="4">-35/+10</td><td colspan="4">-20/+10</td><td colspan="4">-50/+10</td></tr>
<tr><td>Volume variation</td><td>%</td><td colspan="4">-1/+5</td><td colspan="4">-7/+5</td><td colspan="4">-1/+30</td><td colspan="4">-5/+5</td></tr>
<tr><td rowspan="3">Foaming tendency</td><td rowspan="3">D892
without option A</td><td rowspan="3">Tendency - stability</td><td>ml</td><td colspan="20">Sequence I (24˚C) 10 - nil</td></tr>
<tr><td>ml</td><td colspan="20">Sequence II (94˚C) 50 - nil</td></tr>
<tr><td>ml</td><td colspan="20">Sequence III (24˚C) 10 - nil</td></tr>
<tr><td>High temperature foaming tendency</td><td>D6082</td><td>Tendency - stability</td><td>ml</td><td colspan="20">Sequence IV (150˚C) 200-50</td></tr>
<tr><td>Oxidation</td><td>(CEC-L-85-T-99)
(PDSC)</td><td>Oxidation induction time</td><td>mins, min.</td><td colspan="5">-</td><td colspan="5">-</td><td colspan="5">-</td><td colspan="5">35</td></tr>
<tr><td>Corrosion</td><td>D6594</td><td>Lead Increase</td><td>ppm, max.</td><td colspan="5">-</td><td colspan="5">-</td><td colspan="5">-</td><td colspan="5">100</td></tr>
<tr><td>TBN</td><td>D2896</td><td>mg KOH/g, min.</td><td></td><td colspan="5">-</td><td colspan="5">12</td><td colspan="5">-</td><td colspan="5">-</td></tr>
</table>

Note:

(2) Use either complete DaimlerChrysler 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 as above + DC requirements for AEM.

ACEA 2007 Service-Fill Oils For Heavy Duty Diesel Engines

Requirements	Method	Properties	Units	Limits			
				E2 -96 Issue 5	**E4** -07	**E6** -04 Issue 2	**E7** -04 Issue 2
Bore Polishing / Piston Cleanliness (3)	CEC-L-42-T-99 (OM 364 LA)	Bore polishing	%, max.	3.5	-	-	-
		Piston cleanliness	merit, max.	40.0	-	-	-
		Average cylinder wear	µm, max.	3.5	-	-	-
		Sludge	merit, max.	9.4	-	-	-
		Oil consumption	kg/test, max.	16.0	-	-	-
Wear (4)	CEC-L-51-A-97 (OM 602 A)	Cam wear	µm, max.	50.0	50.0	50.0	50.0
		Viscosity increase at 40˚C	%, max.	-	90	90	90
		Bore polishing	%, max.	-	7.0	7.0	7.0
		Cylinder wear	µm, max.	-	20.0	20.0	20.0
		Oil consumption	kg/test, max.	-	10	10	10
Soot in oil (5)	ASTM D5967 (Mack T-8E) ASTM D4485 (Mack T-8)	Test duration: (hrs.)		-	300	300	300
		Relative viscosity at 1 test/2 test/3 test average		-	4.8% soot		
			mm^2/s, max.	-	2.1/2.2/2.3	2.1/2.2/2.3	2.1/2.2/2.3
		Relative viscosity at 1 test/2 test/3 test average		-	3.8% soot		
			mm^2/s, max.	-	11.5/12.5/13.0	11.5/12.5/13.0	11.5/12.5/13.0
		Filter plugging, Diff, Pressure	kPa, max.	-	138	138	138
		Oil consumption	g/kWh, max.	-	0.304	0.304	0.304
Bore polishing Piston cleanliness Turbocharger deposits (6)	CEC-L-52-T-97 (OM 441 LA)	Bore polishing	%, max.	-	2.0	2.0	2.0
		Piston cleanliness	merit, max.	-	40.0	40.0	40.0
		Boost pressure loss at 400 hrs	%, max.	-	4	4	4
		Oil consumption	kg/test, max	-	40	40	40

Note:

(3) Results from a CEC-L-52-T-97 (OM 441 LA) test as part of a DaimlerChrysler sheet 228.1 approval can be used as an alternative. Only tests according to CEC-L-52-T-97 are acceptable.

(4) OM 646 LA results at an equivalent performance level can be used as soon as the test becomes available as a CEC test. In the event the OM 602 A and the OM 646 are not available, then ACEA will define an alternative.

(5) Mack T11 (ASTM D7156) 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.

(6) OM 501 LA results at an equivalent performance level can be used as soon as the test becomes available as a CEC test.

ACEA 2007 Service-Fill Oils For Heavy Duty Diesel Engines

Requirements	Method	Properties	Units	Limits			
				E2 -96 Issue 5	E4 -07	E6 -04 Issue 2	E7 -04 Issue 2
Soot induced wear [7]	Cummins ISM	Rocker pads average weight loss at 3.9% soot. 1 test/2 test/3 test average	mg, max.	-	-	-	7.5/7.8/7.9
		Oil filter diff. press @ EOT 1 test/2 test/3 test average	kPa, max.	-	-	-	55/67/74
		Engine sludge 1 test/2 test/3 test average	merit, max.	-	-	-	8.1/8.0/8.0
Wear (liner ring-bearings) [8]	Mack T10	Merit				1000	1000
	ASTM D6987	Average. liner wear	µm, max.			32 (26)	32 (26)
	(Mack T12)	Average top ring weight loss	mg, max.			158 (117)	158 (117)
		End of test lead	ppm, max.			35 (42)	35 (42)
		Delta lead 250-300 hrs	ppm, max.			14 (918)	14 (918)
		Oil consumption (Phase II)	g/hr, max.			65 (95)	65 (95)

Note:

(7) Results from Cummins a M11 HST (ASTM D6838) at API CH-4 or M11 EGR test (ASTM D6975) at API CI-4 or CI-4. Plus can be used in place of the Cummins ISM test.

(8) Mack T12 results can be used in place of Mack T10. In this case the merit scale for CI-4 plus approvals must be applied to the Mack T12 results. Maximum allowable values for the Mack T12 test are given in parentheses.

ACEA 2008 Service-Fill Oils For Gasoline And Diesel Engines

Requirements	Method	Properties	Unit	Limits A1 / B1-08	Limits A3 / B3-08	Limits A3 / B4-08	Limits A5 / B5-08
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.			
Shear stability	CEC-L-14-A-93 or ASTM D6278	100°C Viscosity after 30 cycles	mm²/s	xW-20 Stay-in-grade xW-30 ≥ 9.3 xW-40	All grades to be Stay-in-grade	All grades to be Stay-in-grade	All grades to be Stay-in-grade
Viscosity at high temp. & high shear rate	CEC-L-36-A-90 (2nd Edition) (Ravenfield)	Viscosity at 150°C and $10^6\ s^{-1}$ shear rate	mPa.s	max. 3.5. xW-20 2.6. min All others 2.9 min.	≥ 3.5	≥ 3.5	min 2.9 max. 3.5
Evaporative loss	CEC-L-40-A-93 (NOACK)	Max. weight loss after 1 hr at 250°C	%	≤ 15	≤ 13	≤ 13	≤ 13
NOTE: The following sections apply to all sequences							
Sulphated ash	ASTM D874		% m/m	≤ 1 .3 (2)	≤ 1.5 (2)	≤ 1.6 (2)	≤ 1.6 (2)
Sulphur (1)	ASTM D5185		% m/m	Report			
Phosphorous (1)	ASTM D5185		% m/m	Report			
Chlorine	ASTM D6443		ppm m/m	Report			

Requirements	Method	Properties	Unit	Elastomer type RE1	RE2-99	RE3-04	RE4	
Oil / elastomer compatibility	CEC-L-39-T-96 (3)	Max variation of characteristics after immersion for 7 days in fresh oil without pre-aging						AEM VAMAC As per Daimler Chrysler
		Hardness DIDC	points	-1/+5	-5/+8	-22/+1	-5/+5	
		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	

Requirements	Method	Properties	Unit	Limits
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
High temperature foaming tendency	ASTM D6082 High temperature foam test	Tendency - stability	ml	Sequence IV (150°C) 100 - nil

Note:

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

(2) Maximum limits. Values take into account method and productions 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: D8948/200.1 (150°C +/- 2°C)) + RE3, or complete requirements above + Daimler requirements for AEM.

ACEA 2008 Service-Fill Oils For Gasoline And Diesel Engines - Engine Tests

Requirements	Method	Properties	Units	Limits			
				A1 / B1 -08	A3 / B3 -08	A3 / B4 -08	A5 / B5 -08
High temperature deposits Ring sticking Oil thickening	CEC-L-88-T-02 (TU5JP-L4) 72 hr test	Ring Sticking (each part)	merit, max.	9.0	9.0	9.0	9.0
		Piston Varnish (6 elements, average of 4 pistons)	merit, min.	RL 216	RL 216	RL 216	RL 216
		Absolute viscosity increase at 40˚C between min. and max. values during test	mm^2/s, max.	≤ 0.8 x RL 216	≤ 0.8 x RL 216	≤ 0.8 x RL 216	≤ 0.8 x RL 216
		Oil consumption	kg/test	Report	Report	Report	Report
Low temperature sludge	ASTM D6593-00 (Sequence VG) Under protocol & requirements for API [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
		Compression ring (hot stuck)		none	none	none	none
		Oil screen clogging	%	≤ 20	≤ 20	≤ 20	≤ 20
Valve train scuffing wear	CEC-L-38-A-94 (TU3M)	Average cam wear	µm	≤ 10	≤ 10	≤ 10	≤ 10
		Cam wear	µm	≤ 15	≤ 15	≤ 15	≤ 15
		Pad merit (avg. of 8 pads)	merit	≥ 7.5	≥ 7.5	≥ 7.5	≥ 7.5
Black Sludge	CEC-L-53-T-95 (M111)	Average engine sludge	≥ RL 140	≥ RL 140 + 4σ or ≥ 9.0	≥ RL 140 + 4σ or ≥ 9.0	≥ RL 140 + 4σ or ≥ 9.0	≥ RL 140 + 4σ or ≥ 9.0

Note:

(4) The limits shown are based upon those applied in US market requirements. ACEA will continuously review the situation to ensure that these limits are appropriate for European vehicles and lubricants.

Afton CHEMICAL

ACEA 2008 Service-Fill Oils For Gasoline And Diesel Engines - Engine Tests

Requirements	Method	Properties	Units	Limits			
				A1 / B1 -04	A3 / B3 -04	A3 / B4 -04	A5 / B5 -04
Fuel economy [5]	CEC-L-54-T-96 (M111)	Fuel economy improvement vs. reference oil RL191 (15W-40)	%	≥ 2.5	-	-	≥ 2.5
Medium temperature dispersivity	CEC-L-093 (DV4TD)	Absolute viscosity increase at 100°C and 6% soot	mm^2/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 -2.5 pts)	≥ (RL223 -2.5 pts)	≥ (RL223 -2.5 pts)	≥ (RL223 -2.5 pts)
Wear [6]	CEC-L-099-08 (OM 646 LA)	Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 140	≤ 140	≤ 120	≤ 120
		Cam wear inlet (avg. max. wear 8 cam) [8]	µm	≤ 110	≤ 110	≤ 100	≤ 100
		Cylinder wear (avg. 4 cyl) [8]	µm	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
		Bore polishing (13 mm) max. value of 4 cylinders [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 8 cams)	µm	Report	Report	Report	Report
		Piston cleanliness (avg. 4 pistons)	merit	Report	Report	Report	Report
		Average Engine sludge	merit	Report	Report	Report	Report
DI diesel Piston cleanliness & Ring sticking [9]	CEC-L-078-99 (VW TDI)	Piston cleanliness	merit	≥ RL 206 - 4 pts	≥ RL 206 - 4 pts	≥ RL 206	≥ RL 206
		Ring sticking (rings 1 & 2)					
		Avg of all 8 rings	ASF	≤ 1.2	≤ 1.2	≤ 1.0	≤ 1.0
		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) [7] [8]	mgKOH/g	≥ 4.0	≥ 4.0	≥ 4.0	≥ 4.0
		EOT TAN (ASTM D664) [7]	mgKOH/g	Report	Report	Report	Report

Note:

(5) ACEA considers the CEC-L-54-T-96 test the only valid comparator against which claims of lubricant fuel economy improvements should be made.

(6) For A1/B1 claims OM 602 A passing results obtained before the end of 2008 can be used instead of OM 646 LA results.

(7) The report has to give measured values before and 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.

Afton CHEMICAL

ACEA 2008 Service-Fill Oils For Gasoline And Diesel Engines With After Treatment Devices

Requirements	Method	Properties	Units	Limits			
				C1 -08	C2 -08	C3 -08	C4 -08
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.			
Shear stability	CEC-L-14-A-93 or ASTM D6278	100°C Viscosity after 30 cycles	mm^2/s	Stay-in-grade	Stay-in-grade	Stay-in-grade	Stay-in-grade
Viscosity at high temp. & high shear rate	CEC-L-36-A-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
Evaporative loss	CEC-L-40-A-93 (NOACK)	Max. weight loss after 1 hr at 250°C	%	≤ 13	≤ 13	≤ 13	≤ 11
Sulphur	ASTM D5185	(1)	% m/m	≤ 0.2	≤ 0.3	≤ 0.3	≤ 0.2
Phosphorus	ASTM D5185	(1)	% m/m	≤ 0.05	≥0.070 and ≤0.090 (2)	≥0.070 and ≤0.090 (2)	≤ 0.090 (2)
Sulphated ash	ASTM D874		% m/m	≤ 0.5 (2)	≤ 0.8 (2)	≤ 0.8 (2)	≤ 0.5 (2)
Chlorine	ASTM D6443		ppm - m/m,	Report	Report	Report	Report
TBN	ASTM D2896		mg KOH/g	-	-	≥ 6.0	≥ 6.0

Note:

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

(2) Maximum limits, values take into account method and productions tolerances.

Afton CHEMICAL

ACEA 2008 Service-Fill Oils For Gasoline And Diesel Engines With After Treatment Devices

Requirements	Method	Properties	Units	Limits				
				C1 -08	C2 -08	C3 -08	C4 -08	
				NOTE: The following sections apply to all sequences				
Oil / elastomer compatibility	CEC-L-39-T-96 (3)	Max. variation of characteristics after immersion for 7 days in fresh oil without pre-aging		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	
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				
High temperature foaming tendency	ASTM D6082 High temperature foam test	Tendency - stability	ml	Sequence IV (150°C) 100 - nil				

Note:

(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: D8948/200.1 (150°C +/- 2°C)) + RE3, or complete requirements above + Daimler requirements for AEM.

ACEA 2008 Service-Fill Oils For Gasoline And Diesel Engines With After Treatment Devices

Requirements	Method	Properties	Units	Limits			
				C1 -08	C2 -08	C3 -08	C4 -08
High temperature deposits Ring sticking Oil thickening	CEC-L-88-T-02 (TU5JP-L4) 72 hr 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 @ 40°C between min. and max. values during test	mm2/s	≤ 0.8 x RL 216	≤ 0.8 x RL 216	≤ 0.8 x RL 216	≤ 0.8 x RL 216
		Oil consumption	kg/test	Report	Report	Report	Report
Low temperature sludge	ASTM D6593-00 (Sequence VG) Under protocol & requirements for API (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
Valve train scuffing wear	CEC-L-38-A-94 (TU3M)	Cam wear average	μm	≤ 10	≤ 10	≤ 10	≤ 10
		Cam wear max.	μm	≤ 15	≤ 15	≤ 15	≤ 15
		Pad merit (avg. of 8 pads)	merit	≥ 7.5	≥ 7.5	≥ 7.5	≥ 7.5
Black Sludge	M111SL CEC-L-53-T-95	Average engine sludge	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
Fuel economy (5)	CEC-L-54-T-96 (M111)	Fuel economy improvement vs. reference oil RL 191 (15W40)	%	≥ 3.0	≥ 2.5	≥ 1.0 for xW30 grades	≥ 1.0 for xW30 grades

Note:

(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.

(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.

ACEA 2008 Service-Fill Oils For Gasoline And Diesel Engines With After Treatment Devices

Requirements	Method	Properties		Units	Limits			
					C1 -08	C2 -08	C3 -08	C4 -08
Medium temperature dispersivity	CEC-L-093-04 (DV4TD)	Absolute viscosity increase @ 100°C and 6% of 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 -2.5 pts)	≥ (RL223 -2.5 pts)	≥ (RL223 -2.5 pts)	≥ (RL223 -2.5 pts)
DI diesel Piston cleanliness & Ring sticking (10)	CEC-L-78-T-99 (VW TDI)	Piston cleanliness		merit	≥ RL 206	≥ RL 206	≥ RL 206	≥ RL 206
		Ring sticking (rings 1 & 2)						
			Average of all 8 rings	(ASF), max.	1.0	1.2	1.0	1.0
			Max. for any 1st ring	(ASF), max.	1.0	2.5	1.0	1.0
			Max. for any 2nd ring	(ASF), max.	0.0	0.0	0.0	0.0
		EOT TBN (ISO 3771) (7)		mgKOH/g	Report	Report	Report	Report
		EOT TAN (ASTM D664) (7)		mgKOH/g	Report	Report	Report	Report
Wear (6)	CEC-L-099-08 (OM 646 LA)	Cam wear outlet (avg. max. wear 8 cams)		µm	≤ 120	≤ 120	≤ 120	≤ 120
		Cam wear inlet (avg. max. wear 8 cam) (9)		µm	≤ 100	report, (8)	≤ 100	≤ 100
		Cylinder wear (avg. 4 cyl) (9)		µm	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
		Bore polishing (13 mm) max. value of 4 cylinders (9)		%	≤ 3.0	≤ 3.0	≤ 3.0	≤ 3.0
		Tappet wear inlet (avg. max. wear 8 cams)		µm	Report	Report	Report	Report
		Tappet wear outlet (avg. max. wear 8 cams)		µm	Report	Report	Report	Report
		Piston cleanliness (avg. 4 pistons)		merit	Report	Report	Report	Report
		Average engine sludge		merit	Report	Report	Report	Report

Note:

(6) Limits for C1 might be revised if needed. For C1 claims OM 602 A passing results obtained before the end of 2008 can be used instead of OM 646 LA results.

(7) Test report has to give measured values before and 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 2008 Service-Fill Oils For Heavy Duty Diesel Engines

Requirements	Method	Properties	Units	Limits			
				E4 -08	E6 -08	E7 -08	E9 -08
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.			
Shear stability	CEC-L-14-A-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		
Viscosity, High temperature, High shear rate	CEC-L-36-A-90 (2^{nd} Edition) (Ravenfield)	Viscosity at 150˚C and 10^6 s^{-1} shear rate	mPa·s	≥ 3.5			
Evaporative loss	CEC-L-40-A-93 (NOACK)	Max. weight loss after 1 hr at 250˚C	%	≤ 13			
Sulphated ash	ASTM D874		% m/m	≤ 2.0	≤ 1.0	≤ 2.0	≤ 1.0
Phosphorous (1)	ASTM D5185		% m/m		≤ 0.08		≤ 0.12
Sulphur (1)	ASTM D5185		% m/m		≤ 0.3		≤ 0.4

Note:

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

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ACEA 2008 Service-Fill Oils For Heavy Duty Diesel Engines

Requirements	Method	Properties	Units	Limits				
				E4 -08	E6 -08	E7 -08	E9 -08	
Oil elastomer compatibility [2]	CEC-L-39-T-96 [3]			Elastomer Type				
		Max. variation of characteristics after immersion for 7 days in fresh oil without pre-aging		RE1	RE2-99	RE3-04	RE4	AEM VAMAC As per Daimler-Chrysler
		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	
Foaming tendency	(D892) without option A	Tendency - stability	ml	Sequence I (24˚C) 10 - nil			Seq I 10/0	
			ml	Sequence II (94˚C) 50 - nil			Seq II 20/0	
			ml	Sequence III (24˚C) 10 - nil			Seq I 10/0	
High temperature foaming tendency	(D6082)	Tendency - stability	ml	Sequence IV (150°C) 100-nil				
Oxidation	CEC-L-085-99 (PDSC)	Oxidation induction time	min.	R&R	R&R	≥ 65	≥ 65	
Corrosion	(D6594)	Copper increase	ppm	R&R	R&R	R&R	≤ 20	
		Lead increase	ppm	R&R	R&R	≤ 100	≤ 100	
		Copper strip rating	max.	R&R	R&R	R&R	3	
Turbocharger performance [3]								
TBN	(D2896)	mg KOH/g		≥ 12	≥ 7	≥9 [4]	≥ 7	

Note:

(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 above, or complete requirements above + Daimler requirements for AEM.

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

(4) Values < 9.00 are not accepted.

ACEA 2008 Service-Fill Oils For Heavy Duty Diesel Engines

Requirements	Method	Properties	Units	Limits			
				E4 -08	E6 -08	E7 -08	E9 -08
Bore Polishing / Piston Cleanliness	CEC-L-101-08 (OM 501 LA)	Average Bore polishing	%	≤ 1.0	≤ 1.0	≤ 2.0	≤ 2.0
		Average Piston cleanliness	merit	≥ 26	≥ 26	≥ 17	≥ 17
		Oil consumption	kg/test	≤ 9	≤ 9	≤ 9	≤ 9
		Average engine sludge (8)	merit	R&R (9) (10)	R&R (9) (10)	R&R (9) (10)	R&R (9) (10)
Wear	CEC-L-099-08 (OM 646 LA)	Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 140 (5) (6)	≤ 140 (5) (6)	≤ 155 (5) (6)	≤ 155 (5) (6)
Soot in oil (7)	ASTM D5967 (Mack T-8E)	Test duration: 300 hrs Relative viscosity at 4.8% soot 1 test/2 test/3 test average	mm^2/s	≤ 2.1 / 2.2 / 2.3	≤ 2.1 / 2.2 / 2.3	≤ 2.1 / 2.2 / 2.3	
Soot in oil	Mack T11 ASTM D7159 (T-11)	Min TGA soot @ 4.0 cSt (100°C)	%				3.5/3.4/3.3
		Min TGA soot @ 12.0 cSt (100°C)					6.0/5.9/5.9
		Min TGA soot @ 15.0 cSt (100°C)					6.7/6.6/6.5

Note:

(5) OM 602 A data can be used instead of OM 646 LA 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 program, can be used in place of Mack T-8E.

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

(9) OM 441 LA data can be used instead of OM 501 LA 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.

ACEA 2008 Service-Fill Oils For Heavy Duty Diesel Engines

Requirements	Method	Properties	Units	Limits			
				E4 -08	E6 -08	E7 -08	E9 -08
Soot induced wear	Cummins ISM ASTM D7468	Merit					≥ 1000
		Rocker pad average weight loss at 3.9% soot	mg			≤ 7.5 /7.8 / 7.9	≤ 7.1
		1 test / 2 test / 3 test average Oil filter different pressure @150 hrs	kPa	-	-	≤ 55/67/74	≤ 19
		1 test / 2 test / 3 test average Engine sludge	merit	-	-	≥ 8.1/8.0/8.0 (11)	≥ 8.7
		1 test / 2 test / 3 test average Adjust screw weight loss	mg	-	-		≤ 49
Wear (liner ring-bearings)	ASTM D7422 (Mack T-12)	Merit			≥ 1000	≥ 1000	≥ 1000
		Average liner wear	μm		≤ 26	≤ 26	≤ 24
		Average top ring weight loss	mg		≤ 117	≤ 117	≤ 105
		End of test lead	ppm		≤ 42	≤ 42	≤ 35
		Delta lead 250 - 300 hrs	ppm		≤ 18	≤ 18	≤ 15
		Oil consumption (Phase II)	g/hr		≤ 95 (12)(13)	≤ 95 (12)(13)	≤ 85

Note:

(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.

ACEA 2010 Service-Fill Oils For Gasoline And Diesel Engines

Requirements	Method	Properties	Unit	Limits				
				A1 / B1-10	A3 / B3-10	A3 / B4-10	A5 / B5-10	
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.				
Shear stability	CEC-L-14-A-93 or ASTM D6278	100˚C Viscosity after 30 cycles	mm²/s	xW-20 Stay-in-grade xW-30 ≥ 9.3 xW-40 ≥ 12.0	All grades to be Stay-in-grade	All grades to be Stay-in-grade	All grades to be Stay-in-grade	
Viscosity at high temp. & high shear rate	CEC-L-36-A-90	Viscosity at 150˚C and 10^6 s^{-1} shear rate	mPa.s	max. 3.5. xW -20 2.6. min All others 2.9 min.	≥ 3.5	≥ 3.5	min 2.9 max. 3.5	
Evaporative loss	CEC-L-40-A-93 (NOACK)	Max. weight loss after 1 hr at 250˚C	%	≤ 15	≤ 13	≤ 13	≤ 13	
NOTE: The following sections apply to all sequences								
TBN.	ASTM D2896		mgKOH/g	≥ 8.0	≥ 8.0	≥ 10.0	≥ 8.0	
Sulphated ash	ASTM D874		% m/m	≤ 1.3 (2)	≥ 0.9 and ≤ 1.5 (2)	≥ 1.0 and ≤ 1.6 (2)	≤ 1.6 (2)	
Sulphur(1)	ASTM D5185		% m/m	Report				
Phosphorous(1)	ASTM D5185		% m/m	Report				
Chlorine	ASTM D6443		ppm m/m	Report				
Oil / elastomer compatibility	CEC-L-39-T-96 (3)	Max variation of characteristics after immersion for 7 days in fresh oil without pre-aging		Elastomer type				
				RE1	RE2-99	RE3-04	RE4	AEM VAMAC As per Daimler Chrysler
		Hardness DIDC	points	-1/+5	-5/+8	-22/+1	-5/+5	
		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	
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				
High temperature foaming tendency	ASTM D6082 High temperature foam test	Tendency - stability	ml	Sequence IV (150˚C) 100 - nil				

Note:

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

(2) Maximum limits. Values take into account method and production 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: D8948/200.1 (150°C +/- 2°C)) + RE3, or complete requirements according to 1.10 above + Daimler requirements for AEM.

ACEA 2010 Service-Fill Oils For Gasoline And Diesel Engines - Engine Tests

Requirements	Method	Properties	Units	Limits			
				A1 / B1 -10	A3 / B3 -10	A3 / B4 -10	A5 / B5 -10
High temperature deposits Ring sticking Oil thickening	CEC-L-88-T-02 (TU5JP-L4) 72 hr test	Ring Sticking (each part)	merit, max.	9.0	9.0	9.0	9.0
		Piston Varnish (6 elements, average of 4 pistons)	merit, min.	RL 216			
		Absolute viscosity increase at 40°C between min. and max. values during test	mm^2/s, max.	≤ 0.8 x RL 216			
		Oil consumption	kg/test	Report	Report	Report	Report
Low temperature sludge	ASTM D6593-00 (Sequence VG) Under protocol & requirements for API [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
		Compression ring (hot stuck)		none	none	none	none
		Oil screen clogging	%	≤ 20	≤ 20	≤ 20	≤ 20
Valve train scuffing wear	CEC-L-38-A-94 (TU3M)	Average cam wear	µm	≤ 10	≤ 10	≤ 10	≤ 10
		Cam wear	µm	≤ 15	≤ 15	≤ 15	≤ 15
		Pad merit (avg. of 8 pads)	merit	≥ 7.5	≥ 7.5	≥ 7.5	≥ 7.5
Black Sludge	(10) (11)	Average engine sludge	≥ RL 140	≥ RL 140 + 4σ or ≥ 9.0	≥ RL 140 + 4σ or ≥ 9.0	≥ RL 140 + 4σ or ≥ 9.0	≥ RL 140 + 4σ or ≥ 9.0

Note:

(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.

(10) Until a new CEC Test Method is developed, the gasoline sludge protection performance of engine oil formulations must be proofed by the M 271 sludge test procedure as described by Daimler AG. Test results obtained by the M 271 procedure will be accepted under the condition that they come from test rigs being referenced and quality controlled by Daimler AG. Limits are based on the same reference oil as with the old M 111 sludge test.

(11) Existing results from tests with CEC-L-053 may be used where applicable. In this case limits for all ACEA A/B categories (including A1/B1) are: ≥ RL 140 + 40 or ≥ 9.0.

ACEA 2010 Service-Fill Oils For Gasoline And Diesel Engines - Engine Tests

Requirements	Method	Properties	Units	Limits			
				A1 / B1 -10	A3 / B3 -10	A3 / B4 - 10	A5 / B5 -10
Fuel economy (5)	CEC-L-54-T-96 (M111)	Fuel economy improvement vs. Reference oil RL191 (15W-40)	%	≥ 2.5	-	-	≥ 2.5
Medium temperature dispersivity	CEC-L-093-04 (DV4TD)	Absolute viscosity increase at 100˚C and 6% soot	mm^2/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 -2.5 pts)	≥ (RL223 -2.5 pts)	≥ (RL223 -2.5 pts)	≥ (RL223 -2.5 pts)
Wear (6)	CEC-L-099-08 (OM 646 LA)	Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 140	≤ 140	≤ 120	≤ 120
		Cam wear inlet (avg. max. wear 8 cam) (8)	µm	≤ 110	≤ 110	≤ 100	≤ 100
		Cylinder wear (avg. 4 cyl) (8)	µm	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
		Bore polishing (13 mm) max. value of 4 cylinders (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 8 cams)	µm	Report	Report	Report	Report
		Piston cleanliness (avg. 4 pistons)	merit	Report	Report	Report	Report
		Average Engine sludge	merit	Report	Report	Report	Report
DI Diesel Piston cleanliness & Ring sticking (9)	CEC-L-078-99 (VW TDI)	Piston cleanliness	merit	≥ RL 206 - 4 pts	≥ RL 206 - 4 pts	≥ RL 206	≥ RL 206
		Ring sticking (rings 1 & 2)					
		Avg. of all 8 rings	ASF	≤ 1.2	≤ 1.2	≤ 1.0	≤ 1.0
		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) (7) (8)	mgKOH/g	≥ 4.0	≥ 4.0	≥ 6.0	≥ 4.0
		EOT TAN (ASTM D664) (7)	mgKOH/g	Report	Report	Report	Report

Note:

(5) ACEA considers the CEC-L-54-T-96 test the only valid comparator against which claims of lubricant fuel economy improvements should be made.
(6) For A1/B1 claims OM 602 A passing results obtained before the end of 2008 can be used instead of OM 646 LA results.
(7) The report has to give measured values before and after the test, all measurements to be taken in the same lab. Note: TAN is considered to become a future performance criteria.
(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 2010 Service-Fill Oils For Gasoline And Diesel Engines With After Treatment Devices

Requirements	Method	Properties	Units	Limits			
				C1 -10	**C2 -10**	**C3 -10**	**C4 -10**
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.			
Shear stability	CEC-L-14-A-93 or ASTM D6278	100˚C Viscosity after 30 cycles	mm^2/s	Stay-in-grade	Stay-in-grade	Stay-in-grade	Stay-in-grade
Viscosity at high temp. & high shear rate	CEC-L-36-A-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
Evaporative loss	CEC-L-40-A-93 (NOACK)	Max. weight loss after 1 hr at 250˚C	%	≤ 13	≤ 13	≤ 13	≤ 11
Sulphur	ASTM D5185	see (1)	% m/m	≤ 0.2	≤ 0.3	≤ 0.3	≤ 0.2
Phosphorus	ASTM D5185	see (1)	% m/m	≤ 0.05 (2)	≤0.090 (2)	≥0.070 and ≤0.090 (2)	≤ 0.090 (2)
Sulphated ash	ASTM D874		% m/m	≤ 0.5 (2)	≤ 0.8 (2)	≤ 0.8 (2)	≤ 0.5 (2)
Chlorine	ASTM D6443		ppm - m/m	Report	Report	Report	Report
TBN	ASTM D2896		mg KOH/g	-	-	≥ 6.0	≥ 6.0

Note:

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

(2) Maximum limits. Values take into account method and production tolerances.

ACEA 2010 Service-Fill Oils For Gasoline And Diesel Engines With After Treatment Devices

Requirements	Method	Properties	Units	Limits				
				C1 -10	C2 -10	C3 -10	C4 -10	
				NOTE: The following sections apply to all sequences				
Oil / elastomer compatibility	CEC-L-39-T-96 (3)	Max. variation of characteristics after immersion for 7 days in fresh oil without pre-aging		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	
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				
High temperature foaming tendency	ASTM D6082 High temperature foam test	Tendency - stability	ml	Sequence IV (150˚C) 100 - nil				

Note:

(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: D8948/200.1 (150°C +/- 2°C)) + RE3, + Daimler requirements for AEM.

ACEA 2010 Service-Fill Oils For Gasoline And Diesel Engines With After Treatment Devices

Requirements	Method	Properties	Units	Limits			
				C1 -10	C2 -10	C3 -10	C4 -10
High temperature deposits Ring sticking Oil thickening	CEC-L-88-T-02 (TU5JP-L4) 72 hr 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 @40°C between min. and max. values during test	mm2/s	≤ 0.8 x RL 216	≤ 0.8 x RL 216	≤ 0.8 x RL 216	≤ 0.8 x RL 216
		Oil consumption	kg/test	Report	Report	Report	Report
Low temperature sludge	ASTM D6593-00 (Sequence VG) Under protocol & requirements for API (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
Valve train scuffing wear	CEC-L-38-A-94 (TU3M)	Average Cam wear	µm	≤ 10	≤ 10	≤ 10	≤ 10
		Cam wear max.	µm	≤ 15	≤ 15	≤ 15	≤ 15
		Pad merit (avg. of 8 pads)	merit	≥ 7.5	≥ 7.5	≥ 7.5	≥ 7.5
Sludge	(11) (12)	Average engine sludge	merit	≥ RL 140 + 4σ	≥ RL 140 + 4σ	≥ RL 140 + 4σ	≥ RL 140 + 4σ
Fuel economy (5)	CEC-L-54-T-96 (M111)	Fuel economy improvement vs. reference oil RL 191 (15W40)	%	≥ 3.0	≥ 2.5	≥ 1.0 for xW-30 grades	≥ 1.0 for xW-30 grades

Note:

(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.

(11) Until a new CEC Test Method is developed, the gasoline sludge protection performance of engine oil formulations must be proofed by the M 271 sludge test procedure as described by Daimler AG. Test results obtained by the M 271 procedure will be accepted under the condition that they come from test rigs being referenced and quality controlled by Daimler AG. Limits are based on the same reference oil as with the old M 111 sludge test.

(12) Existing results from tests with CEC-L-053 may be used where applicable. In this case limits for all ACEA C categories are: ^{3} RL 140 + 4σ or ≥ 9.0

ACEA 2010 Service-Fill Oils For Gasoline And Diesel Engines With After Treatment Devices

Requirements	Method	Properties	Units	Limits			
				C1 -10	C2 -10	C3 -10	C4 -10
Medium temperature dispersivity	CEC-L-093-04 (DV4TD)	Absolute viscosity increase @ 100°C and 6% of 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 -2.5 pts)	≥ (RL223 -2.5 pts)	≥ (RL223 -2.5 pts)	≥ (RL223 -2.5 pts)
DI diesel Piston cleanliness & Ring sticking (10)	CEC-L-78-T-99 (VW TDI)	Piston cleanliness	merit	≥ RL 206	≥ RL 206	≥ RL 206	≥ RL 206
		Ring sticking (rings 1 & 2)					
		Average of all 8 rings	(ASF), max.	1.0	1.2	1.0	1.0
		Max. for any 1st ring	(ASF), max.	1.0	2.5	1.0	1.0
		Max. for any 2nd ring	(ASF), max.	0.0	0.0	0.0	0.0
		EOT TBN (ISO 3771) (7)	mgKOH/g	Report	Report	Report	Report
		EOT TAN (ASTM D 664) (7)	mgKOH/g	Report	Report	Report	Report
Wear (6)	CEC-L-099-08 (OM 646 LA)	Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 120	≤ 120	≤ 120	≤ 120
		Cam wear inlet (avg. max. wear 8 cam) (9)	µm	≤ 100	report (8)	≤ 100	≤ 100
		Cylinder wear (avg. 4 cyl) (9)	µm	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
		Bore polishing (13 mm) max. value of 4 cylinders (9)	%	≤ 3.0	≤ 3.0	≤ 3.0	≤ 3.0
		Tappet wear inlet (avg. max. wear 8 cams)	µm	Report	Report	Report	Report
		Tappet wear outlet (avg. max. wear 8 cams)	µm	Report	Report	Report	Report
		Piston cleanliness (avg. 4 pistons)	merit	Report	Report	Report	Report
		Average engine sludge	merit	Report	Report	Report	Report

Note:

(6) Limits for C1 might be revised if needed. For C1 claims OM 602 A passing results obtained before the end of 2008 can be used instead of OM 646 LA 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 2010 Service-Fill Oils For Heavy Duty Diesel Engines

Requirements	Method	Properties	Units	Limits			
				E4 -08 (Issue 2)	**E6 -08 (Issue 2)**	**E7 -08 (Issue 2)**	**E9 -08 (Issue 2)**
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.			
Shear stability	CEC-L-14-A-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		
Viscosity, High temperature, High shear rate	CEC-L-36-A-90 (2^{nd} Edition) (Ravenfield)	Viscosity at 150˚C and 10^6 s^{-1} shear rate	mPa.s	≥ 3.5			
Evaporative loss	CEC-L-40-A-93 (NOACK)	Max. weight loss after 1 hr at 250˚C	%	≤ 13			
Sulphated ash	ASTM D874		% m/m	≤ 2.0	≤ 1.0	≤ 2.0	≤ 1.0
Phosphorous (1)	ASTM D5185		% m/m		≤ 0.08		≤ 0.12
Sulphur (1)	ASTM D5185		% m/m		≤ 0.3		≤ 0.4

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

ACEA 2010 Service-Fill Oils For Heavy Duty Diesel Engines

Requirements	Method	Properties	Units	Limits				
				E4 -08 (Issue 2)	E6 -08 (Issue 2)	E7 -08 (Issue 2)	E9 -08 (Issue 2)	
Oil elastomer compatibility (2)	CEC-L-39-T-96			NOTE: The following sections apply to all sequences				
				Elastomer Type				
		Max. variation of characteristics after immersion for 7 days in fresh oil without pre-aging		RE1	RE2-99	RE3-04	RE4	AEM VAMAC As per Daimler-Chrysler
		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	
Foaming tendency	(ASTM D892) without option A	Tendency - stability	ml	Sequence I (24˚C) 10 - nil			Seq I 10/0	
			ml	Sequence II (94˚C) 50 - nil			Seq II 20/0	
			ml	Sequence III (24˚C) 10 - nil			Seq I 10/0	
High temperature foaming tendency	(ASTM D6082)	Tendency - stability	ml	Sequence IV (150°C) 100-nil				
Oxidation	CEC-L-085-99 (=DSC)	Oxidation induction time	min.	R&R	R&R	≥ 65	≥ 65	
Corrosion	(ASTM D6594)	Copper increase	ppm	R&R	R&R	R&R	≤ 20	
		Lead increase	ppm	R&R	R&R	≤ 100	≤ 100	
		Copper strip rating	max.	R&R	R&R	R&R	3	
Turbocharger performance (3)								
TBN	(ASTM D2896)	mg KOH/g		≥ 12	≥ 7	≥9 (4)	≥ 7	

Note:

(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 to set performance limits providing adequate data is available.

(4) Values < 9.00 are not accepted.

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ACEA 2010 Service-Fill Oils For Heavy Duty Diesel Engines

Requirements	Method	Properties	Units	Limits			
				E4 -08 (Issue 2)	**E6 -08 (Issue 2)**	**E7 -08 (Issue 2)**	**E9 -08 (Issue 2)**
Bore Polishing / Piston Cleanliness	CEC-L-101-08 (OM 501 LA)	Average Bore polishing	%	≤ 1.0	≤ 1.0	≤ 2.0	≤ 2.0
		Average Piston cleanliness	merit	≥ 26	≥ 26	≥ 17	≥ 17
		Oil consumption	kg/test	≤ 9.0	≤ 9.0	≤ 9.0	≤ 9.0
		Average engine sludge (8)	merit	R&R (9) (10)	R&R (9) (10)	R&R (9) (10)	R&R (9) (10)
Wear	CEC-L-099-08 (OM 646 LA)	Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 140 (5) (6)	≤ 140 (5) (6)	≤ 155 (5) (6)	≤ 155 (5) (6)
Soot in oil (7)	ASTM D5967 (Mack T-8E)	Test duration: 300 hrs Relative viscosity at 4.8% soot 1 test/2 test/3 test average	mm^2/s	≤ 2.1 / 2.2 / 2.3	≤ 2.1 / 2.2 / 2.3	≤ 2.1 / 2.2 / 2.3	
Soot in oil	ASTM D7156 (Mack T11)	Min. TGA soot @ 4.0 cSt (100°C)	%				3.5/3.4/3.3
		Min. TGA soot @ 12.0 cSt (100°C)					6.0/5.9/5.9
		Min. TGA soot @ 15.0 cSt (100°C)					6.7/6.6/6.5

Note:

(5) OM 602 A data can be used instead of OM 646 LA 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 T-8E.

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

(9) OM 44 LA data can be used instead of OM 501 LA 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.

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ACEA 2010 Service-Fill Oils For Heavy Duty Diesel Engines

Requirements	Method	Properties	Units	Limits			
				E4 -08 (Issue 2)	**E6 -08 (Issue 2)**	**E7 -08 (Issue 2)**	**E9 -08 (Issue 2)**
Soot induced wear	Cummins ISM	Merit					≥ 1000
		Rocker pad average weight loss at 3.9% soot	mg			≤ 7.5 /7.8 / 7.9	≤ 7.1
		1 test / 2 test / 3 test average Oil filter diff. pressure @150 hrs	kPa	-	-	≤ 55/67/74	≤ 19
		1 test / 2 test / 3 test average Engine sludge	merit	-	-	≥ 8.1/8.0/8.0 (11)	≥ 8.7
		1 test / 2 test / 3 test average Adjust screw weight loss	mg	-	-		≤ 49

Note:

(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.

ACEA 2010 Service-Fill Oils For Heavy Duty Diesel Engines

Requirements	Method	Properties	Units	Limits			
				E4 -08 (Issue 2)	E6 -08 (Issue 2)	E7 -08 (Issue 2)	E9 -08 (Issue 2)
Wear (liner ring-bearings)	Mack T12	Merit			≥ 1000	≥ 1000	≥ 1000
		Average liner wear	µm		≤ 26	≤ 26	≤ 24
		Average top ring weight loss	mg		≤ 117	≤ 117	≤ 105
		End of test lead	ppm		≤ 42	≤ 42	≤ 35
		Delta lead 250-300 hrs	ppm		≤ 18	≤ 18	≤ 15
		Oil consumption (Phase II)	g/hr		≤ 95 (12)(13)	≤ 95 (12)(13)	≤ 85

Note:

(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.

US Military Specifications: Engine Test Requirements

MIL-L		46152D	46152E	2104E
L-38	Bearing Weight Loss, mg. max.	40	40	50
IID	Rust, min.	8.5	8.5	8.1
	Stuck Lifters	None	None	None
IIIE	Viscosity increase 64 hrs. 40°C. %. max.	375	375	-
	Piston Varnish, min.	8.9	8.9	-
	Oil Ring Land Varnish, min.	3.5	3.5	-
	Sludge, min.	9.2	9.2	-
	Ring Sticking	None	None	-
	Lifter Sticking	None	None	-
	Cam or Lifter Scuffing	None	None	None
	Cam plus Lifter Wear, avg. max. µm.	30	30	64
	max. µm.	64	64	178
VE	Average Sludge, min.	9.0	9.0	8.5
	Rocker Cover Sludge, min.	7.0	7.0	6.5
	Average Varnish, min.	5.0	5.0	4.2
	Piston Varnish, min.	6.5	6.5	6.0
	Oil Ring Clogging, %, max.	15	15	15
	Oil Screen Plugging, %, max.	20	20	23
	Ring Sticking	None	None	None
	Cam Wear, avg. max. µm.	127	127	203
	max. µm.	381	381	457
1-H2	TGF, vol. %, max.	45	45	-
	WTD, max.	140	140	-
1-G2	TGF, vol. %, max.	-	-	80
	WTD, max.	-	-	300

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Additional Test Requirements For MIL-L-2104E

Test	Parameter	MIL-L-2104E
Detroit Diesel 6V-53T (FTM 355T)	Piston Area	
	Avg. total deposits, max.	400
	Hot stuck rings	None
	Average Ring Face Distress, demerits, %, max.	-
	Fire ring	Report
	Nos 2 and 3 compression	13.0
	Liner and Head Area	-
	Avg. liner scuffing, %, max.	12.0
	Valve distress	None
	Port plugging, %	Report
Allison C-3 (Seal)	Total Immersion (Buna N)	-
	Volume change, %	0 to +5
	Hardness change, points	-5 to +5
	Dip Cycle (Polyacrylate)	-
	Volume change, %	0 to 10
	Hardness change, points	10 to 0
	Tip Cycle (Silicone)	-
	Volume change, %	0 to +5
	Hardness change, points	-10 to 0
C-3 (Time/Torque)	Slip Time at 5500 cycles max.	0.85
	Torque, Nm. at 0.2s. slip time, min.	101.7
	Δ between 1500 & 5500 cycles, max.	40.7
Caterpillar TO-2	Stopping Time Increase, %, max.	15 (1) (2)
	Average Total Wear, μm. max.	350

Note:

(1) 20% max. for 10W.
(2) In duplicate tests.

MIL-L-2104F Engine Test Requirements

		Number of Tests Run		
		1	2	3
1K	Top Groove Fill (TGF) %. max.	24	27	29
	WDK Demerits, max.	332	347	353
	Top Land Heavy Carbon (TLHC) %. max.	4	5	5
	Oil Consumption, g/kW-hr, max.	0.5	0.5	0.5
	Scuffing and Ring Sticking	None	None	None
IIIE	Viscosity Increase, 40°C. %. max.	750		
	Oil Ring Land Deposits, min.	1.5		
	Piston Skirt Varnish, min.	8.7		
	Sludge, min.	9.0		
	Stuck Rings	None		
	Stuck Lifters	None		
	Cam and Lifter Scuffing	None		
	Cam plus Lifter Wear:	-		
	Avg. max. µm.	64		
	Maximum, µm.	145		
L-38	Bearing Weight Loss, mg. max.	50		
	Piston Skirt Varnish, min.	9.0		
Mack T7	Avg. rate of Viscosity Increase, last 50 hr. cSt. @ 100°C/hr. max.	0.040		
6V-92TA	Skirts, Tin Removed	Report	Report	Report
	Wrist Pin Slipper Bushing, Copper removed	Report	Report	Report
	Ring Face Distress, demerits, max.			
	Fire Ring	0.33	0.34	0.36
	No. 2 & 3 Compression Rings	0.28	0.29	0.30
	Broken Rings	None	None	None
	Cylinder Liner scuffing, %. max.	60.0	63.5	65.0
	Port Plugging, % area, max.			
	Average	2	2	2
	Single Cylinder	5	5	5

MIL-L-2104F Transmission Test Requirements

		Graphite	Paper	
		5500	0 - 5,000	5,000 - 10,000
Allison C-4 Friction	Slip Time at Cycles, secs. max.	0.74	0.67	0.56
	Mid-Point Co-efficient of Friction at Cycles min.	0.097	0.066	0.086
Seals	Total Immersion (Buna N)			
	Volume change, %	0 to +5		
	Hardness change, points	-5 to +5		
	Dip Cycle (Polyacrylate)			
	Volume change, %	0 to +10		
	Hardness change, points	0 to +5		
	Tip Cycle (Silicone)			
	Volume change, %	0 to +5		
	Hardness change, points	-10 to 0		
	Total Immersion (Fluoroelastomer)			
	Volume change, %	0 to +4		
	Hardness change, points	-4 to +4		
		Sequence 1220	Sequence FRRE	
Cat TO-4	Average Dynamic Co-efficient, %	90 - 140	-	
	After 3,000 cycles	-	85 - 130	
	After 8,000 cycles	-	90 - 125	
	After 15,000 cycles	-	90 - 125	
	After 25,000 cycles	-	95 - 125	
	Average Static Co-efficient, %	91 - 127	95 - 120	
	Disc Wear, mm. max.	0.04	-	
	Energy Limit, %	25	-	
Cat TO-3	Stopping Time Increase, %	Report		
	Average Total Wear, µm.	Report		
	Seals	Report		

US Military Specifications: MIL-PRF-2104H

(July 2004, Superseding MIL-PRF-2104G)
Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service

Property	Limits		
	SAE Grade 40	SAE Grade 15W-40	SAE Grade 5W-40
Kinematic Viscosity @ 100°C, cSt	≥ 12.5 and < 16.3	≥ 12.5 and < 16.3	≥ 12.5 and < 16.3
Low Temperature Cranking viscosity, cP, ASTM D5293	-	7000 @ -25°C, min	6200 @ -35°C, min
	-	7000 @-20°C, max	6600 @-30°C, max
HTHS @ 150°C, cP, ASTM D4683	-	≥ 3.7	≥ 3.7
Low Temperature Pumping Viscosity, cP, max, ASTM D4684	-	60 000 @ -25	60 000 @ -35
Pour Point, °C, max.	-15	-25	-40
Flash Point, °C, min, ASTM D92	225	215	210
Evaporative Loss, %, max, ASTM D5800	-	15	15
Sulfated Ash, %, max, ASTM D874	1.5	1.5	1.5
Foaming, ASTM D 892 (option A not allowed)			
Sequence I, foam/settling, ml, max.	10/0		
Sequence II, foam/settling, ml, max.	50/0		
Sequence III, foam/settling, ml, max.	10/0		
Aeration, ASTM D6894			
Aeration (EOAT), Volume, %, max.	8.0 (MTAC) [1]		
Shear Stability Performance, ASTM D6278			
Kinematic viscosity after shearing, cSt, min.	-	12.5	

Note:
(1) Multiple Test Acceptance Criteria (MTAC) is a data-based approach for evaluation of the quality and performance of a formulation where more than one test may be run.

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US Military Specifications: MIL-PRF-2104H

(July 2004, Superseding MIL-PRF-2104G)

Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service

Material	Rated or Measured parameters	Primary Performance Criteria		
		One Test	Two Test	Three Test
Piston deposits and scuffing performance				
Aluminium CAT 1K ASTM D6750	Weighted Piston Demerits (WPD), max.	332	347	353
	Top Groove Fill (TGF), %, max.	24	27	29
	Top Land Heavy Carbon (TLHC), %, max.	4	5	5
	Average Oil Consumption, g/kW-hr, max.	0.5	0.5	0.5
	Piston, Ring and Liner scuffing	none	none	none
Steel CAT 1P ASTM D6684	Weighted Piston Demerits (WPD), max.	350	378	390
	Top Groove Carbon (TGC), demerit, max.	36	39	41
	Top Land Carbon (TLC), demerit, max.	40	46	49
	Average Oil Consumption, (0-360 hrs.), g/h, max.	12.4	12.4	12.4
	Final Oil Consumption, (312-360 hrs.), g/h, max.	14.6	14.6	14.6
	Piston, Ring and Liner scuffing	none	none	none
Properties of Sludge control, filterability and sliding valvetrain wear, Cummins M11 EGR, ASTM D6975				
Avg. Crosshead weight loss, mg, max.		20	21.8	22.6
Avg. Top ring weight loss, mg, max.		175	186	191
Oil filter delta pressure @ 250 hrs, kPa, max.		275	320	341
Avg. Engine sludge, CRC merit, min.		7.8	7.6	7.5
Soot control, MACK T-8E, ASTM D5967				
Relative viscosity at 4.8% soot, max. (2)		1.8	1.9	2

Note:

(2) Relative viscosity = (Viscosity at 4.8% soot) / (Viscosity of new oil shared in ASTM D6278).

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US Military Specifications: MIL-PRF-2104H

(July 2004, Superseding MIL-PRF-2104G))
Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service

Rated or Measured parameters		Primary Performance Criteria		
		One Test	Two Test	Three Test
Used Oil pumpability, ASTM D4684				
Requirement A	Viscosity after 75 hrs. of Mack T-10 test, tested @ -20°C, mPa-s, max.	-	25 000	
Requirement B	Viscosity after 75 hrs. of Mack T-10 test, tested @ -20°C, mPa-s, max.	-	25 000	
	Yield Stress, Pa	-	< 35	
Properties of two-stroke cycle diesel engine				
Average ring face distress				
Fire Ring, avg.		0.33	0.34	0.36
Nos 2 and 3 compression ring, avg.		0.28	0.29	0.3
Broken rings, avg.		none	none	none
Cylinder liner area				
Liner distress, % area, avg, max.		60	63.5	65
Port plugging, % area, avg, max.				
Average		2	2	2
Single Cylinder		5	5	5
Valvetrain wear control criteria, ASTM D5966				
Average Pin wear, µm, max.		7.6	8.4	9.1

US Military Specifications: MIL-PRF-2104H

(July 2004, Superseding MIL-PRF-2104G)
Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service

Rated or Measured Parameters	Primary Performance Criteria		
	One Test	Two Test	Three Test
The following parameters are required to ensure the right protection when the oil is used in power shift transmission, cooled friction component or hydraulic systems such as steering braking and disconnect clutches			
Frictional characteristics and wear			
Allison Graphite and Paper Friction Test Mid Point dynamic friction coefficient (3)(4)	Measured mid-point friction shall be greater than or equal to the qualified batch sample mean mid-point friction coefficient minus 0.012		
Allison Graphite and Paper Friction Test Slip Time, seconds (3)(4)	Slip time shall be less than or equal to the maximum acceptable slip time criteria		
Caterpillar TO-4 / TO-4M, Seq 1220 (5)			
Average dynamic coefficient, %	90-140		
Average static coefficient, %	91-127		
Disc wear, mm, max.	0.04		
Energy limit, m/s, min.	25		
Caterpillar TO-4 / TO-4M, SEQFRRET (5)			
Average dynamic coefficient, %			
@ 3000 cycles	85-130		
@ 8000 cycles	90-125		
@ 15,000 cycles	90-125		
@ 25,000 cycles	95-125		

Note:

(3) Variation in frictional performance from one batch of friction plates to the next demands that minimum acceptance criteria be developed with respect to individual batches.

(4) Maximum acceptable slip time (tmax)

a. Allison Paper Friction Test : tmax = 0.1108-0.6012μ

b. Allison Graphite Friction Test : tmax = 1/[-221*(μ-0.1421)2+1.756]

c. Where μ is the minimum acceptable coefficient at mid-point

(5) TO-4M requirements are only for 5W-40 and 15W-40 viscosity grades.

US Military Specifications: MIL-PRF-2104H

(July 2004, Superseding MIL-PRF-2104G)
Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service

Rated or Measured Parameters	Primary Performance Criteria		
	One Test	Two Test	Three Test
The following parameters are required to ensure the right protection when the oil is used in power shift transmission, cooled friction component or hydraulic systems such as steering braking and disconnect clutches			
Caterpillar TO-4M, EHD Film-Forming Test [5]			
% of Elastohydrodynamic (EHD) reference film thickness at 2 m/s	-		
@ 70°C	-	≥ 90	
@ 100°C	-	≥ 96	
@ 130°C	-	≥ 98	
Piston ring, liner and bearing wear control, ASTM D6987 (T-10)			
Merit rating, min.	1000		
Property of oxidation and nitration control, ASTM D6984			
% increase kinematic viscosity @ 40°C, max.	275 (MTAC) [1]		
Interface Requirements			
Homogeneity and miscibility, ASTM D6922	Pass		
Elastomer Seal compatibility, GMN10055 DEXRON-III, H Revision Automatic Transmission Fluid Specifications	Pass		
Corrosion control, HTCBT, ASTM D6594			
Copper increase, ppm, max.		20	
Lead increase, ppm, max.		120	
Tin increase, ppm, max.		50	
Copper strip coupon rating, max.[6]		3	

Note:

(1) Multiple Test Acceptance Criteria (MTAC) is a data-based approach for evaluation of the quality and performance of a formulation where more than one test may be run.

(5) TO-4M requirements are only for 5W-40 and 15W-40 viscosity grades.

(6) The rating system in test method ASTM D130 is used to rate the copper strip coupon.

Diesel Engine Oil Standards

			Units	Performance Criteria		
				DH-1-05	DH-2-05	DL-1-05
Viscosity Grade				-	-	xW-30, xW-20
Jaso Hot Tube Test Hot Surface Deposit Control	@ 280˚C		Merit Rating	7.0 min.	7.0 min.	7.0 min.
Anti-foaming	Sequence I	Foaming/ Stability	ml/ml	10/0 max.	10/0 max.	10/0 max.
	Sequence II		ml/ml	50/0 max.	50/0 max.	50/0 max.
	Sequence III		ml/ml	10/0 max.	10/0 max.	10/0 max.
High Temp Anti-foaming	Sequence IV		ml/ml	-	-	100/0 max.
Volatility	Evaporative Loss		mass %	18.0 max.	18.0 max.	15.0 max.
Anti-Corrosion	Copper		mass ppm	20 max.	20 max.	20 max.
	Lead		mass ppm	120 max.	100 max.	120 max.
	Tin		mass ppm	50 max.	50 max.	50 max.
	Discolouration of Copper coupon after test @ 135˚C		-	3 max.	3 max.	3 max.
Shear Stability	Kinetic viscosity of oil after test @ 100˚C		mm^2/s	Stay-in-grade of virgin oil viscosity classification in SAE J300	Stay-in-grade of virgin oil viscosity classification in SAE J300	xW-30:8.6 min. xW-20: Stay-in-grade of virgin oil viscosity classification in SAE J300
Sulphated Ash			mass %	-	1.0 ±0.1	0.6 max.
Base Number			mgKOH/g	10.0 min.	5.5 min. -	- -
Phosphorus			mass %	-	0.12 max.	0.10 max.
Sulphur			mass %	-	0.5 max.	0.5 max.
Chlorine			mass ppm	-	50 max.	50 max.
Seal Compatibility	RE1 (Fluoro)	Hardness Change	Point	-1 to +5	-1 to +5	-1 to +5
		Tensile Strength Rate of Change	%	-40 to +10	-50 to +10	-40 to +10
		Elongation Rate of Change	%	-50 to +10	-60 to +10	-50 to +10
		Volume Rate of Change	%	-1 to +5	-1 to +5	-1 to +5
	RE2-99 (Acrylic)	Hardness Change	Point	-5 to +8	-5 to +8	-5 to +8
		Tensile Strength Rate of Change	%	-15 to +18	-15 to +18	-15 to +18
		Elongation Rate of Change	%	-35 to +10	-35 to +10	-35 to +10
		Volume Rate of Change	%	-7 to +5	-7 to +5	-7 to +5

Diesel Engine Oil Standards

			Units	Performance Criteria		
				DH-1-05	DH-2-05	DL-1-05
Seal Compatibility	RE3 (Silicon)	Hardness Change	point	-25 to +1	-25 to +1	-25 to +1
		Tensile Strength Rate of Change	%	-45 to +10	-45 to +10	-45 to +10
		Elongation Rate of Change	%	-20 to +10	-20 to +10	-20 to +10
		Volume Rate of Change	%	-1 to +30	-1 to +30	-1 to +30
	RE4 (Nitrile)	Hardness Change	point	-5 to +5	-5 to +5	-5 to +5
		Tensile Strength Rate of Change	%	-20 to +20	-20 to +20	-20 to +20
		Elongation Rate of Change	%	-50 to +10	-50 to +10	-50 to +10
		Volume Rate of Change	%	-5 to +5	-5 to +5	-5 to +5
	AEM (Ethylene Acrylic)	Hardness Change	point	Per agreement between concerned parties	Per agreement between concerned parties	Per agreement between concerned parties
		Tensile Strength Rate of Change	%			
		Elongation Rate of Change	%			
		Volume Rate of Change	%			
Nissan TD25 (M336) Piston Detergency	TGF (Top Groove Fill)		vol %	60.0	60.0	60.0
	Piston Ring Stickings			All free	All free	All free
	Deposits on Ring Lands		Merit Rating	Report	Report	Report
Mitsubishi 4D34T4 Valve Train Wear Protection (M354)	Average Cam Diameter Loss (Normalised at 4.5 mass % Carbon Residue Increase)		µm, max.	95.0	95.0	95.0
	Maximum Cam Diameter Loss (Normalised at 4.5 mass % Carbon Residue Increase)		µm, max	210	210	210
	Cam Surface Wear			No pitting	No pitting	No pitting
Mack T8A Soot Dispersancy (D5967)	Viscosity Increase (100 to 150 hr) @ 100˚C		mm^2/s h	0.2	0.2	0.2
Sequence IIIE High Temperature Oxidation Stability (D6984)	Viscosity Increase @ 40˚C, max.		% max.	200	200	-
	or Viscosity Increase @ 40˚C (60 hr)		%, max.	295	295	-
	Viscosity Increase @ 40˚C (80 hr)		%, max.	-	-	275
Fuel Economy (CEC-L-54-T-96)	Fuel Economy Improvement, min.		%, min.	-	-	2.5

JASO 2008 Diesel Engine Oil Standards

			Units	Performance Criteria			Method
				DH-1-05	DH-2-08	DL-1-08	
Viscosity grade				--	--	xW-30, xW-20	SAE J300
Piston Detergency JASO M336	TGF (Top Groove Fill)		vol %	60.0 max.	60.0 Max.	60.0 Max.	JASO M336
	Piston Ring Stickings		All free	All free	All free	All free	
	Deposit on Ring lands		Merit Rating	Report	Report	Report	
Valve Train Wear Protection	Average Cam Diameter Loss (Normalized at 4.5 mass % Carbon Residue Increase)		µm	95.0 max.	95.0 max.	95.0 max.	JASO M354
	Maximum Cam Diameter Loss (Normalized at 4.5 mass % Carbon Residue Increase)		µm	210 max.	210 max.	210 max.	
	Cam Surface Wear		No pitting	No pitting	No pitting		
Soot Dispersancy	Viscosity increase (100 to 150 hrs.) @ 100°C		mm2/s h	0.2 max.	0.2 max.	0.2 max.	ASTM D5967 (Mack T8A and 8E)
High Temperature Oxidation Stability	Viscosity increase @ 40°C max		% max.	200 max.	200 max.	-	ASTM D5533 Seq IIIE
	Or Viscosity increase @ 40°C (60 hrs.)		% max.	295 max.	295 max.	-	ASTM D6984 Seq IIIF
	Viscosity increase @ 40°C (80 hrs.)		% max.	-	-	275 max.	ASTM D6984 Seq IIIF
Fuel Economy	Fuel Economy Improvement		% min.	-	-	2.5	CEC-L-54-T-96
Hot Surface Deposit Control	@ 280°C		Merit Rating	7.0 min.	7.0 min.	7.0 min.	JPI-5S-55-99
Anti-foaming	Sequence I	Foaming/ Stability	ml/ml	10/0 max.	10/0 max.	10/0 max.	JIS-K-2518:2003
	Sequence II		ml/ml	50/0 max.	50/0 max.	50/0 max.	
	Sequence III		ml/ml	10/0 max.	10/0 max.	10/0 max.	
High Temp Anti-Foaming	Sequence IV		ml/ml	-	-	100/0 max.	ASTM D6082
Volatility	Evaporation Loss @ 250°C		mass %	18.0 max.	18.0 max.	15.0 max.	JPI-5S-41-2004
Anti-Corrosion	Copper		mass ppm	20 max.	20 max.	20 max.	ASTM D6594
	Lead		mass ppm	120 max.	100 max.	120 max.	
	Tin		mass ppm	50 max.	50 max.	50 max.	
	Discolouration of Copper Coupon after test @ 135°C		-	3 max.	3 max.	3 max.	ASTM D130
Shear Stability	Kinetic Viscosity of Oil after Test @ 100°C		mm^2/s	Stay-in-grade of virgin oil viscosity classification in SAE J300	Stay-in-grade of virgin oil viscosity classification in SAE J300	xW-30 : 8.6 Min. xW-20 Stay-in-grade of virgin oil viscosity classification in J300	ASTM D6278

Afton CHEMICAL

JASO 2008 Diesel Engine Oil Standards

			Units	Performance Criteria			Method
				DH-1-05	DH-2-08	DL-1-08	
Sulfated Ash			mass %	-	1.0 +/- 0.1	0.6 Max	JIS-K-2272 1998-5
Base Number			mg KOH/g	10.0 min.	5.5 min.	-	JIS-K-2501 20003 8
					-	-	ASTM D4739
Phosporous			mass %	-	0.12 max.	0.10 max.	JPI-5S-38-2003
Sulphur			mass %	-	0.5 max.	0.5 max.	JIS-K-2541 2003 5
Chlorine			mass ppm	-	150 max.	150 max.	JPI-5S-64-2002
Seal Compatibility	RE1 (Fluoro)	Hardness Change	Point	-1 to +5	-1 to +5	-1 to +5	CEC-L -39-T-96
		Tensile Strength Rate of Change	%	-40 to +10	-50 to +10	-40 to +10	
		Elongation Rate of Change	%	-50 to +10	-60 to +10	-50 to +10	
		Volume Rate of Change	%	-1 to +5	-1 to +5	-1 to +5	
	RE2-99 (Acrylic)	Hardness Change	Point	-5 to +8	-5 to +8	-5 to +8	
		Tensile Strength Rate of Change	%	-15 to +18	-15 to +18	-15 to +18	
		Elongation Rate of Change	%	-35 to +10	-35 to +10	-35 to +10	
		Volume Rate of Change	%	-7 to +5	-7 to +5	-7 to +5	
	RE3 (Silicon)	Hardness Change	Point	-25 to +1	-25 to +1	-25 to +1	
		Tensile Strength Rate of Change	%	-45 to +10	-45 to +10	-45 to +10	
		Elongation Rate of Change	%	-20 to +10	-20 to +10	-20 to +10	
		Volume Rate of Change	%	-1 to +30	-1 to +30	-1 to +30	
	RE4 (Nitrile)	Hardness Change	Point	-5 to +5	-5 to +5	-5 to +5	
		Tensile Strength Rate of Change	%	-20 to +10	-20 to +10	-20 to +10	
		Elongation Rate of Change	%	-50 to +10	-50 to +10	-50 to +10	
		Volume Rate of Change	%	-5 to +5	-5 to +5	-5 to +5	
	AEM (Ethylene Acrylic)	Hardness Change	Point	Per agreement between concerned parties	Per agreement between concerned parties	Per agreement between concerned parties	
		Tensile Strength Rate of Change	%				
		Elongation Rate of Change	%				
		Volume Rate of Change	%				

Global Engine Oil Service Specifications DHD-1 Laboratory Tests

Test	Performance Criteria	Limits			
Corrosion Bench Test	Used Oil Element Content above Baseline, ppm, max.	Copper 20, Lead 120, Tin 50			
Elastomer Compatibility (1)	Variation after 7 days fresh oil, No pre-aging	Elastomer Type			
		RE 1	RE 2	RE 3	RE 4
	Hardness DIDC, points, max.	-1/+5	-5/+5	-25/+1	-5/+5
	Tensile Strength, %. max.	-50/+10	-15/+10	-45/+1	-20/+10
	Elongation rupture, %. max.	-60/+10	-35/+10	-20/+10	-50/+10
	Volume variation, %. max.	-1/+5	-5/+5	-1/+30	-5/+5
Foaming Tendency	Tendency / Stability, ml. max. after 1 min. settling	Sequence I (24°C) 10 - nil			
		Sequence II (94°C) 50 - nil			
		Sequence III (24°C) 10 - nil			
Foaming - High Temperature	Tendency / Stability, ml. max. after 1 min. settling	Sequence IV (150°C) 200 - 50			
PDSC	Oxid. Induction Time, min.	35			
Shear Stability Bosch Injector Test	Viscosity after 30 cycles, measured at 100°C.	Stay-in-grade			
Sulphated Ash	Mass %. max.	2.0			
HT/HS Viscosity Tapered Bearing Simulator / Ravenfield	High Temperature / High Shear Rate Viscosity, cP. min.	35			
NOACK Volatility	% Mass Loss, max.	15			

Note:

(1) The Elastomer Compatibility Limits are those stated in ACEA 1999 European Oil Sequences and apply to the elastomer batches available at that time. Consult the most recent ACEA Oil Sequence publication for the information on the limits with more recent elastomer batches.

Global Engine Oil Service Specifications DHD-1 — Engine Tests

Test	Performance Criteria	Limits		
Caterpillar 1R [(1)]	Weighted Demerits (WDR), max.	397	416	440
	Total Groove Carbon, %. max.	40	42	44
	Top Land Carbon, %. max.	37	42	46
	Oil Consumption g./hr. Initial max./Final max.	13.1 / 1.5 X Initial		
Cummins M11 HST [(3)]	Oil Filter Diff. Press. kPa. max.	79	93	100
	Eng. Sludge, CEC Merits, min.	8.7	8.6	8.5
	Rocker Pad Average Weight Loss, Normalized to 4.5% soot mg. max.	6.5	7.5	8.0
Mack T-9 [(4)]	Used Oil Lead, ppm. max.	15 [(2)]		
	TAN Increase at EOT, max.	2.0		
	Average Wear Normalized to 1.75% soot Liner µm. max.	25.4	26.6	27.1
	Top Ring % wt. Loss, mg. max.	120	136	144
Mack T-8E	Relative Viscosity at 4.8% soot	2.1	2.2	2.3
6.5L RFWT	Pin Wear, µm. max.	7.6	8.4	9.1
Seq IIIF, 60 hrs.	Kv 40°C Viscosity Increase, %. max.	200		
HEUI	Aeration, vol. %. max.	8.0		
Mercedes Benz OM 441 LA	Bore Polish, % Area. max.	2.0		
	Boost Pressure Loss at 400 hrs, %. max.	4		
	Weighted Merits, min.	25.0		
	Oil Consumption, kg./test max.	40		
Mitsubishi 4D34T4 160 hrs.	Avg. Cam Lobe Wear, µm.	95.0		

Note:

(1) The requirements for this characteristic may be met with a CH-4 level passing result in an original API CH-4 qualification.

(2) Lead Maximum 25 ppm if fresh oil has TBN (ASTM D4739) greater than 10.

(3) Cummins ISM being considered as a replacement test.

(4) Mack T-12 is an approved alternative.

Two-Stroke Classifications: API TC

	Engine	Parameter	Limits
API TC (CEC TSC-3)	Yamaha CE 50S	Tightening, Mean Torque Drop	≤ Ref. Oil
	Yamaha CE 50S	Pre-ignition, occurrences	1 max. in 50 hr. test
	Yamaha 350 M2	Piston Varnish Ring Sticking Piston Deposits Piston Scuffing	Better than or equal to reference oil

Note:

TA (TSC-1) not released as a full specification, but the test methods are recognised by ASTM as valid for assessing the capabilities of two-stroke oils.

TB (TSC-2) not released as a full specification due to the withdrawal of the supporting OEM. No new work is in progress.

Two-Stroke Classifications: ISO/JASO

ISO			EGB	EGC	EGD		
JASO			FB	FC	FD		
Physical Chemical Properties							
Evaluation Item			**Limit**			**Test Procedure**	
						JIS	**ASTM**
Kinematic viscosity @ 100°C, cSt			6.5 min.			JIS K 2283	D445
Flash Point, °C			70 min.			JIS K 2265	D83
Sulfated Ash, % wt.			0.25	0.25	0.18	JIS K 2272	D874
Test procedures and Standard Indices							
Evaluation item			**Standard Index (min.)**			**Test Procedure**	
Lubricity (1)					95	JASO M340	
Initial Torque (1)					98	JASO M340	
Detergency (1)	Evaluation after 60 min.	Fundamental Part	85	95	-	JASO M341 60 min. Test	
		Piston Skirt Part	-	-	-		
	Evaluation after 180 min.	Fundamental Part	-	-	125	JASO M341 180 min. Test	
		Piston Skirt Part	-	-	95		
Exhaust Smoke (2)			45	85	85	JASO M342	
Exhaust System blocking (2)				90	90	JASO M343	

Note:

(1) Engine : HONDA DIO AF27.

(2) Engine : SUZUKI SX800R.

Specification description:

FA Obsolete

FB / EGB Increased lubricity, detergency, exhaust smoke and exhaust system blocking requirements over FA.

FC / EGC Lubricity and initial torque requirements same as FB, however far higher detergency, exhaust smoke and exhaust system blocking requirements over FB.

FD / EGD Same as FC with far higher detergency requirement.

Afton CHEMICAL

Two-Stroke Classifications: TISI 1040

Test	Parameter	Limits
Bench Tests	Viscosity, 100°C, cSt.	5.6 - 16.3
	Viscosity Index, min.	95
	Flash Point, °C min.	70
	Pour Point, °C max.	-5
	Sulphated Ash, % wt. max.	0.5
	Metallic Element content, % wt.	Report
Kawasaki KH 125M	Piston Seizure and Ring Scuffing	No seizure
	Detergency (general cleanliness)	
	Ring Sticking, min.	8 merit
	Piston Cleanliness, min.	48 merit
	Exhaust Port Blocking	None
Suzuki SX 800R (JASO M 342-92)	Exhaust Smoke, min.	85

Note:

Since mid-1991, all two-stroke oils used in Thailand are required to meet TISI requirements.

Tests use different fuel:oil ratios to evaluate performance.

Piston Seizure and Ring Scuffing various down to 200:1

Detergency 40:1

Exhaust Smoke 10:1

Two-Stroke Classifications: NMMA TC-W3 For Outboard Motors

NMMA - National Marine Manufacturer Association (1)

Test	Parameter
Analytical Test Results	
Viscosity, cSt, 40°C	
Pour Point, °C	
Flash Point, ASTM D93, °C	
Nitrogen, %wt.	
TBN, ASTM D2896, mgKOH/g	
Cloud Point, ASTM D2500, °C	
Bench Test Results	
Compatibility, % Sediments	Homogeneous after mixed separately with each reference oil (*,**) and stored 48 hrs
Brookfield (Fluidity) @ -25°C, cP	≤ 7500
Miscibility @ -25°C, cP Inversions	No more than 10% inversions than reference
% Rust	Equal to or less than reference
Filterability, % change	Decrease in flow rate no more than 20%
Engine Test Results	
OMC 40 Horsepower Test (98) hrs	
Average Piston Varnish	Equal to or better than reference - 0.6*
Top Ring Sticking	Equal to or better than reference - 0.6*
OMC 70 Horsepower Test (98) hrs	
Average Piston Deposits	Equal to or better than reference - 0.5*
Second Ring Stick	Equal to or better than reference based on formula * : 0.537 * Reference + 4.4
Mercury 15 Horsepower Test (100) hrs. (2 consecutive passes are required)	
Circumferential Scuffing	Equal to or less than 15%
Compression Loss	Less than 20psig
Average Second Ring Sticking	Equal to or better than 8.0
Average Second Land Deposits	Equal to or better than 6.0
Ring Wiping	Less than 5%
Needle Bearing Stickiness - Original	Must Pass
Needle Bearing Stickiness - Proposed	Must Pass
Yamaha CE50S Tightening / Lubricity Test	
Torque Drop, Lb-in.	Equal to or less than reference ** within 90% confidence level
Yamaha CE50S Preignition Test (100) hrs	
Major preignitions	Equal to or less than reference *
AF-27 Lubricity Test	
Torque Loss, Nm	Equal to or less than reference oil XPA 3259 within 90% confidence limit

Note:

* # 93738

** XPA-3259

(1) Some specifics read-across rules applied, check the Product Approval System (Specifications).

Four-Stroke Classifications: JASO T903: 2006, 2011

Requirements		Performance Criteria	Test Procedure
Sulphated Ash, mass %, max.		1.2	JIS-K-2272
Phosphorus Content mass %, min.		≥ 0.08 and ≤ 0.12	JPI-5S-38
Evaporative Loss mass %, max.		20	JPI-5S-41
Foaming Tendency (foaming/settling)	Sequence I ml	10/0	JIS K 2518
	Sequence II ml	50/0	
	Sequence III ml	10/0	
Shear Stability (Kinematic Viscosity (100°C) mm^2/s, min. after test)		xW-30: 9.0 xW-40: 12.0 xW-50: 15.0 Other grades: Stay-in-grade	JPI-5S-29 (1)
High temperature high shear viscosity mPa^2s		2.9 min	JPI-5S-36

Above requirements apply to both 2006 and 2011. Friction requirements below differ between 2006 and 2011 Specifications.

Four-Stroke Classifications: JASO T903, 2006

JASO T904	Dynamic Friction Characteristic Index (DFI)	Static Friction Characteristic Index (SFI)	Stop Time Index (STI)
JASO MA	1.45 ≤ DFI < 2.50	1.15 ≤ SFI < 2.50	1.55 ≤ STI < 2.50
JASO MA1	1.45 ≤ DFI < 1.80	1.15 ≤ SFI < 1.70	1.55 ≤ STI < 1.90
JASO MA2	1.80 ≤ DFI < 2.50	1.70 ≤ SFI < 2.50	1.90 ≤ STI < 2.50
JASO MB	0.50 ≤ DFI < 1.45	0.50 ≤ SFI < 1.15	0.50 ≤ STI <1.55

Four-Stroke Classifications: JASO T903, 2011

JASO T904	Dynamic Friction Characteristic Index (DFI)	Static Friction Characteristic Index (SFI)	Stop Time Index (STI)
JASO MA	1.30 ≤ DFI < 2.50	1.25 ≤ SFI < 2.50	1.45 ≤ STI < 2.50
JASO MA1	1.30 ≤ DFI < 1.80	1.25 ≤ SFI < 1.70	1.45 ≤ STI < 1.85
JASO MA2	1.85 ≤ DFI < 2.50	1.70 ≤ SFI < 2.50	1.85 ≤ STI < 2.50
JASO MB	0.50 ≤ DFI < 1.30	0.50 ≤ SFI < 1.25	0.50 ≤ STI <1.45

Note:

(1) Test shall be conducted by diesel injector method under the standard test conditions (30 cycles).

The JASO T903 specifications were implemented to ensure oils with the correct viscosity and friction characteristics were available in the market for four-stroke motorcycles. These oils must meet a minimum requirement of API SG, SH. SJ, SL, SM*, NS** or ILSAC GF-2, GF-3 or ACEA A1/B1, A3/B3, A5/B5, C2, C3, C4 and must meet these physical/chemical requirements in addition to the JASO T904: 2006 friction test.

* SM excluding SM-EC

** SN excluding SN-RC

Four-Stroke Classifications: NMMA FCW

Engine Tests	Test Method	Result
Kinematic Viscosity @ 40˚C	D445	Report only
Viscosity Index	D2270	Report only
Specific Gravity	D1298 OR D4052	Report only
Total Base Number	D2896	Report only
Total Acid Number	D664	Report only
Elements	D4951, D4927 OR D4628	Report only
Sulphur Content	D5453	Report only
Nitrogen Content	D5291 OR D5762	Report only
IR Spectrum	E1421	Report only
Kinematic Viscosity @ 100˚C	D445	Per SAE Grades
Cold Crank Viscosity	D5293	Per SAE Grades
MRV-TP-1 Viscosity	D4684	Per SAE Grades
Foam, Seq. I, ml	D892	10/0 maximum
Foam, Seq. II, ml	D892	50/0 maximum
Foam, Seq. III, ml	D892	10/0 maximum
Foam, Seq. IV, ml	D6082	200/50 maximum
Shear Stability, 30 cycles	D6278	Report only
HTHS (after 30 cycles of D6278), cP	D4683, D4741 OR D548	3.3 minimum
Rust, %	NMMA FC-W® method	≤ Reference Oil
NOACK Volatility, %	ASTM D5800	Report only
EOFT, % change	GM 9099P	≤ 50
115 HP Gen. Perf. Test	NMMA FC-W® method	A Pass is determined by inspection of the following parts; Cam lobes Cam caps Cam journals Cam bearings Piston rings Piston Con rod bearing Cylinder bore Main bearing Crank journals Fuel pump lobe, reference only

Note:
NMMA developed the FCW specifications for four-stroke outboard engines, in response to the increasing need for a dedicated lubricant for this application, as opposed to the use of a traditional passenger car engine oil. Oils seeking NMMA FCW approval must meet a minimum of API SG in addition to responding to the corrosion inhibition and anti-wear requirements of an outboard engine.

OEM Specifications: General Motors dexos1™ and dexos2™

<table>
<tr><th rowspan="2">Requirements</th><th rowspan="2">Parameter</th><th rowspan="2">Units</th><th colspan="2">Limits</th></tr>
<tr><th>dexos1™
(Gasoline engines)</th><th>dexos2™
(Diesel engines)</th></tr>
<tr><td>Viscosity Classification Service Fill</td><td>SAE J300</td><td>SAE Grade</td><td>0W-20, 0W-30; 5W-20, 5W-30</td><td>0W-30, 5W-30; 0W-40, 5W-40</td></tr>
<tr><td>Viscosity Classification Factory Fill</td><td>SAE J300</td><td>SAE Grade</td><td>5W-30</td><td>5W-30</td></tr>
<tr><td rowspan="2">HTHS Viscosity</td><td rowspan="2">CEC-L-36-A-90, ASTM D4741</td><td rowspan="2">mPa.s</td><td>xW-20 ≥ 2.6</td><td rowspan="2">≥ 3.5</td></tr>
<tr><td>xW-30 ≥ 2.9</td></tr>
<tr><td rowspan="2">Low Temperature Cranking Viscosity</td><td rowspan="2">ASTM D5293</td><td rowspan="2">mPa.s</td><td>SAE 0W ≤ 6.200 @ -35 °C</td><td>SAE 0W ≤ 6.200 @ -35 °C</td></tr>
<tr><td>SAE 5W ≤ 6.600 @ -30 °C</td><td>SAE 5W ≤ 6.600 @ -30 °C</td></tr>
<tr><td>Low Temperature Pumping Visc. -40°C (no yield stress)</td><td>ASTM D4684</td><td>mPa.s</td><td>SAE 0W ≤ 40.000 SAE 5W Rate & Report</td><td>SAE 0W ≤ 40.000 SAE 5W Rate & Report</td></tr>
<tr><td>Low Temperature Pumping Visc. -35°C (no yield stress)</td><td>ASTM D4684</td><td>mPa.s</td><td>SAE 5W ≤ 40.000 SAE 0W Rate & Report</td><td>SAE 5W ≤ 40.000 SAE 0W Rate & Report</td></tr>
<tr><td>Evaporative Loss (NOACK)</td><td>CEC-L-40-A-93, ASTM D5800/A</td><td>% wt.</td><td>≤ 13.0</td><td>≤ 13.0</td></tr>
<tr><td>Sulphated Ash</td><td>DIN 51 575, ASTM D874</td><td>% wt.</td><td>≤ 1.0</td><td>≤ 0.8</td></tr>
<tr><td>Kin. Viscosity +100°C</td><td>DIN ISO 3104, ASTM D445</td><td>mm²/s</td><td>9.3 - <12.5</td><td>SAE 30: 9.3 - <12.5
SAE 40: 12.5 - 16.3</td></tr>
<tr><td>Total Base Number</td><td>DIN ISO 3771, ASTM D2896</td><td>mg KOH/g</td><td>≥ 6.0</td><td>≥ 6.0</td></tr>
<tr><td>Chlorine</td><td>ISO 15597 (XRF)</td><td>mg / kg</td><td>≤ 150</td><td>≤ 150</td></tr>
<tr><td>Phosphorus</td><td>DIN 51 363-3, ASTM D4951 (ICP) DIN 51 363-2, ASTM 6443 (XRF)</td><td>mg / kg</td><td>≤ 850</td><td>700-900</td></tr>
<tr><td>Sulphur</td><td>DIN 51 400-10, ASTM D4951 (ICP) EN ISO 14596, ASTM D2622 (XRF)</td><td>mg / kg</td><td>≤ 4500</td><td>≤ 3500</td></tr>
<tr><td>Foaming Tendency / Stability</td><td colspan="4"></td></tr>
<tr><td>Sequence I (24°C)</td><td rowspan="3">ASTM D892</td><td rowspan="3"></td><td colspan="2">10/0</td></tr>
<tr><td>Sequence II (94°C)</td><td colspan="2">50/0</td></tr>
<tr><td>Sequence III (24°C)</td><td colspan="2">10/0</td></tr>
<tr><td>HT Foaming Tendency</td><td colspan="4"></td></tr>
<tr><td>Sequence IV (150°C)</td><td>ASTM D6082</td><td>ml</td><td colspan="2">100/0</td></tr>
<tr><td>Ball Rust Test</td><td>ASTM D6557</td><td>avg. grey value</td><td>≥ 100</td><td></td></tr>
<tr><td>Corrosion Performance</td><td>LBCH02-45[ISO 6270-2 (2005) & prep. acc. ASTM D6594, 8.3]</td><td>merit</td><td>1</td><td>1</td></tr>
<tr><td rowspan="2">Shear Stability - Bosch Injector (kin. Viscosity at 100°C)</td><td rowspan="2">CEC-L-14-A-93, DIN ISO 3104, ASTM D664</td><td rowspan="2">mm²/s</td><td>SAE 20: ≥ 5.6</td><td>SAE 30: ≥ 9.3</td></tr>
<tr><td>SAE 30: ≥ 9.3</td><td>SAE 40: ≥ 12.5</td></tr>
</table>

OEM Specifications: General Motors dexos1™ and dexos2™

Requirements	Parameter	Units	Limits	
			dexos1™ (Gasoline engines)	dexos2™ (Diesel engines)
Elastomer Test / Materials				
ACEA Elastomer - RE1 (FPM)				
Hardness DIDC	CEC-L-39-T-96	points	-1 / +5	-1 / +5
Tensile strength		%	-40 / +10	-40 / +10
Elongation at rupture		%	-50 / +10	-50 / +10
Volume variation		%	-1 / +5	-1 / +5
ACEA Elastomer - RE4 (NBR)				
Hardness DIDC	CEC-L-39-T-96	points	-5 / +5	-5 / +5
Tensile strength		%	-20 / +10	-20 / +10
Elongation at rupture		%	-50 / +10	-50 / +10
Volume variation		%	-5 / +5	-5 / +5
ACEA Elastomer - AEM				
Hardness DIDC	VDA 675301	Shore A	-5 / +10	-5 / +10
Tensile strength		%	≥ -35	≥ -35
Elongation at rupture		%	≥ -50	≥ -50
Volume variation		%	-5 / +15	-5 / +15
SAE Elastomer - SAE J2643 ACM-1				
Hardness DIDC	ASTM D2240	points	-5 / +5	-5 / +5
Tensile strength	ASTM D412	%	-20 / +10	-20 / +10
Elongation at rupture	ASTM D412	%	-35 / ±0	-35 / ±0
Volume variation	ASTM D471	%	-5 / +5	-5 / +5
Change in tensile stress at 50% elongation	ASTM D412	%	-10 / +35	-10 / +35
SAE Elastomer - SAE J2643 VMQ-1				
Hardness DIDC	ASTM D2240	points	-20 / +10	-20 / +10
Tensile strength	ASTM D412	%	-45 / ±0	-45 / ±0
Elongation at rupture	ASTM D412	%	-40 / ±0	-40 / ±0
Volume variation	ASTM D471	%	-5 / +40	-5 / +40
Change in tensile stress at 50% elongation	ASTM D412	%	-50 / +10	-50 / +10
Engine Tests - ACEA Gasoline				
Peugeot TU5JP-L4 High Temperature Deposits Ring Sticking Oil Thickening CEC-L-88-T-02	Ring Sticking (each part)	merit	≥ 9.0	≥ 9.0
	Average Piston Varnish (6 elements)	merit	≥ RL216	≥ RL216
	Avg. Piston Varnish of RL216	merit	-	-
	Absolute Viscosity Increase at 40°C between min. and max. values during test	mm²/s	≤ 0.8 x RL216	≤ 0.8 x RL216
	Absolute Viscosity Increase with RL216	mm²/s	-	-
	Oil consumption	kg/test	RR	RR

OEM Specifications: General Motors dexos1™ and dexos2™

Requirements	Parameter	Units	Limits	
			dexos1™ (Gasoline engines)	dexos2™ (Diesel engines)
Engine Tests - ACEA Gasoline				
Sequence VG, Low Temperature Sludge, ASTM D6593	Average Engine Sludge	merit	≥ 8.3	≥ 8.3
	Rocker Cover Sludge	merit	≥ 8.5	≥ 8.5
	Average Piston Skirt Varnish	merit	≥ 7.5	≥ 7.5
	Average Engine Varnish	merit	≥ 8.9	≥ 8.9
	Compression Ring (Hot Stuck)	-	None	None
	Oil Screen Clogging	%	≤ 5	≤ 5
Peugeot TU3M Wear Test, Valve Train, Scuffing Wear, CEC-L-38-A-94	Average Cam Wear	µm	≤ 10	≤ 10
	Max. Cam Wear	µm	≤ 15	≤ 15
	Pad Merit (avg. of 8 pads)	merit	≥ 7.5	≥ 7.5
MB M111 Black Sludge, CEC-L-53-T-95	Average Engine Sludge	merit	≥ RL140	≥ RL140
	Average Engine Sludge of RL140	merit	Report	Report
	Average Cam Wear	µm	Rate & Report	Rate & Report
M111 Fuel Economy, CEC-L-54-T-96	Fuel Economy Improvement vs. RL 191(SAE 15W-40)	%	Report (If results are available)	≥ 2.0
Engine Tests - ILSAC Gasoline				
Sequence IIIG, High Temperature Deposits, Ring Sticking, Oil Thickening	Viscosity Increase at 100 hrs.	%	≤ 150	≤ 150
	Average weighted Piston Deposits	merit	≥ 4.5	≥ 4.5
	Hot stuck rings		none	none
	Average Cam plus Lifer wear	µm	≤ 60	≤ 60
	Oil Consumption	kg/test	Rate & Report	Rate & Report
Sequence IIIGA, ASTM D4684	Aged oil low temperature pumping viscosity	mPa.s	Meet requirement of original grade or next higher grade depending on results of ASTM D5293	Meet requirement of original grade or next higher grade depending on results of ASTM D5293
Sequence VIB, Fuel Economy, ASTM D6837	Fuel Economy Improvement 1	%	"xW-20 ≥ 2.3 xW-30 ≥ 1.8"	-
	Fuel Economy Improvement 2	%	"xW-20 ≥ 2.0 xW-30 ≥ 1.5"	-
Sequence VIII, Bearing Corrosion, ASTM D6709	Bearing weight loss	mg	≤ 26	≤ 26
	10 hr stripped viscosity	mm²/s	Stay-in-grade	Stay-in-grade

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OEM Specifications: General Motors dexos1™ and dexos2™

Requirements	Parameter	Units	Limits	
			dexos1™ (Gasoline engines)	dexos2™ (Diesel engines)
Engine Tests - ACEA Light Duty Diesel				
DV4TD, Medium Temperature Dispersivity, CEC-L-093	Absolute Viscosity Increase at +100°C and 6% soot	mm2/s	-	≤ 0.60 x RL223
	Absolute Viscosity Increase of RL223	mm2/s	-	-
OM 646 LA, Wear, Viscosity Stability, Oil Consumption, Draft CEC-L-099	Average Cam Wear	µm	-	tbd
	Viscosity Increase @ +40°C	%	-	tbd
	Bore Polishing	%	-	tbd
	Average Cylinder Wear	µm	-	tbd
	Oil Consumption	kg / test	-	tbd

OEM Specifications: General Motors dexos1™ and dexos2™

Requirements	Parameter	Units	Limits	
			dexos1™ (Gasoline engines)	dexos2™ (Diesel engines)
Engine Tests - GM				
Oil Release Test Gasol. Engines (OP1), GMPTE-T DUR020	Function Test, Oil pressure	bar	OK	OK
	Run in oil consumption	g/h	15-39	15-39
	Kin. Viscosity Increase @ +40°C, DIN ISO 3104	^%	≤ 130	≤ 130
	Total Acid Number after Test, ASTM D664	mgKOH/g	≤ 8.0	≤ 8.0
	Nitration after Test, DIN 51 453	A/cm	≤ 30	≤ 30
Aeration Test, GMPTE-T MEC024	Aeration rate of Candidate Oil vs. Reference Oil		Candidate Oil ≤ Reference Oil	Candidate Oil ≤ Reference Oil
	Maximum Difference in Aeration of aged Candidate Oil vs. Reference Oil	%	Aged Candidate oil - fresh Reference oil < +2	Aged Candidate oil - fresh Reference oil < +2
Valve Train Wear Test, Radionuclid - Method, GMPTE-T DUR021	Maximum Cam Wear	nm/h	≤ 5.0	≤ 5.0
	Maximum Tappet Wear	nm/h	≤ 2.0	≤ 2.0
Oil Release Test, Diesel Engines, GMPTE-T DUR019, Duration: 400 hrs.	Piston Ring Clearance 1st ring (avg.)	mm	-	≤ 0.05
	Piston Ring Clearance 2nd ring (avg.)	mm	-	≤ 0.15
	Piston Ring Clearance 3rd ring (avg.)	mm	-	≤ 0.08
	Con Rod Bearing Wear	μm	-	≤ 3
	Main bearing Wear (avg.)	μm	-	≤ 3
	Average Camshaft Wear (avg.)	μm	-	≤ 10
	Timing Chain Elongation	mm	-	≤ 0.8
	Duplex Chain Elongation	mm	-	≤ 0.7
	Balancer Chain Elongation	mm	-	≤ 1.5
	Piston Cleanliness	merit	-	RR
	Oil Consumption (max.)	g/h	-	≤ 15
	Blow-by (max.)	L/min	-	≤ 50
	Viscosity Increase @ +100°C and 2,5% wt. soot (DIN 51 452), DIN ISO 3104	mm2/s	-	≤ 6

OEM Specifications: Mercedes Benz Sheets For Passenger Car Engine Oils v.2009.1

Sheet Number	Units	229.1	229.3	229.31	229.5	229.51
Viscosity Requirements						
Mono / Multigrade		Multi	Multi	Multi	Multi	Multi
Viscosity Grades	SAE	acc. ACEA	0W-, 5W-, 10W-X	0W-, 5W-, 10W-X	0W-, 5W-, 10W-X	0W-, 5W-, 10W-X
Read-Across Guidelines						
MB Read-Across [1]	RA	yes	yes	yes	yes	yes
MB Package Pass [1]	RA	no	no	no	no	no
ACEA Oil Sequences required	ACEA	When any ACEA Ax, Bx, Cx or Ex oil sequence is claimed, then all tests within this oil sequence are mandatory				
API Oil Categories required, min.	API	-	-	-	-	-
DDC Oil Specification level	PGOS	-	-	-	-	-
Laboratory Tests						
Sulphated ash (DIN 51575 or ASTM D874)	%b.w	> 0,8 & ≤ 1,5	> 0,8 & ≤ 1,5	≤ 0,8	> 0,8 & ≤ 1,5	≤ 0,8
TBN (ISO 3771 or ASTM D2896 fresh oil)	mg KOH/g	6.0	7.0	6.0	8.0	6.0
TBN (ASTM D4739 fresh oil)	mg KOH/g	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report
Pour Point (ISO 3016 or ASTM D97)	°C	-27	-27	-27	-27	-27
Evaporative loss CEC-L-40-A-93, NOACK	%	13	13	12	10	10
Viscosity HTHS, CEC-L-36-A-90, i3 2nd edition	mPa.s	3.5	3.5	3.5	3.5	3.5
Zinc, min. (DIN 51391 -2/-3 or ASTM D5185 / 6443)	% b.w	0.04	0.04	0.04	0.04	0.04
Sulphur (DIN EN ISO 14596 or ASTM D5185 / 2622)	% b.w	Rate & Report	0.5	0.3	0.5	0.3
Phosphorus (DIN 51363 -2/-3 / ASTM D5185 / 4951)	% b.w	Rate & Report	0,05 - 0,11	0,05 - 0,09	0,05 - 0,11	0,05 - 0,09
Chlorine (DIN ISO 15597:2006-01 or ASTM D6443)	% b.w	Rate & Report	0,0150	0,0150	0,0150	0,0150

Note:

(1) Read-Across only according to MB Read-Across Guidelines for engine tests (based on latest ATC and ATIEL Code of Practice).
MB Package Pass only for Mineral Oils (SN, ATIEL Grp. I & II) and for SAE 15W-40, 20W-40, 15W-50, 20W-50.

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OEM Specifications: Mercedes Benz Sheets For Passenger Car Engine Oils v.2009.1

Sheet Number	Units	229.1	229.3	229.31	229.5	229.51
Laboratory Tests (continued)						
Oxidation Test (DAI In-house Method)						
Variation KV @ 100°C Relative	%	Equal or better than ref oil	Equal or better than ref oil	Equal or better than ref oil	Equal or better than ref oil	Equal or better than ref oil
Variation KV @ 100°C Absolute	mm2/s	Equal or better than ref oil	Equal or better than ref oil	Equal or better than ref oil	Equal or better than ref oil	Equal or better than ref oil
Oxidation DIN 51 453	A/cm	Equal or better than ref oil	Equal or better than ref oil	Equal or better than ref oil	Equal or better than ref oil	Equal or better than ref oil
SRV (Schwing Reib Verschleiß) (DAI Method) COF* after 3 hrs		< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
Deposit test (MTU, DIN 51535)	mg	-	-	-	-	-
TC Perfom. test CEC-TDG-L-100 - when ready	mg	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report
Sooted Oil MRV T11/11A ASTM D6896						
180 hr sample T-11/T11 A drain MRV	mPas	-	-	-	-	-
MRV Yield Stress	Pa	-	-	-	-	-
Corrosion Tendency ASTM D6594 (135°C, HTCBT)						
Cu, ppm increase	ppm					
Pb, ppm increase	ppm					
Copper strip rating						
Shear Stability CEC-L-14-93, ASTM D6278 / 7109		Pass @ 30 cyl	Pass @ 30 cyl	Pass @ 30 cyl	Pass @ 90 cyl	Pass @ 90 cyl
Kinematic Viscosity after 30 / 90 Pass Shearing @ 100°C	mm^2/s	Stay-in-grade	Stay-in-grade	Stay-in-grade	Stay-in-grade	Stay-in-grade
Foaming Tendency		Pass	Pass	Pass	Pass	Pass
Sequence I (24°C) ASTM D892 w/o option A	ml	10 / 0	10 / 0	10 / 0	10 / 0	10 / 0
Sequence II (94°C) ASTM D892 w/o option A	ml	50 / 0	20 / 0	20 / 0	20 / 0	20 / 0
Sequence III (24°C) ASTM D892 w/o option A	ml	10 / 0	10 / 0	10 / 0	10 / 0	10 / 0
Sequence IV (150°C) ASTM D6082	ml	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report
Related DBL	DBL	6615	6615	6615	6615	6615
Elastomer Compatibility (2)	DBL	Pass	Pass	Pass	Pass	Pass

Note: (2) Elastomer compatibility tests according to VDA 675301 and DBL 6674 / 6610 / 6615 with materials NBR34, AK6, ACM E7503, VMQ RE3-04 and EAM D8948-200.1. Limits according to DBL 6610 / 6615.

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OEM Specifications: Mercedes Benz Sheets For Passenger Car Engine Oils v.2009.1

Sheet Number	Units	229.1	229.3	229.31	229.5	229.51
Engine Tests (x = number of tests for Package Pass)						
M 271 (MB DL, Sludge) (3)						
Engine sludge avg. (with fuel batch 1), merit, min.		8.5	8.8	8.8	9.1	9.1
M 271 (MB DL, Wear, 250 hrs.) (3)		Pass	Pass	Pass	Pass	Pass
Cam wear inlet / outlet valve (avg. max. wear 8 cams)	µm	5,0 / 5,0	5,0 / 5,0	5,0 / 5,0	5,0 / 5,0	5,0 / 5,0
Piston Ring wear radial @ ring 1 / ring 2 (avg.) (4)	µm	5,0 / 12,0	5,0 / 12,0	5,0 / 12,0	5,0 / 12,0	5,0 / 12,0
Piston Ring wear axial @ ring 1 / groove 1 (avg.) (4)	µm	5,0 / 15,0	5,0 / 15,0	5,0 / 15,0	5,0 / 15,0	5,0 / 15,0
Ring sticking	Yes/No	no	no	no	no	no
Main Bearing wear (avg.) (4) / (max.)	µm	1,5 / 3,5	1,5 / 3,5	1,5 / 3,5	1,5 / 3,5	1,5 / 3,5
Conrod Bearing wear (avg.) (4) / (max.)	µm	1,5 / 3,5	1,5 / 3,5	1,5 / 3,5	1,5 / 3,5	1,5 / 3,5
Timing Chain wear (elongation)	%	0,25	0,25	0,25	0,25	0,25
Timing Chain wear (single chain link)	%	1,0	1,0	1,0	1,0	1,0
Timing Chain wear (single chain link), %, max.		1.0	1.0	1.0	1.0	1.0
M 111 (CEC SG-L-54)			Pass	Pass	Pass	Pass
Fuel economy improvement vs. RL 191 (15W-40)	%	-	1,0	1,0	1,7	1,7

Note:

(3) Re-rating by Daimler at EP/MOR for all related engine parts.

(4) The worst result (outlier result) will be replaced by the second worst to calculate the average to control outliers.

OEM Specifications: Mercedes Benz Sheets For Passenger Car Engine Oils v.2009.1						
Sheet Number	**Units**	**229.1**	**229.3**	**229.31**	**229.5**	**229.51**
OM 646 DE22 LA (CEC SG-L-099) (3)		Pass	Pass	Pass	Pass	Pass
Cam wear inlet (avg. max. wear 8 cams)	µm	120	110	110	100	100
Cam wear outlet (avg. max. wear 8 cams)	µm	155	140	140	120	120
Cylinder wear (avg. 4 cylinder)	µm	5,0	5,0	5,0	5,0	5,0
Bore polishing (13 mm) - max. value of 4 cyl.	%	4,0	3.5	3.5	3.0	3.0
Piston cleanliness (avg. 4 pistons)	merit	10,0	12.0	12.0	14.0	14.0
Engine sludge avg.	merit	8,5	8,7	8,7	9,0	9,0
Ring sticking	yes/no	no	no	no	no	no
Tappet wear inlet (avg. max. wear 8 cams)	µm	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report
Tappet wear outlet (avg. max. wear 8 cams)	µm	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report

Note:

(3) Re-rating by Daimler at EP/MOR for all related engine parts.

OEM Specifications: Mercedes Benz Sheets For Passenger Car Engine Oils v.2009.1

Sheet Number	Units	229.1	229.3	229.31	229.5	229.51
OM 646 DE22 LA (CEC SG-L-099) (3)		Pass	Pass	Pass	Pass	Pass
Bearing wear main / con rod bearing	µm	2,1/2,1	2,1/2,1	2,1/2,1	2,1/2,1	2,1/2,1
Piston ring wear axial @ ring 1 (4)	µm	10,4	10,4	10,4	8,7	8,7
Piston ring wear axial @ ring 2 (4)	µm	6,0	6,0	6,0	4.0	4.0
Piston ring wear axial @ ring 3 (4)	µm	5,0	5,0	5,0	3.0	3.0
Piston ring wear radial @ ring 1 (4)	µm	10,0	10,0	10,0	10,0	10,0
Piston ring wear radial @ ring 2 (4)	µm	12,0	12,0	12,0	12,0	12,0
Piston ring wear radial @ ring 3 (4)	µm	8,0	8,0	8,0	8,0	8,0
Timing chain wear (elongation)	%	0,4	0,4	0,4	0,4	0,4
Oil consumption	g/test	7000	7000	7000	7000	7000
Soot	%	4,0 - 7,0	4,0 - 7,0	4,0 - 7,0	4,0 - 7,0	4,0 - 7,0
Viscosity increase at 100°C	%	100	100	100	90	90

Note:

(3) Re-rating by Daimler at EP/MOR for all related engine parts.

(4) The worst result (outlier result) will be replaced by the second worst to calculate the average to control outliers.

OEM Specifications: Mercedes Benz Sheets For Passenger Car Engine Oils v.2009.1

Sheet Number	Units	229.1	229.3	229.31	229.5	229.51
NEFZ Dyno Test - when ready						
Chassis: W204 C250CDI / Engine: OM 651	%	tbd	tbd	tbd	tbd	tbd
Chassis: W204 C350CDI / Engine: OM 642	%	tbd	tbd	tbd	tbd	tbd
Chassis: W204 C200K / Engine: M271 ML18	%	tbd	tbd	tbd	tbd	tbd
Chassis: W204 C350CGI / Engine: M272 DE35	%	tbd	tbd	tbd	tbd	tbd
VW TDI (CEC-SG-L-078)		Pass	Pass	Pass	Pass	Pass
Piston cleanliness (avg.)	merit	RL 206 - 4	RL 206	RL 206	RL 206	RL 206
All other requirements as listed in ACEA B4 & C3-08	Pass	B3	B4	C3	B4	C3
VW PV 1449		-	Pass	Pass	Pass	Pass
VW 502.00 or PV 1449	Pass		Yes	Yes	Yes	Yes

OEM Specifications: BMW

Specification	BMW Longlife-01	BMW Longlife-01 FE	BMW Longlife-04
Viscosity grades	SAE 0W-30, 0W-40, 5W-30, 5W-40		
Based performance	ACEA A3/B4	ACEA A5/B5	ACEA C3
Kinematic Viscosity @ 100°C, cSt	As described per SAE J300	10.0 min.	As described per SAE J300
HTHS, mPa.s		3.0 min.	
BMW N52 (1)	required	required	required
BMW N42, wear test	required	required	required
BMW In-house Fuel Economy	-	required	-

Note:

(1) BMW N52 will be replaced by N20 test during 2012.

OEM Specifications: Volkswagen

Requirements	VW 501 01	VW 502 00	VW 504 00	VW 505 00	VW 505 01	VW 507 00
Minimum ACEA performance level	A3/B3	-	-	-	-	-
Viscosity grades	All grades	0W-30, 0W-40, 5W-30, 5W-40, 10W-30, 10W-40	5W-30 0W-30	5W/10W/15W 20W-X XW-30/40/50/60	0W-30, 0W-40 5W-30, 5W-40 10W-30, 10W-40	5W-30 0W-30
TBN, mg KOH/g (DIN ISO 3771) min.	7	7	-	-	7	-
Sulphated ash, % wt. (DIN 51575) max.	1.5	1.5	1.5	1.5	0.8	1.5
Phosphorus, % wt. (DIN 51363-3) min.	0.08	0.08 In combination with VW 505 00 0.07 In combination with VW 505 01		0.08	0.07	-
NOACK, %wt. (CEC-L-40-A-93) max.	13	13	11	13	13	11
High Temperature High Shear viscosity, 150°C, $10^6 s^{-1}$ (CEC-L-36-A-90) min.	3.5	3.5	3.5	3.5	3.5	3.5
Shear Stability (Bosch)						
Viscosity at 100°C, cSt, min.	Stay-in-grade	Stay-in-grade	9.3	Stay-in-grade	Stay-in-grade	9.3
Viscosity loss, %, max.	15.0	15.0	15	15.0	15.0	15
Seals compatibility (PV 3344)	See last page of this section					
Cam and Tappet (PV 5106)						
Cam pitting, µm, max.	20	20	20	20	20	20
Tappet pitting, µm, max.	20	20	20	20	20	20
Cam wear, µm, max.	75	75	75	75	75	75
Tappet wear, µm, max.	100	100	100	100	100	100
TU5 JP-L4 (CEC-L-88-T-02)		-	-	-	-	-
Piston ring sticking, points, min.	9.0	-	-	-	-	-
Piston varnish, merit, min.	RL 216	-	-	-	-	-
Viscosity increase @ 40°C, mm^2/s, max.	0.8 X RL216	-	-	-	-	-

OEM Specifications: Volkswagen

Requirements	VW 501 01	VW 502 00	VW 504 00	VW 505 00	VW 505 01	VW 507 00
M271 Sludge MB In-house Method						
Sludge rating, avg, merit	8.6	8.6	8.6	-	-	-
Differential pressure on oil filter, bar, max.	-	1.8	1.8	-	-	-
VW T4 (PV 1449)	-	-	-	-	-	-
Viscosity at 40°C at end of the test, mm²/s	-	$\leq 200 - V_{fresh\ oil} \times X$ (1)	$\leq 200 - V_{fresh\ oil} \times X$ (1)	-	-	-
Viscosity increase at 40°C, mm2/s	-	$\leq 130 - X$ (1)	$\leq 130 - X$ (1)			-
EOT TBN, mg KOH/g	-	$\geq 5 + TBN_{new\ oil} \times Y$ (2)	$\geq 5 + TBN_{new\ oil} \times Y$ (2)			-
Piston ring sticking, ASF	-	-	> 1 point	-	-	-
Piston cleanliness, merit	-	-	0 ASF	-	-	-
VW Fuel Economy Test (PV 1451), %, min.						
Fuel Economy, % (comparison with RL 191)	-	-	≥ 2.0 for 5W-30 and ≥2.5 for 0W-30	-	-	≥ 2.0 for 5W-30 and ≥2.5 for 0W-30
Fuel Economy of each phases, %	-	-	Phase 1: 3.0 ≤ FE ≤ 5.0 Phase 2: 1.0 ≤ FE ≤ 3.0 Phase 3: 0.0 ≤ FE ≤ 2.0	- -	- -	Phase 1: 3.0 ≤ FE ≤ 5.0 Phase 2: 1.0 ≤ FE ≤ 3.0 Phase 3: 0.0 ≤ FE ≤ 2.0
VW FSI (Direct Injection Gasoline) (PV 1481)	-	-	-	-	-	-
Engine oil for reference runs	-	-	FSI 5510	-	-	-
Weight increase of the 8 intake valves, g	-	-	$\leq MW_{Test\ bed\ (FSI\ 5510)}$ - 40%	-	-	-
VW ICTD (PV 1431)	-	-	-	-	-	-
Piston ring sticking, ASF	-	0	0	-	-	-
Piston cleanliness, merit	-	>1	>1	-	-	-

Note:

(1) X = Δv (reference oil) - Δv (candidate oil) with Δv being the variation of viscosity @ 40°C for the specified oil during the test.

(2) Y = ΔTBN (reference oil) - ΔTBN (candidate oil) with ΔTBN being the variation of TBN for the specified oil during the test.

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OEM Specifications: Volkswagen

Requirements (1)	VW 501 01	VW 502 00	VW 504 00	VW 505 00	VW 505 01	VW 507 00
VW TDi (PV 1452)	-	-	-	-	-	-
Piston cleanliness, merit, min.	-	-	-	-	RL 206 +s-3	RL 206 +s-3
Piston ring sticking	-	-	-	-	-	-
Average of all 1st rings, ASF, max.	-	-	-	-	1	1
Max. for any 1st ring, ASF, max.	-	-	-	-	1	1
Max. for any 2nd ring, ASF, max.	-	-	-	-	0	0
Diesel Particle Filter Test (2)	-	-	-	-	-	required
Baumusterprüfung (2)	-	-	-	-	-	-
RNT Wear Test	-	-	(650 hrs.)	-	(250 hrs.)	(650 hrs.)
Gasoline Engine Tests (2)	-	-	required	-	-	-
Diesel Engine Tests (2)	-	-	-	-	required	required

Note:

(1) Possible approval combinations are VW 501.01/505.00, VW 505.00, VW 502.00/505.00, VW 502.00/505.01, VW 504.00/507.00.

(2) Needs to be discussed with VW on a case by case basis.

Renault Service Fill RN0700 - Laboratory Tests (ACEA A3/B4 or A5/B5)

Requirements	Test Method	Properties	Unit	Limits
1.1 Viscosity grades		SAE J300 Latest active issue		0W-30/5W-30 0W-40/5W-40/10W-40
1.2 Shear stability	CEC-L-014-93 or ASTM D6278	Viscosity after 30 cycles @ 100°C	mm2/s	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 for 5W30 and ≥ 3.5 for 5W40
1.4 Evaporative loss	CEC-L-040-93 (NOACK)	Max weight loss after 1 hr @ 250°C	%	≤ 13.0
1.5 Sulphur (1)	ASTM D5185		%m/m	Report
1.6 Phosporous (1)	ASTM D5185		%m/m	Report
1.7 Sulphated ash	ASTM D874		%m/m	< 1.5
1.8 Chlorine	ASTM D6443		ppm m/m	Report
1.9 TBN	ASTM D2896		mgKOH/g	≥ 8.0
1.10 Oil / Elastomer compatibility	CEC-L-039-96 (3)	Max variation of characteristics after immersion for 7 days in fresh oil without pre-aging		As ACEA A5/B5-04
		Hardness DIDC	points	
		Tensile strength	%	
		Elongation at rupture	%	
		Volume variation	%	
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
1.13 Dynamic Viscosity CCS	ASTM D5293	Dynamic viscosity @ -20°C		See SAE J300
		Dynamic viscosity @ -30°C		
1.14 Pumpability limit temperature	ASTM D4684	Pumpability temperature	°C	<-30
1.15 Density	ISO 12185		kg/m3	Report
1.16 Open cup flash point	ISO 2592		°C	> 200
1.17 Pour point	ISO 3016		°C	Report
1.18 Copper corrosion (3 hrs. @ 150°C)	ISO 2160		Cotation	1a

Note:

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

(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: D8948/200.1 (150°C +/- 2°C)) + RE3, or complete requirements above + Daimler requirements for AEM.

Renault Service Fill RN0700 - Laboratory Tests (ACEA A3/B4 or A5/B5)

Requirements	Test Method	Properties	Unit	Limits
1.19 Anti-wear properties (60min-40daN)	D551994	Average diameter	mm	< 0.5
1.20 De-airing @ 40°C	NFT 60 149		min.	< 35
1.21 Water content	D50 1622		%	< 0.05
1.22 Type of base oil		Percent of each type (Gp I, Gp II, Gp III, GP IV, Gp V)	%	
1.23 Oxidation test TOC	D553099	Big Tube (150g), 170°C, 360ppm of Iron, 10L/hr air		
		Samples at 0, 8, 80, 96, 104 hrs		
		(TAN, PAI CO, Viscosity)		
		TAN @ 80 hrs	mgKOH/g	Report
		PAI CO @ 80 hrs.		< 400
		Variation of viscosity at 40°C @ 80 hrs	%	< 200
		Variation of viscosity at 1000°C @ 80 hrs	%	Report
1.24 MCT Cokefaction test	GFC Lu 27		Merit cotation 1	> 6.0
1.25 Auto-ignition temperature	ASTM E659		°C	Report
1.26 Storage Stability test*	See annex 1 (Official RN0700 Spec Sheet)	After a temperature cycle:		No cloudiness, No deposit, No salting-out
		Variation in viscosity @ 40°C	%	≤ 2
		Variation in HTHS	mPa.s	≤ 0.13
		After 2 months of storage		No cloudiness, No deposit, No salting-out
		Variation in viscosity @ 40°C	%	≤ 2
		Variation in HTHS	mPa.s	≤ 0.13
1.27 Compatibility with current Renault First Fill oils	See annex 2 (Official RN0700 Spec Sheet)			No cloudiness, No deposit, No salting-out
1.28 Compatibility with plastics*	See annex 3 (Official RN0700 Spec Sheet)			See annex 3 (RN0700 Spec Sheet)
1.29 Particular contamination*	ISO 4426	Measured with HIAC or manually with microscope on industrial batch	Code ISO	16/13
1.30 Filterability (PALL Method)*	ME 64120 A 014/--B	Filter KN (7µ > 1000)	kPa	< 0.05 after 5 min
				< 0.2 after 50 min

* Only for first fill oil

Renault Service Fill RN0700 - Engines Tests (ACEA A3/B4 or A5/B5)

Requirements	Test Method	Properties	Unit	Limits
2. ACEA Engine test				
2.1 High temperature deposits Ring sticking Oil thickening	CEC-L-088-A-02 (PSA TU5JP-L4) 72 hrs. test	Ring sticking (each part)	merit	≥ 9.0
		Piston varnish (6 elements, average of 4 pistons)	merit	≥ RL 216
		Absolute viscosity increase @40°C between min. and Max. values during test	mm2/s	≤ 0.8 * RL216
		Oil consumption	kg/test	Report
2.2 Low temperature sludge	ASTM D6593-00 (sequence VG) Under protocol and requirements for API(4)	Average engine sludge	merit	≥ 7.8
		Rocker cover sludge	merit	≥ 8.0
		Average piston skirt varnish	merit	≥ 7.5
		Average engine varnish	merit	≥ 8.9
		Comp. ring (hot stuck)		none
		Oil screen clogging	%	≤ 20
2.3 Valve train scuffing wear	CEC-L-038-A-94 (TU3M)	Cam wear average	µm	≤ 10
		Cam wear max.	µm	≤ 15
		Pad merit (avg. of 8 pads)	merit	≥ 7.5
2.4 Sludge	MB In-house Method (M271)	Average engine sludge (4)	merit	8.6
2.5 Fuel economy (5)	CEC-L-54-T-96 (M111FE)	Fuel economy improvement vs. reference oil RL 191 (15W40)	%	≥ 2.5 for 5W30
2.6 Medium temperature dispersivity	CEC-L-093-04 (DV4TD)	Absolute viscosity increase @ 100°C and 6% of soot	mm2/s	≤ 0.60 * RL233
		Piston merit	merit	≥ (RL233-2.5pts)
2.7 DI Diesel Piston cleanliness & Ring sticking	CEC-L-078-99 (VW TDI)	Piston cleanliness	merit	≥ RL206 for xW30 and ≥ RL206 - 3pts for xW40
		Ring sticking (rings 1 & 2)		
		Avg. of all 8 rings	ASF	≤ 1.2
		Max. for any 1st ring	ASF	≤ 2.5
		Max. for any 2nd ring	ASF	0.0
		EOT TBN (ISO 3771)	mg KOH/g	≥ 4.0
		EOT TAN (ASTM D664)	mg KOH/g	Report
2.8 Wear, Viscosity stability & Oil consumption	CEC-L-51-A-98 (OM 602 A)	Average Cam wear (new tappet)	µm	≤ 50.0
		Viscosity increase @ 40°C	%	≤ 90
		Bore polishing	%	≤ 7
		Average Cylinder wear	µm	≤ 20
		Oil consumption	kg/test	≤ 10

Note:

(4) The limits are based upon those applied in the US 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 improvements should be made.

Renault Service Fill RN0700 - Engines Tests (ACEA A3/B4 or A5/B5)

Requirements	Test Method	Properties	Unit	Limits
2.8 Wear	CEC-L-099-08 (OM 646 LA) Replacement of OM 602 A	Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 120
		Cam wear inlet (avg. max wear 8 cam) (6)	µm	≤ 100
		Cylinder wear (avg. 4 cyl) (6)	µm	≤ 5.0
		Bore polishing (13 mm) max. value of 4 cylinders (6)	%	≤ 3.0
		Tappet wear inlet (avg. max. wear 8 cams)	µm	Report
		Tappet wear outlet (avg. max. wear 8 cams)	µm	Report
		Piston cleanliness (avg. 4 pistons)	merit	Report
		Engine sludge avg.	merit	Report

Note:

(6) Not yet official CEC parameters.

Renault Service Fill RN0710 - Laboratory Test (ACEA A3/B4)

Requirements	Test Method	Properties	Unit	Limits
1.1 Viscosity grades		SAE J300 Latest active issue		0W-40/5W-40/ 5W-30 for first fill only
1.2 Shear stability	CEC-L-014-93 or ASTM D6278	Viscosity after 30 cycles @ 100°C	mm2/s	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 for 5W30 and ≥ 3.5 for 5W40
1.4 Evaporative loss	CEC-L-040-93 (NOACK)	Max. weight loss after 1 hr @ 250°C	%	≤ 11.0
1.5 Sulphur (1)	ASTM D5185		%m/m	Report
1.6 Phosporous (1)	ASTM D5185		%m/m	Report
1.7 Sulphated ash	ASTM D874		%m/m	< 1.5
1.8 Chlorine	ASTM D6443		ppm m/m	Report
1.9 TBN	ASTM D2896		mgKOH/g	≥ 8.0
1.10 Oil / Elastomer compatibility	CEC-L-039-96 (3)	Max. variation of characteristics after immersion for 7 days in fresh oil without pre-aging		As ACEA A5/B5-04
		Hardness DIDC	points	
		Tensile strength	%	
		Elongation at rupture	%	
		Volume variation	%	
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
1.13 Dynamic Viscosity CCS	ASTN D5293	Dynamic viscosity @ -20°C		See SAE J300
		Dynamic viscosity @ -30°C		
1.14 Pumpability limit temperature	ASTM D4684	Pumpability temperature	°C	<-30
1.15 Density	ISO 12185		kg/m3	Report
1.16 Open cup Flash point	ISO 2592		°C	> 200
1.17 Pour point	ISO 3016		°C	Report
1.18 Copper corrosion (3 hr @ 150°C)	ISO 2160		Cotation	1a

Note:

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

(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: D8948/200.1 (150°C +/- 2°C)) + RE3, or complete requirements according to 1.10 above + Daimler requirements for AEM.

Renault Service Fill RN0710 - Laboratory Test (ACEA A3/B4)

Requirements	Test Method	Properties	Unit	Limits
1.19 Anti-wear properties (60min-40daN)	D551994	Average diameter	mm	< 0.5
1.20 De-airing @ 40°C	NFT 60 149		min	< 35
1.21 Water content	D50 1622		%	< 0.05
1.22 Type of base oil		Percent of each type (Gp I, Gp II, Gp III, GP IV, Gp V)	%	
1.23 Oxidation test TOC	D553099	Big Tube (150g), 170°C, 360ppm of Iron, 10l /hr air		
		Samples at 0, 8, 80, 96, 104 hr		
		(TAN, PAI CO, Viscosity)		
		TAN @ 80 hrs	mgKOH/g	Report
		PAI CO @ 80 hrs.		< 400
		Variation of viscosity @ 40°C @ 80 hrs	%	< 200
		Variation of viscosity at 1000°C @ 80 hrs	%	Report
1.24 MCT Cokefaction test	GFC Lu 27		Merit cotation 1	> 6.0
1.25 Auto-ignition temperature	ASTM E659		°C	Report
1.26 Storage Stability test *	See annex 1 (Official RN0700 Spec Sheet)	After a temperature cycle:		No cloudiness, No deposit, No salting-out
		Variation in viscosity at 40°C	%	≤ 2
		Variation in HTHS	mPa.s	≤ 0.13
		After 2 months of storage		No cloudiness, No deposit, No salting-out
		Variation in viscosity at 40°C	%	≤ 2
		Variation in HTHS	mPa.s	≤ 0.13
1.27 Compatibility with current Renault First Fill oils	See annex 2 (Official RN0700 Specs Sheet)			No cloudiness, No deposit, No salting-out
1.28 Compatibility with plastics *	See annex 3 (Official RN0700 Specs Sheet)			See annex 3 (RN0700 Specs Sheet)
1.29 Particular contamination *	ISO 4426	Measured with HIAC or manually with microscope on industrial batch	Code ISO	16/13
1.30 Filterability (PALL Method)*	ME 64120 A 014/--B	Filter KN (7µ > 1000)	kPa	< 0.05 after 5 min
				< 0.2 after 50 min
1.31 Filterability (PALL Method)*	ME 64120 A 014/--B	FMA	Micron	≥ 12

* Only for first fill oil

Renault Service Fill RN0710 - Engines Tests (ACEA A3/B4)

Requirements	Test Method	Properties	Unit	Limits
2. ACEA Engine test				
2.1 High temperature deposits Ring sticking Oil thickening	CEC-L-088-A-02 (PSA TU5JP-L4) 72 hr test	Ring sticking (each part)	merit	≥ 9.0
		Piston varnish (6 elements, average of 4 pistons)	merit	≥ RL 216
		Absolute viscosity increase @ 40°C between min. and max. values during test	mm2/s	≤ 0.8 * RL216
		Oil consumption	kg/test	Report
2.2 Low temperature sludge	ASTM D6593-00 (sequence VG) under protocol and requirements for API(4)	Average engine sludge	merit	≥ 7.8
		Rocker cover sludge	merit	≥ 8.0
		Average piston skirt varnish	merit	≥ 7.5
		Average engine varnish	merit	≥ 8.9
		Comp. ring (hot stuck)		none
		Oil screen clogging	%	≤ 20
2.3 Valve train scuffing wear	CEC-L-038-A-94 (TU3M)	Cam wear average	µm	≤ 10
		Cam wear max	µm	≤ 15
		Pad merit (avg. of 8 pads)	merit	≥ 7.5
2.4 Sludge	MB In-house Method (M271)	Average engine sludge (4)	merit	8.6
2.5 Fuel economy (5)	CEC-L-54-T-96 (M111FE)	Fuel economy improvement vs. reference oil RL 191 (15W40)	%	≥ 2.5 for 5W30
2.6 Medium temperature dispersivity	CEC-L-093-04 (DV4TD)	Absolute viscosity increase @ 100°C and 6% of soot	mm2/s	≤ 0.60 * RL233 results
		Piston merit	merit	≥ (RL233-2.5pts)
2.7 DI Diesel Piston cleanliness & Ring sticking	CEC-L-078-99 (VW TDI)	Piston cleanliness	merit	≥ RL206
		Ring sticking (ring 1 & 2)		
		Avg. of all 8 rings	ASF	≤ 1.2
		Max. for any 1st ring	ASF	≤ 2.5
		Max. for any 2nd ring	ASF	0.0
		EOT TBN (ISO 3771)	mg KOH/g	≥ 4.0
		EOT TAN (ASTM D664)	mg KOH/g	Report
2.8 Wear, Viscosity stability & Oil consumption	CEC-L-51-A-98 (OM 602 A)	Average cam wear (new tappet)	µm	≤ 50.0
		Viscosity increase @ 40°C	%	≤ 90
		Bore polishing	%	≤ 7
		Average cylinder wear	µm	≤ 20
		Oil consumption	kg/test	≤ 10

Note:

(4) The limits are based upon those applied in the US 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 improvements should be made.

Renault Service Fill RN0710 - Engines Tests (ACEA A3/B4)				
Requirements	**Test Method**	**Properties**	**Unit**	**Limits**
2.8 Wear	CEC-L-099-08 (OM 646 LA) Replacement of OM 602 A	Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 120
		Cam wear inlet (avg. max. wear 8 cam) (6)	µm	≤ 100
		Cylinder wear (avg. 4 cyl) (6)	µm	≤ 5.0
		Bore polishing (13 mm) max. value of 4 cylinders (6)	%	≤ 3.0
		Tappet wear inlet (avg. max. wear 8 cams)	µm	Report
		Tappet wear outlet (avg. max. wear 8 cams)	µm	Report
		Piston cleanliness (avg. 4 pistons)	merit	Report
		Engine sludge avg.	merit	Report
3. Renault Engine Test				
3.1 Turbosludge Test F4Rt		IN DEVELOPMENT		TO BE DEFINED

Note:

(6) Not yet official CEC parameters.

Renault Service Fill RN0720 - Laboratory Test (ACEA C4)

Requirements	Test Method	Properties	Unit	Limits
1.1 Viscosity grades		SAE J300 Latest active issue		0W30/5W30/ 0W40/5W40
1.2 Shear stability	CEC-L-014-93 or ASTM D6278	Viscosity after 30 cycles @ 100°C	mm2/s	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	≥ 3.5
1.4 Evaporative loss	CEC-L-040-93 (NOACK)	Max. weight loss after 1hr @ 250°C	%	≤ 11.0
1.5 Sulphur (1)	ASTM D5185		%m/m	≤ 0.2
1.6 Phosporous (1)	ASTM D5185		%m/m	≤ 0.09
1.7 Sulphated ash	ASTM D874		%m/m	≤ 0.50
1.8 Chlorine	ASTM D6443		ppm m/m	Report
1.9 TBN	ASTM D2896		mgKOH/g	≥ 6.0
1.10 Oil / Elastomer compatibility	CEC-L-039-96 (3)	Max. variation of characteristics after immersion for 7 days in fresh oil without pre-aging		AS ACEA C3-04
		Hardness DIDC	points	
		Tensile strength	%	
		Elongation at rupture	%	
		Volume variation	%	
Renault Specifications		To be defined		
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
1.13 Dynamic Viscosity CCS	ASTN D5293	Dynamic viscosity @ -20°C		See SAE J300
		Dynamic viscosity @ -30°C		
1.14 Pumpability limit temperature	ASTM D4684	Pumpability temperature	°C	<-30
1.15 Density	ISO 12185		kg/m3	Report
1.16 Open cup flash point	ISO 2592		°C	> 200
1.17 Pour point	ISO 3016		°C	Report
1.18 Copper corrosion (3 hrs. @ 150°C)	ISO 2160		Cotation	1a

Note:

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

(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: D8948/200.1 (150°C +/- 2°C)) + RE3, or complete requirements according to 1.10 above + Daimler requirements for AEM.

Renault Service Fill RN0720 - Laboratory Test (ACEA C4)

Requirements	Test Method	Properties	Unit	Limits
1.19 Anti-wear properties (60min-40daN)	D551994	Average diameter	mm	< 0.5
1.20 De-airing @ 40°C	NFT 60 149		min.	< 35
1.21 Water content	D50 1622		%	< 0.05
1.22 Type of base oil		Percent of each type (Gp I, Gp II, Gp III, GP IV, Gp V)	%	
1.23 Oxidation test TOC	D553099	Big Tube (150g) 170°C, 360ppm of Iron, 10L/hrs. air		
		Samples at 0, 8, 80, 96, 136, 168 hrs		
		(TAN, PAI CO, Viscosity)		
		TAN @ 96 hrs	mgKOH/g	Report
		PAI CO @ 96 hrs.		< 400
		Variation of viscosity at 40°C @ 96 hrs	%	< 200
		Variation of viscosity at 1000°C @ 96 hrs.	%	Report
1.24 MCT Cokefaction test	GFC Lu 27		Merit cotation 1	> 6.0
1.25 Auto-ignition temperature	ASTM E659		°C	Report
1.26 Storage Stability test*	See annex 1 (Official RN0700 Spec Sheet)	After a temperature cycle		No cloudiness, No deposit, No salting-out
		Variation in viscosity at 40°C	%	≤ 2
		Variation in HTHS	mPa.s	≤ 0.13
		After 2 months of storage		No cloudiness, No deposit, No salting-out
		Variation in viscosity at 40°C	%	≤ 2
		Variation in HTHS	mPa.s	≤ 0.13
1.27 Compatibility with current Renault First Fill oils	See annex 2 (Official RN0700 Spec Sheet)			No cloudiness, No deposit, No salting-out
1.28 Compatibility with plastics*	See annex 3 (Official RN0700 Spec Sheet)			See annex 3 (Official RN0700 Spec Sheet)
1.29 Particular contamination*	ISO 4426	Measured with HIAC or manually with microscope on industrial batch	Code ISO	16/13
1.30 Filterability (PALL Method)*	ME 64120 A 014/--B	Filter KN (7µ > 1000)	kPa	< 0.05 after 5 min.
				< 0.2 after 50 min.
1.31 Filterability (PALL Method)*	ME 64120 A 014/--B	FMA	Micron	≥ 12

* Only for first fill oil.

Renault Service Fill RN0720 - Engines Tests (ACEA C4)

Requirements	Test Method	Properties	Unit	Limits
2. ACEA Engine test				
2.1 High temperature deposits Ring sticking Oil thickening	CEC-L-088-A-02 (PSA TU5JP-L4) 72 hrs. test	Ring sticking (each part)	merit	≥ 9.0
		Piston varnish (6 elements, avg. of 4 pistons)	merit	≥ RL 216
		Absolute viscosity increase @40°C between min. and max. values during test	mm2/s	≤ 0.8 * RL216
		Oil consumption	kg/test	Report
2.2 Low temperature sludge	ASTM D6593-00 (sequence VG) Under protocol and requirements for API(4)	Average engine sludge	merit	≥ 7.8
		Rocker cover sludge	merit	≥ 8.0
		Average piston skirt varnish	merit	≥ 7.5
		Average engine varnish	merit	≥ 8.9
		Comp. ring (hot stuck)		none
		Oil screen clogging	%	≤ 20
2.3 Valve train scuffing wear	CEC-L-038-A-94 (TU3M)	Cam wear average	μm	≤ 10
		Cam wear max.	μm	≤ 15
		Pad merit (avg. of 8 pads)	merit	≥ 7.5
2.4 Sludge	MB In-house Method (M271)	Average engine sludge (4)	merit	8.6
2.5 Fuel economy (5)	CEC-L-54-T-96 (M111FE)	Fuel economy improvement vs. reference oil RL 191 (15W40)	%	≥ 1.0 for xW30 grades
2.6 Medium temperature dispersivity	CEC-L-093-04 (DV4TD)	Absolute viscosity increase @ 100°C and 6% of soot	mm2/s	≤ 0.60 * RL233
		Piston merit	merit	≥ (RL233-2.5pts)
2.7 DI Diesel Piston cleanliness & Ring sticking	CEC-L-078-99 (VW TDI)	Piston cleanliness	merit	≥ RL206
		Ring sticking (rings 1 & 2)		
		Avg. of all 8 rings	ASF	≤ 1.0
		Max. for any 1st ring	ASF	≤ 1.0
		Max. for any 2nd ring	ASF	0.0
		EOT TBN (ISO 3771)	mg KOH/g	Report
		EOT TAN (ASTM D664)	mg KOH/g	Report
2.8 Wear, Viscosity stability & Oil consumption	CEC-L-51-A-98 (OM 602 A)	Average cam wear (new tappet)	μm	≤ 45.0
		Viscosity increase @ 40°C	%	≤ 70
		Bore polishing	%	≤ 4.5
		Average cylinder wear	μm	≤ 15
		Oil consumption	kg/test	≤ 10

Note:

(4) The limits are based upon those applied in the US 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 improvements should be made.

Renault Service Fill RN0720 - Engines Tests (ACEA C4)

Requirements	Test Method	Properties	Unit	Limits
2.8 Wear	CEC-L-099-08 (OM 646 LA) Replacement of OM 602 A	Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 120
		Cam wear inlet (avg. max. wear 8 cam) (6)	µm	≤ 100
		Cylinder wear (avg. 4 cyl) (6)	µm	≤ 5.0
		Bore polishing (13 mm) max. value of 4 cylinders (6)	%	≤ 3.0
		Tappet wear inlet (avg. max. wear 8 cams)	µm	Report
		Tappet wear outlet (avg. max. wear 8 cams)	µm	Report
		Piston cleanliness (avg. 4 pistons)	merit	Report
		Average engine sludge	merit	Report
3. Renault Engine Test				
3.1 LLR Renault In-house Test		Oil oxidation at the end of the test:		
		PAI CO		250
		Viscosity increase at 40°C	%	≤ 100
		Oil Consumption	g/h	Report
		Piston deposits:		
		Cotation	merit	
		Ring sticking		No sticking (for all rings)

Note:

(6) Not yet official CEC parameters.

PSA First-fill Specifications

Requirements	Limits			
	B71 2295	B71 2294	B71 2296	B71 2290
ACEA	A3/B3	A3/B3 or A3/B4	A3/B4 or A5/B5	C2
SAE J300	depending on geographical area and engine type			
Bosch shear stability CEC-L-14-A-88 30 cycl.	xW-30: 9 min. xW-40: 12 min. xW-50: 15 min.	Stay-in-grade	Stay-in-grade	10 cSt min.
HTHS	> 3,5	> 3,5	A5/B5: > 2.9 others: >3.5	2.9 min.
NOACK	5W: 13% max. > 5W: 15% max.	< 13	<13	<13
Sulphated ash	< 1.5%	A3/B3: < 1.5% A3/B4: <1.6%	< 1.6%	<0.8%
Seal compatibility	RE1 - RE5 according to ACEA 2008			
TBN ASTM D4739	EC: 8 min.	EC: 8 min.	EC: 8 min.	3 min.
TBN D2896	Outside EC: 10 min.	Outside EC: 10 min.	Outside EC: 10 min.	6 min.
Cokefaction PCT (24 hrs. @ 288°C)	8 min.	8 min.	8 min.	8 min.
Four Ball, wear	0,5 mm, 100kg min.			
Oxidation test	see separate sheet			
Engine performance level				
ACEA 2008	A3/B3	A3/B3 or A3.B4	A3/B4 or A5/B5	C2
DW 10TD PSA 845.04 Endurance test				
Viscosity increase	+ 3 cSt	+ 3 cSt	+ 3 cSt	+ 3 cSt
Piston deposits	10/10	10/10	10/10	10/10

PSA Service Oils - NIV.2 ACEA A3/B4 Specification 2010 71 2300

Bench Testing	Test Method	Properties	Unit	Limits
Viscosity Grades	SAE J300 Latest active issue			
Shear Stability	CEC-L-014-93 or ASTM D6278	Viscosity after 30 cycles @ 100°C	mm2/s	Stay-in-grade
Viscosity at high temperature and high shear rate	CEC-L-036-90	Viscosity at 150°C and $10^6 s^{-1}$ shear rate	mPa.s	≤ 3.5
Evaporative loss (NOACK)	CEC-L-040-93 (NOACK)	Max weight loss after 1hr @ 250°C	%	< 13
Sulphated ash	As ACEA 2008		%m/m	< 1.6 for A3/B4 oils
Aeration	Time for desertion + curve			
Oil/Elastomer compatibility	CEC-L-039-96	RE1, RE2, RE3, RE4 & RE5		As per ACEA 08
		Hardness DIDC	points	
		Tensile Strength	%	
		Elongation at rupture	%	
		Volume variation	%	
TBN.	ASTM 4739	Zone Europe	mgKOH/g	≥ 8
TBN.	ASTM 2896A	Outside Europe	mgKOH/g	≥ 10
Cokefaction PCT	24 hrs. @ 288°C	Pictures to be shown	merit	≥ 8
Cokefaction PCT	16 hrs. @ 305°C	Pictures to be shown	merit	Report
Four-Ball Test (limits to be targeted indication)	Wear (60 min, 1500rpm	Wear scare	mm	≤ 0.50
	EP (1 min, 1500rpm)	Load before welding	kg	≥ 100

PSA Service Oils - NIV.2 ACEA A3/B4 Specification 2010 71 2300

Bench Testing	Test Method	Properties	Unit	Limits
Oxidation stability (170°C) + 100ppm Iron	According to PSA CPBM_ CMPM07_1564	% KV variation @ 48 hrs	% cSt	Report
		% KV variation @ 72 hrs	% cSt	Report
		% KV variation @ 96 hrs	% cSt	-20% or +20% max. or max. of grade tested.
		% KV variation @ 120 hrs	% cSt	+250% max.
		PAI or TAN @ 72 hrs, 96 hrs. and 120 hrs		Report
		Insoluble content. Visual aspect and/or evaluation if deposits present	% (Deposits)	< 0.05
Oxidation stability (170°C) + 100ppm Iron + FAME in GOPSA10 LUB	According to PSA CPBM_ CMPM07_0961 (available at TOTAL ACS)	% KV variation @ 48 hrs	% cSt	Report
		% KV variation @ 72 hrs	% cSt	Report
		% KV variation @ 96 hrs	% cSt	-20% or +20% max. or max. of grade tested
		% KV variation @ 120 hrs	% cSt	Report
		PAI or TAN @ 72 hrs, 96 hrs. and 120 hrs		Report
		Insoluble content. Visual aspect and/or evaluation if deposits present	% (Deposits)	< 0.05
Nitro-oxidation stability (EHN 1%)	Performed by PSA. Accepted by PSA			
Durability and compatibility with E10 Fuel	Performed by PSA. Accepted by PSA			

PSA Service Oils - NIV.2 ACEA A3/B4 Specification 2010 71 2300

Engine Testing	Test Method	Limits
ACEA Engine Test		
All ACEA Engine Tests	See ACEA 08	ACEA C2 - 2008 level Following reports have to be sent to PSA: CEC-L-088-T-02 (TU5JP-L4) CEC-L-038-94 (TU3M) CEC-L-093-04 (DV4TD) Other reports have to be available on demand
Specific PSA Tests		
Endurance Test DW10 Engines	Method PSA 845.04 or PSA 01523_09_00234 if available	Complete report has to be sent to PSA: - Specific Criteria - Acceptability by PSA
If Read-Across rules are used, a document with oil references (oil reference and batch number used) and its components (oil bases: type and percentage, additive packages: name and percentage) have to be sent with the engine test reports.		

PSA Service Oils - Low SAPs ACEA C3 Specification 2010 B71 2297

Bench Testing	Test Method	Properties	Unit	Limits
Viscosity Grades	SAE J300 Latest active issue			
Shear Stability	CEC-L-014-93 or ASTM D6278	Viscosity after 30 cycles @ 100°C	mm2/s	≥ 10
Viscosity at high temperature and high shear rate	CEC-L-036-90	Viscosity at 150°C and $10^6 s^{-1}$ sheer rate	mPa.s	≤ 3.5
Evaporative loss (NOACK)	CEC-L-040-93 (NOACK)	Max weight loss after 1 hr @ 250°C	%	< 13
Sulphated ash	As ACEA 2008		%m/m	< 0.8
Aeration	Time for desertion + curve			
Oil / Elastomer compatibility	CEC-L-039-96	RE1, RE2, RE3, RE4 & RE5		As per ACEA 08
		Hardness DIDC	points	
		Tensile Strength	%	
		Elongation at rupture	%	
		Volume variation	%	
TBN.	ASTM 4739		mgKOH/g	≥ 3
TBN.	ASTM 2896A		mgKOH/g	≥ 6
Cokefaction PCT	24 hrs. at 288°C	Pictures to be shown	merit	≥ 8
Cokefaction PCT	16 hrs. at 305°C	Pictures to be shown	merit	Report
Four-Ball Test (limits to be targeted indication)	Wear (60 min, 1500rpm,	Wear scare	mm	≤ 0.50
	EP (1 min, 1500rpm)	Load before welding	kg	≥ 100

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PSA Service Oils - Low SAPs ACEA C3 Specification 2010 B71 2297

Bench Testing	Test Method	Properties	Unit	Limits
Oxidation stability (170°C) + 100ppm Iron	According to PSA CPBM_ CMPM07_1564	% KV variation @ 120 hrs	% cSt	Grade 30: -20% max. Grade 40: 9,3 cSt min.
		% KV variation @ 120 hrs	% cSt	+20% max. or max. of grade tested
		% KV variation @ 144 hrs	% cSt	+200% max.
		PAI or TAN @ 72 hrs, 96 hrs. and 120 hrs		Report
		Insoluble content. Visual aspect and/or evaluation if deposits present	% (Deposits)	< 0.05
Oxidation stability (170°C) + 100ppm Iron + FAME in GOPSA10 LUB	According to PSA CPBM_ CMPM07_0961 (available at TOTAL ACS)	% KV variation @ 48 hrs	% cSt	Report
		% KV variation @ 72 hrs	% cSt	Report
		% KV variation @ 96 hrs	% cSt	-20% or + 20% max. or max. of grade tested
		% KV variation @ 120 hrs	% cSt	Report
		PAI or TAN @ 72 hrs, 96 hrs. and 120 hrs		Report
		Insoluble content. Visual aspect and/or evaluation if deposits present	% (Deposits)	< 0.05
Nitro-oxidation stability (EHN 1%)	Performed by PSA. Accepted by PSA			
Durability and compatibility with E10 Fuel	Performed by PSA. Accepted by PSA			

PSA Service Oils - Low SAPs ACEA C3 Specification 2010 B71 2297

Engine Testing	Test Method	Limits
ACEA Engine Test		
All ACEA Engine Tests	See ACEA 08	ACEA C2 - 2008 level Following reports have to be sent to PSA: CEC-L-088-T-02 (TU5JP-L4) CEC-L-038-94 (TU3M) CEC-L-093-04 (DV4TD) Other reports have to be available on demand
Specific PSA Tests		
Endurance Test DW10 Engines	Method PSA 845.04 or PSA 01523_09_00234 if available	Complete report has to be sent to PSA: - Specific Criteria - Acceptability by PSA
If Read-Across rules are used, a document with oil references (oil reference and batch number used) and its components (oil bases: type and percentage, additive packages: name and percentage) have to be sent with the engine test reports.		

OEM Specifications: Mercedes Benz Sheets For Heavy Duty Diesel Engine Oils v.2009.1

Sheet Number	Units	226.9	228.0/.1	228.2/.3	228.31	228.5	228.51
Mono / Multigrade		multi	mono/multi	mono/multi	multi	multi	multi
Viscosity Grades							
Read-Across Guidelines							
MB Read-Across (1)	RA	no	yes	yes	yes	yes	yes
MB Package Pass (1)	RA	no	yes	yes	yes	no	no
ACEA Oil Sequences required	ACEA	When any ACEA Ax, Bx, Cx or Ex oil sequence is claimed, then all tests within this oil sequence are mandatory					
API Oil Categories required, min.	API	-	-	-	API CJ-4	-	-
DDC Oil Specification level	PGOS	-	-	-	(93K218)	-	-
Laboratory Tests							
Sulphated ash (DIN 51575 or ASTM D874)	%b.w	≤ 1,0	≤ 2,0	> 1,0 & ≤ 2,0	≤ 1,0	> 1,0 & ≤ 2,0	≤ 1,0
TBN (ISO 3771 or ASTM D2896 fresh oil)	mg KOH/g	-	6.0	8.0	7.0	12.0	7.0
TBN (ASTM D4739 fresh oil)	mg KOH/g	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report
Pour Point (ISO 3016 or ASTM D97)	°C	-27	R&R/-27	R&R/-27	-27	-27	-27
Evaporative loss CEC-L-40-A-93, NOACK	%	13	13	13	13	13	12
Viscosity HTHS, CEC-L-36-A-90, i3 2nd edition	mPa.s	3.5	3.5	3.5	3.5	3.5	3.5
Zinc, min. (DIN 51391 -2/-3 or ASTM D5185 / 6443)	% b.w	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report
Sulphur (DIN EN ISO 14596 or ASTM D5185 / 2622)	% b.w	Rate & Report	Rate & Report	Rate & Report	0.4	Rate & Report	0.3
Phosphorus (DIN 51363 -2/-3 / ASTM D5185 / 4951)	% b.w	Rate & Report	Rate & Report	Rate & Report	0,12	Rate & Report	0,08
Chlorine (DIN ISO 15597:2006-01 or ASTM D6443)	% b.w	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report	0,0150
Deposit test (MTU, DIN 51535)	mg	-	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report
TC Perfom. test CEC TDG-L-100 - when ready	mg	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report
Sooted Oil MRV T11/11A ASTM D6896		Pass					
180 hr sample T-11/T11 A drain MRV	mPas	-	-	-	18.000	-	-
MRV Yield Stress	Pa	-	-	-	35	-	-

Note:

(1) Read-Across only according to MB Read-Across Guidelines for engine tests (based on latest ATC and ATIEL Code of Practice).
MB Package Pass only for Mineral Oils (SN, ATIEL Grp. I & II) and for SAE 15W-40, 20W-40, 15W-50, 20W-50.

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OEM Specifications: Mercedes Benz Sheets For Heavy Duty Diesel Engine Oils v.2009.1

Sheet Number	Units	226.9	228.0/.1	228.2/.3	228.31	228.5	228.51
Corrosion Tendency ASTM D6594 (135°C, HTCBT)					Pass		
Cu, ppm increase	ppm	-	-	-	20	-	-
Pb, ppm increase	ppm	-	-	-	120	-	-
Copper strip rating		-	-	-	3	-	-
Shear Stability CEC-L-14-93, ASTM D6278 / 7109		Pass @ 30 cyl	Pass @ 30 cyl	Pass @ 30 cyl	Pass @ 90 cyl	Pass @ 90 cyl	Pass @ 90 cyl
KV. after 30 / 90 pass Shearing @ 100°C	mm^2/s	Stay-in-grade	Stay-in-grade	Stay-in-grade	Stay-in-grade	Stay-in-grade	Stay-in-grade
Foaming Tendency		Pass	Pass	Pass	Pass	Pass	Pass
Sequence I (24°C) ASTM D892 w/o option A	ml	10 / 0	10 / 0	10 / 0	10 / 0	10 / 0	10 / 0
Sequence II (94°C) ASTM D892 w/o option A	ml	50 / 0	50 / 0	20 / 0	20 / 0	20 / 0	20 / 0
Sequence III (24°C) ASTM D892 w/o option A	ml	10 / 0	10 / 0	10 / 0	10 / 0	10 / 0	10 / 0
Sequence IV (150°C) ASTM D6082	ml	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report
Related DBL	DBL	6610	6610	6610	6610	6610	6610
Elastomer Compatibility (2)	DBL	Pass	Pass	Pass	Pass	Pass	Pass

Note:

(2) Elastomer compatibility tests according to VDA 675301 and DBL 6674 / 6610 / 6615 with materials NBR34, AK6, ACM E7503, VMQ RE3-04 and EAM D8948-200.1. Limits according to DBL 6610 / 6615.

OEM Specifications: Mercedes Benz Sheets For Heavy Duty Diesel Engine Oils v.2009.1

Sheet Number	Units	226.9	228.0/.1	228.2/.3	228.31	228.5	228.51
OM 646 DE22LA (CEC-SG-L-099) (3)			Pass	Pass	Pass	Pass	Pass
Cam wear inlet (avg. max. wear 8 cams)	µm	-	120	110	110	100	100
Cam wear outlet (avg. max. wear 8 cams)	µm	-	155	140	140	120	120
Cylinder wear (avg. 4 cylinder), max.	µm	-	5.0	5.0	5.0	5.0	5.0
Bore polishing (13 mm) - max. value of 4 cyl.	%	-	4.0	3.5	3.5	3.0	3.0
Piston cleanliness (avg. 4 pistons), min.	merit	-	10.0	12.0	12.0	14.0	14.0
Engine sludge avg, min.	merit	-	8.5	8.7	8.7	9.0	9.0
Ring sticking	yes/no	-	no	no	no	no	no
Tappet wear inlet (avg. max. wear 8 cams)	µm	-	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report
Tappet wear outlet (avg. max. wear 8 cams)	µm	-	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report
Bearing wear main / con rod bearing (4), max.	µm	-	2,1/2,1	2,1/2,1	2,1/2,1	2,1/2,1	2,1/2,1
Piston ring wear axial @ ring 1 (4), max.	µm	-	10,4	10,4	10,4	8,7	8,7
Piston ring wear axial @ ring 2 (4), max.	µm	-	6,0	6,0	6,0	4.0	4.0
Piston ring wear axial @ ring 3 (4), max.	µm	-	5,0	5,0	5,0	3.0	3.0
Piston ring wear radial @ ring 1 (4), max.	µm	-	10,0	10,0	10,0	10,0	10,0
Piston ring wear radial @ ring 2 (4), max.	µm	-	12,0	12,0	12,0	12,0	12,0
Piston ring wear radial @ ring 3 (4), max.	µm	-	8,0	8,0	8,0	8,0	8,0
Timing chain wear (elongation), max.	%	-	0,4	0,4	0,4	0,4	0,4
Oil consumption, max.	g/test	-	7000	7000	7000	7000	7000
Soot, max.	%	-	4,0 - 7,0	4,0 - 7,0	4,0 - 7,0	4,0 - 7,0	4,0 - 7,0
Viscosity increase at 100°C, max.	%	-	100	100	100	90	90

Note:

(3) Re-rating by Daimler at EP/MOR for all related engine parts.

(4) The worst result (outlier result) will be replaced by the second worst to calculate the average to control outliers.

OEM Specifications: Mercedes Benz sheets For Heavy Duty Diesel Engine Oils v.2009.1

Sheet Number	Units	226.9	228.0/.1	228.2/.3	228.31	228.5	228.51
OM 501 LA Euro 5 (CEC-SG-L-101) (2) (5)		-	Pass	Pass	Pass	Pass	Pass
Piston cleanliness avg. min.	merit	-	14.0	17.0	17.0	26.0	26.0
Ring sticking 2. piston rings. max.	ASF	-	1.0	1.0	1.0	1.0	1.0
Engine sludge avg. min.	merit	-	9.0	9.0	9.0	9.4	9.4
General engine deposits avg. max.	demerit	-	3.0	2.0	2.0	2.0	2.0
Wear rating (visual) avg. max.	demerit	-	3.0	2.0	2.0	2.0	2.0
Bore polishing avg. max.	%	-	3.0	2.0	2.0	1.0	1.0
Cylinder wear avg. max.	mm	-	0,008	0,008	0,008	0,008	0,008
Turbocharger deposits. max.	demerit	-	3,0	2,0	2,0	2,0	2,0
TBN (ASTM D4739) @ end of test	mgKOH/g	-	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report
TAN (ASTM D664) @ end of test	mgKOH/g	-	Rate & Report	Rate & Report	Rate & Report	Rate & Report	Rate & Report
Specific oil consumption. max.	g/h	-	50,0	30,0	30,0	30,0	30,0

Note:

(2) Re-rating by Daimler at EP/MOR for all related engine parts.

(5) Only for xW-30 or 0W-40: Evaluation of bearing wear in a OM 501 LA engine with new crankshaft and pre-measured bearings. Re-rating by Daimler at TP/PHC.

OEM Specifications: Mercedes Benz Sheets For Heavy Duty Diesel Engine Oils v.2009.1

Sheet Number	Units	226.9	228.0/.1	228.2/.3	228.31	228.5	228.51
Mack T-12 EGR (6)		-	-	-	Pass	-	-
Mack Merit Rating, min.	merit	-	-	-	1000	-	-
Mack T-11 (ASTM D7156		-	-	-	Pass	-	-
Minimum TGA % Soot @ 4.0 cSt increase @ 100°C	%	-	-	-	3.5 / 3.4 / 3.3	-	-
Minimum TGA % Soot @ 12.0 cSt increase @ 100°C	%	-	-	-	6.0 / 5.9 / 5.9	-	-
Minimum TGA % Soot @ 15.0 cSt increase @ 100°C	%	-	-	-	6.7 / 6.6 / 6.6	-	-
Cummins ISM EGR (6)		-	-	-	Pass	-	-
Cummins Merit Rating, min.	merit	-	-	-	1000	-	-
Top Ring Weight Loss, max.	mg	-	-	-	100 / 100 / 100	-	-
Cummins ISB EGR		-	-	-	Pass	-	-
Average Slider Tappet Weight Loss	mg	-	-	-	100 / 108 / 112	-	-
Average Cam Lobe Wear, µm, max. 55	µm	-	-	-	55 / 59 / 61	-	-
Average Crosshead Weight Loss, max. R&R	mg	-	-	-	Rate & Report	-	-
Caterpillar C13 (6)		-	-	-	Pass	-	-
CAT Merit Rating, min.	merit	-	-	-	1000	-	-
Hot-stuck piston ring		-	-	-	none	-	-
Caterpillar 1N (ASTM D6750)		-	-	-	Pass	-	-
Weighted Demerits, max.	demerit	-	-	-	286.2 / 311.7 / 323.0	-	-
Top Groove Fill, max.	%	-	-	-	20 / 23 / 25	-	-
Top Land Heavy Carbon, max.	%	-	-	-	3 / 4 / 5	-	-
Oil Consumption (0-252 hrs.), max.	g/ kW h	-	-	-	0,5	-	-
Piston/ring/liner scuffing		-	-	-	none	-	-
Piston ring stick		-	-	-	none	-	-

Note:

(6) Detailed rating for Mack T-12, Cummins ISM and Cat C-13 according to API CJ-4 Merit Systems.

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OEM Specifications: Mercedes Benz Sheets For Heavy Duty Diesel Engine Oils v.2009.1

Sheet Number	Units	226.9	228.0/.1	228.2/.3	228.31	228.5	228.51
Sequence IIIF		-	-	-	Pass	-	-
EOT Kinematic Viscosity / % Incr. @ 40°C, max.		-	-	-	275%(MTAC)	-	-
Sequence IIIG (alternative to IIIF)		-	-	-	Pass	-	-
EOT Kinematic Viscosity / % Incr. @ 40°C, max.		-	-	-	150%(MTAC)	-	-
Roller Follower Wear Test ASTM D5596		-	-	-	Pass	-	-
Average pin wear, mils, max.	mils	-	-	-	0,30 /0,33 /0,36	-	-
or Average pin wear, µm, max.	µm	-	-	-	7,6 / 8,4 / 9,1	-	-
Engine Oil Aeration Test ASTM D6894		-	-	-	Pass	-	-
Oil aeration volume %, max. (MTAC)	%	-	-	-	8,0	-	-

Additional Notes

1. MWM 'B' tests are no longer required or accepted for new oil approvals. Approvals based on MWM 'B' tests invalid after 31 May 1996.

2. Evaporation loss, pour point and flash point limits:

	Evaporation Loss %. max.	Pour Point max. °C.	Flash Point (COC) min. °C.
SAE 10-W	15	-33	205
SAE 10W-40	13	-30	215
SAE 15W-40	13	-27	215
SAE 20W-20	13	-24	210
SAE 20W-30	13	-24	210
SAE 20W-50	13	-24	215
SAE 30	10	-18	220
SAE 40	10	-15	225

3. Base oil blends to meet requirements of MAN N699. Unconventional base oils may require additional testing.

OEM Specifications: MAN 270, MAN 271

Requirements	MAN 270	MAN 271
Performance Level: ACEA	E2-96	E2-96
SAE Viscosity Grades (J300) (1)	10W, 20W-20 20W-30, 30, 40	10W-40 15W-40 20W-50
Viscosity after Shear, mm^2/sec. min.	-	12.0(2)
HTHS, mPa.s, min.	-	3.5
Zinc, % wt. min.	0.08	0.08
Ethylene Glycol, % wt. max.	0.05	0.05
Foaming Tendency, ml, max	10/50/10	10/50/10
Foam Stability, ml, max	180/90/180	180/90/180
NBR-28 Compatibility (100°C/7 days)		
Change in Hardness (Shore A), max.	-10	-10
Tensile Strength, % change, max.	-20	-20
Elongation Change, % of %, max.	-30	-30
Volume Change, %	0/+10	0/+10
FPM-AK6 Compatibility (150°C/7 days)		
Change in Hardness (Shore A)	-5/+5	-5/+5
Tensile Strength, % change, max.	-30	-30
Elongation Change, % of %, max.	-40	-40
Volume Change, %	-2/+5	-2/+5

Note:
(1) Other viscosities need MAN agreement, 10W-40 must contain 25% of unconventional base stocks.
(2) 15 min. for SAE 20W-50.

OEM Specifications: MAN M 3275-1 (Multi-Grade Oils)

Requirements	Method/Units	MAN M 3275		
SAE J300 Viscosity Grades		5W-X	10W-X	15W-X
Density @ 15°C, g/ml	DIN 51757	To be reported		
Apparent viscosity, mPa.s	DIN 51377	according DIN 51511		
Viscosity @ 40°C, mm2/s	DIN 51562-1	To be reported		
Viscosity @ 100°C, mm2/s	DIN 51562-2	according DIN 51511		
HTHS Viscosity, mPa.s	CEC-L-36-A-90	≥ 3.5		
Viscosity after shear, mm2/s	DIN EN ISO 20844	xW-30: ≥ 9 and xW-40: ≥ 12		
NOACK Evaporation Loss, % mass	DIN 51581-1	≤ 13		
Flash Point (COC), °C	DIN EN ISO 2592	≥ 215		
Pour Point, °C, max	DIN ISO 3016	-40	-30	-27
TBN, mg KOH/g	DIN ISO 3771	To be reported		
TAN mg KOH/g	ASTM D664	To be reported		
Metals, Calcium, Magnesium and others % wt.	DIN 51399-1	To be reported		
Zinc, % wt.	DIN 51399-1	≥ 0.08		
Phosphorous, % wt.	DIN 51399-1	To be reported		
Nitrogen (additive)	Calculated	To be reported		
Sulphated Ash, % wt.	DIN 51575	≤ 2.0		
Ethylene Glycol, % wt.	DIN 51375-2	≤ 0.05		
Turbocharger deposits (MTU), mg	DIN 51535	To be reported		
Foaming (without option A)	ASTM D892			
Tendency I,II,III ml		≤ 10/50/10		
Stability I,II,III ml		0		
Seals test NBR 28, AK6		Pass		

OEM Specifications: MAN M 3275-1 (Multi-Grade Oils)

Requirements	Method/Units	MAN M 3275		
SAE J300 Viscosity Grades		5W-X	10W-X	15W-X
Engine Tests				
OM 501 LA (1)	CEC-L-101-08			
Piston cleanliness avg.	merit	≥ 17.0		
Wear rating (visual) avg.	demerit	≤ 3.0		
Bore polishing avg.	%	≤ 2.0		
General engine deposits avg.	demerit	≤ 2.0		
Engine sludge avg.	merit	≥ 9.0		
Turbocharger deposits	demerit	≤ 2.0		
Cylinder wear avg.	mm	≤ 0.008		
Ring sticking 2. piston rings	ASF	≤ 1.0		
Specific oil consumption	g/h	≤ 9		
TBN (ASTM D4739) @ end of test	mgKOH/g	Rate & Report		
TAN (ASTM D664) @ end of test	mgKOH/g	Rate & Report		
OM 646 LA (2) (3)	CEC-L-099-08			
Cam wear inlet (avg. max. wear 8 cams)	µm	≤ 110		
Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 140		
Cylinder wear (avg. 4 cylinder)	µm	≤ 5.0		
Bore polishing (13 mm) - max. value of 4 cyl.	%	≤ 3.5		
Tappet wear inlet (avg. max. wear 8 cams)	µm	Rate & Report		
Tappet wear outlet (avg. max. wear 8 cams)	µm	Rate & Report		
Viscosity increase at 100°C	%	≤ 100		
Oil consumption	g/test	≤ 7		

Note:

(1) MAN In-house Reference oil

(2) Deposits on intercooler or turbocharger with individual rating of 5 will not be accepted.

(3) Test run to be aborted if oil consumption exceeds 9.5 kg oil during the first 100 hrs.

OEM Specifications: MAN M 3275-2 (Mono-Grade Oils)

Requirements	Method/Units	MAN M 3275		
SAE J300 Viscosity Grades		30	40	50
Density @ 15°C, g/ml	DIN 51757	To be reported		
Apparent viscosity, mPa.s	DIN 51377	according DIN 51511		
Viscosity @ 40°C, mm2/s	DIN 51562-1	To be reported		
Viscosity @ 100°C, mm2/s	DIN 51562-2	according DIN 51511		
HTHS Viscosity, mPa.s	CEC-L-36-A-90	≥ 3.5		
Viscosity after shear, mm2/s	DIN EN ISO 20844	xW-30: ≥ 9 and xW-40: ≥ 12		
NOACK Evaporation Loss, % mass	DIN 51581-1	≤ 10		
Flash Point (COC), °C	DIN EN ISO 2592	≥ 215		
Pour Point, °C, max.	DIN ISO 3016	To be reported		
TBN, mg KOH/g	DIN ISO 3771	To be reported		
TAN mg KOH/g	ASTM D664	To be reported		
Metals, Calcium, Magnesium and others % wt.	DIN 51399-1	To be reported		
Zinc, % wt.	DIN 51399-1	≥ 0.08		
Phosphorous, % wt.	DIN 51399-1	To be reported		
Nitrogen (additve)	Calculated	To be reported		
Sulphated Ash, % wt.	DIN 51575	≤ 2.0		
Ethylene Glycol, % wt.	DIN 51375-2	≤ 0.05		
Turbocharger deposits (MTU), mg	DIN 51535	To be reported		
Foaming (without option A)	ASTM D892			
Tendency I,II,III ml		≤ 10/50/10		
Stability I,II,III ml		0		
Seals test NBR 28, AK6		Pass		

OEM Specifications: MAN M 3275-2 (Mono-Grade Oils)

Requirements	Method/Units	MAN M 3275		
SAE J300 Viscosity Grades		5W-X	10W-X	15W-X
Engine Tests				
OM 501 LA (1)	CEC-L-101-08			
Piston cleanliness avg.	merit	≥ 17.0		
Wear rating (visual) avg.	demerit	≤ 3.0		
Bore polishing avg.	%	≤ 2.0		
General engine deposits avg.	demerit	≤ 3.0		
Engine sludge avg.	merit	≥ 9.0		
Turbocharger deposits	demerit	≤ 2.0		
Cylinder wear avg.	mm	≤ 0.008		
Ring sticking 2. piston rings	ASF	≤ 1.0		
Specific oil consumption	g/h	≤ 9		
TBN (ASTM D4739) @ end of test	mgKOH/g	Rate & Report		
TAN (ASTM D664) @ end of test	mgKOH/g	Rate & Report		
OM 646 LA (2) (3)	CEC-L-099-08			
Cam wear inlet (avg. max. wear 8 cams)	µm	≤ 110		
Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 140		
Cylinder wear (avg. 4 cylinder)	µm	≤ 5.0		
Bore polishing (13 mm) - max. value of 4 cyl.	%	≤ 3.5		
Tappet wear inlet (avg. max. wear 8 cams)	µm	Rate & Report		
Tappet wear outlet (avg. max. wear 8 cams)	µm	Rate & Report		
Viscosity increase at 100°C	%	≤ 100		
Oil consumption	g/test	≤ 7		

Note:
(1) MAN In-house Reference oil.
(2) Deposits on intercooler or turbocharger with individual rating of 5 will not be accepted.
(3) Test run to be aborted if oil consumption exceeds 9.5 kg oil during the first 100 hrs.

OEM Specifications: MAN M 3277

Requirements	Method/Units	MAN M 3277	
SAE Viscosity Grades (J300)		**5W-X**	**10W-X**
Density @ 15°C, g/ml	DIN 51757	To be reported	
Apparent viscosity, mPa.s	DIN 51377	According DIN 51511	
Viscosity @ 40°C, mm2/s	DIN 51562-1	To be reported	
Viscosity @ 100°C, mm2/s	DIN 51562-2	According to DIN 51 511	
HTHS Viscosity, mPa.s	CEC-L-36-A-90	≥ 3.5	
Viscosity after shear, mm2/s	DIN EN ISO 20844	xW-30: ≥ 9 and xW-40: ≥ 12	
NOACK Evaporation Loss, % mass	DIN 51581-1	≤ 12	
Flash Point (COC), °C	DIN EN ISO 2592	≥ 215	
Pour Point, °C, max.	DIN ISO 3016	-40	-30
TBN, mg KOH/g	DIN ISO 3771	To be reported	
TAN mg KOH/g	ASTM D664	To be reported	
Metals, Calcium, Magnesium and others % wt.	DIN 51399-1	To be reported	
Zinc, % wt.	DIN 51399-1	To be reported	
Phosphorous, % wt.	DIN 51399-1	To be reported	
Nitrogen (additive), % wt.	Calculated	To be reported	
Sulphated Ash, % wt.	DIN 51575	≤ 2.0	
Ethylene Glycol, % wt.	DIN 51375-2	≤ 0.05	
Foaming (without option A)	ASTM D892		
Tendency I,II,III ml		≤ 10/50/10	
Stability I,II,III ml		0	
Turbocharger Deposit (MTU), mg	DIN 51535	≤ 120	
Seals test NBR 28, AK6		Pass	
Engine tests			
OM 501 LA (1)	**CEC-L-101-08**		
Piston cleanliness avg.	merit	≥ 26.0	
Wear rating (visual) avg.	demerit	≤ 2.0	
Bore polishing avg.	%	≤ 1.0	
General engine deposits avg.	demerit	≤ 2.0	
Engine sludge avg.	merit	≥ 9.4	
Turbocharger deposits	demerit	≤ 2.0	
Cylinder wear avg.	mm	≤ 0.008	
Ring sticking 2. piston rings	ASF	≤ 1.0	
Specific oil consumption	g/h	≤ 9	
TBN (ASTM D4739) @ end of test	mgKOH/g	Rate & Report	
TAN (ASTM D664) @ end of test	mgKOH/g	Rate & Report	
OM 646 LA (2)(3)	CEC-L-099-08		
Cam wear inlet (avg. max. wear 8 cams)	µm	≤ 100	
Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 120	
Cylinder wear (avg. 4 cylinder)	µm	≤ 5.0	
Bore polishing (13 mm) - max. value of 4 cyl.	%	≤ 3.0	
Tappet wear inlet (avg. max. wear 8 cams)	µm	Rate & Report	
Tappet wear outlet (avg. max. wear 8 cams)	µm	Rate & Report	
Viscosity increase at 100°C	%	≤ 90	
Oil consumption	g/test	≤ 7	

Notes:

(1) MAN In-house Reference oil.

(2) Deposits on intercooler or turbocharger with individual rating of 5 will not be accepted.

(3) Test run to be aborted if oil consumption exceeds 9.5 kg oil during the first 100 hrs.

OEM Specifications: MAN M 3277

Requirements	Method/Units	MAN M 3277	
SAE Viscosity Grades (J300)		**5W-X**	**10W-X**
MAN In-house Test	**D2876 LF04**	**M 3477** (1)	
Engine cleanliness			
Sludge	points	≥ 9.0	
Piston			
Piston cleanliness	points	≥ 51.6	
Piston Rings			
Piston Ring wear		Rate & Report	
Ring sticking	merit	≥ 9.7	
Cylinder Liners			
Bore polishing		Rate & Report	
Cylinder Wear	µm	≤ 2.1	
Engine Controls			
Rocker Arm wear		Rate & Report	
Tappets		Rate & Report	
Camshaft		Rate & Report	
Wear - Rocker Arm Axis Outlet	µm	≤ 2.2	
Wear - Valve Bridges Inlet	µm	≤ 7.3	
Wear - Valve Bridges Outlet	µm	≤ 6.4	
Bearing and Oil Pump			
Bearing and Oil Pump		Rate & Report	
Deposits			
Total Engine Deposits (2)	rating	≤ 3.0	
Used Oil Analysis (target values)			
Viscosity Increase at 4% Soot	%	max. 45	
Iron Content at 4% Soot	mg/kg	max. 180	
Oil Consumption (target value)			
Oil Consumption, total, 400 hrs	kg	max. 34.5 (3)	

Notes:

(1) MAN In-house Reference oil.

(2) Deposits on intercooler or turbocharger with individual rating of 5 will not be accepted.

(3) Test run to be aborted if oil consumption exceeds 9.5 kg oil during the first 100 hrs.

Afton CHEMICAL

OEM Specifications: MAN M 3477

Requirements		MAN M 3477	
SAE J300 Viscosity Grades		**0W-X / 5W-X**	**10W-X**
Density @ 15°C, g/ml	DIN 51757	To be reported	
Apparent viscosity, mPa.s	DIN 51377	According DIN 51511	
Viscosity @ 40°C, mm2/s	DIN 51562-1	To be reported	
Viscosity @ 100°C, mm2/s	DIN 51562-2	According to DIN 51 511	
HTHS Viscosity, mPa.s	CEC-L-36-A-90	≥ 3.5	
Viscosity after shear, mm2/s	DIN EN ISO 20844	xW-30: ≥ 9 and xW-40: ≥ 12	
NOACK Evaporation Loss, % mass	DIN 51581-1	≤ 12	
Flash Point (COC), °C	DIN EN ISO 2592	≥ 215	
Pour Point, °C, max.	DIN ISO 3016	-40	-30
TBN, mg KOH/g	DIN ISO 3771	To be reported	
TAN mg KOH/g	ASTM D664	To be reported	
Metals, Calcium, Magnesium and others % wt.	DIN 51399-1	To be reported	
Zinc, %wt.	DIN 51399-1	To be reported	
Phosphorous, % wt.	DIN 51399-1	≤ 0.08	
Bore, % wt.	DIN 51399-1	To be reported	
Nitrogen (additive)	Calculated	To be reported	
Sulphated Ash, % wt.	DIN 51575	≤ 1.0	
Sulphur Total (only additive)	DIN EN ISO 14596	≤ 0.3	
Ethylene Glycol, % wt.	DIN 51375-2	To be reported	
Turbocharger Deposit (MTU), mg	DIN 51535	≤ 120	
Oxidation stability, PDSC, min	CEC-L-85-T-99	≥ 100	
Foaming (without option A)	ASTM D892		
Tendency I,II,III ml		≤ 10/50/10	
Stability I,II,III ml		0	
Seals test NBR 28, AK6		Pass	

Afton CHEMICAL

OEM Specifications: MAN M 3477

Requirements	Method/Units	MAN M 3477	
SAE Viscosity Grades (J300)		**5W-X**	**10W-X**
MAN In-house Test	**D2876 LF04**	**M 3477 (1)**	
Engine cleanliness			
Sludge	points	≥ 9.0	
Piston			
Piston cleanliness	points	≥ 51.6	
Piston Rings			
Piston Ring wear		Rate & Report	
Ring sticking	merit	≥ 9.7	
Cylinder Liners			
Bore polishing		Rate & Report	
Cylinder wear	µm	≤ 2.1	
Engine Controls			
Rocker Arm wear		Rate & Report	
Tappets		Rate & Report	
Camshaft		Rate & Report	
Wear - Rocker Arm Axis Outlet	µm	≤ 2.2	
Wear - Valve Bridges Inlet	µm	≤ 7.3	
Wear - Valve Bridges Outlet	µm	≤ 6.4	
Bearing and Oil Pump			
Bearing and Oil Pump		Rate & Report	
Deposits			
Total Engine Deposits (2)	rating	≤ 3.0	
Used Oil Analysis (target values)			
Viscosity Increase at 4% Soot	%	max. 45	
Iron Content at 4% Soot	mg/kg	max. 180	
Oil Consumption (target value)			
Oil Consumption, total, 400 hrs	kg	max. 34.5 (3)	

Note:
(1) MAN In-house Reference oil.
(2) Deposits on intercooler or turbocharger with individual rating of 5 will not be accepted.
(3) Test run to be aborted if oil consumption exceeds 9.5 kg oil during the first 100 hrs.

OEM Specifications: MAN M 3575

Requirements	Method/Units	MAN M 3575	
SAE J300 Viscosity Grades		**XW-40**	**XW-30**
Density @ 15°C, g/ml	DIN 51757	To be reported	
Apparent viscosity, mPa.s	DIN 51377	According DIN 51511	
Viscosity @ 40°C, mm2/s	DIN 51562-1	To be reported	
Viscosity @ 100°C, mm2/s	DIN 51562-2	According to DIN 51 511	
HTHS Viscosity, mPa.s	CEC-L-36-A-90	≥ 3.5	
Viscosity @ 100 after shear, mm2/s	DIN EN ISO 20844	≥ 12.0	≥ 9.0
NOACK Evaporation Loss, % mass	DIN 51581-1	≤ 13	
Flash Point (COC), °C	DIN EN ISO 2592	≥ 215	
Pour Point, °C, max	DIN ISO 3016	-30	-27
TBN, mg KOH/g	DIN ISO 3771	To be reported	
TAN mg KOH/g	ASTM D664	To be reported	
Metals, Calcium, Magnesium and others % wt.	DIN 51399-1	To be reported	
Zinc, % wt.	DIN 51399-1	To be reported	
Phosphorous, % wt.	DIN 51399-1	≤ 0.12	
Bore, % wt.	DIN 51399-1	To be reported	
Nitrogen (additive)	Calculated	To be reported	
Sulphated Ash, % wt.	DIN 51575	≤ 1.0	
Sulphur Total (only additive)	DIN EN ISO 14596	≤ 0.4	
Ethylene Glycol, % wt.	DIN 51375-2	≤ 0.05	
Turbocharger Deposit (MTU), mg	DIN 51535	≤ 120	
Oxidation stability, PDSC, min.	CEC-L-85-T-99	≥ 100	
Foaming (without option A)	ASTM D892		
Tendency I,II,III ml		≤ 10/50/10	
Stability I,II,III ml		0	
Seals test NBR, FPM		Pass	

Afton CHEMICAL

OEM Specifications: MAN M 3575

Requirements	Method/Units	MAN M 3575	
SAE J300 Viscosity Grades		**XW-40**	**XW-30**
Engine Tests			
OM 501 LA (1)	**CEC-L-101-08**		
Piston cleanliness avg.	merit	≥ 17.0	
Wear rating (visual) avg.	demerit	≤ 3.0	
Bore polishing avg.	%	≤ 2.0	
General engine deposits avg.	demerit	≤ 3.0	
Engine sludge avg.	merit	≥ 9.0	
Turbocharger deposits	demerit	≤ 2.0	
Cylinder wear avg.	mm	≤ 0.008	
Ring sticking 2. piston rings	ASF	≤ 1.0	
Specific oil consumption	g/h	≤ 9	
TBN (ASTM D4739) @ end of test	mgKOH/g	Rate & Report	
TAN (ASTM D664) @ end of test	mgKOH/g	Rate & Report	
OM 646 LA (2)(3)	CEC-L-099-08		
Cam wear inlet (avg. max. wear 8 cams)	µm	≤ 110	
Cam wear outlet (avg. max. wear 8 cams)	µm	≤ 130	
Cylinder wear (avg. 4 cylinder)	µm	≤ 5.0	
Bore polishing (13 mm) - max. value of 4 cyl.	%	≤ 3.5	
Tappet wear inlet (avg. max. wear 8 cams)	µm	Rate & Report	
Tappet wear outlet (avg. max. wear 8 cams)	µm	Rate & Report	
Viscosity increase at 100°C	%	≤ 100	
Oil consumption	g/test	≤ 7	

Note:

(1) MAN In-house Reference oil.

(2) Deposits on intercooler or turbocharger with individual rating of 5 will not be accepted.

(3) Test run to be aborted if oil consumption exceeds 9.5 kg oil during the first 100 hrs.

OEM Specifications: Volvo Drain Specifications (VDS)

Performance Requirements:

API CD/CE

Viscosities shall be SAE 10W-30 or SAE 15W-40,
(SAE 10W-30 approval includes SAE 15W-40 but not vice versa).

Field Trial Requirements:

Minimum of three trucks required equipped with Volvo 12 litre intercooled engine. Field trial shall run for minimum 300,000 km. with 50,000 km. oil and filter changes. Test vehicles should be run on fuel with max. 0.7% by weight sulphur. Oil samples taken after 15,000, 30,000 and 50,000 km. of the change interval are tested for viscosity at 100˚C (ASTM D445). The values must not be less than:

9 cSt for SAE 10W-30
12 cSt for SAE 15W-40

TBN (ASTM D2896) value must not be less than 50% of the fresh oil value. Wear rate must not increase during the test. Oil consumption must not increase during the test. Bore polishing to be 300 cm^2 max. for the entire engine (100 cm^2 max. for any individual liner).

Other:

From January 1st 2012, no new VDS approvals will be issued by Volvo.

Approvals issued before January 1st 2012 will remain valid as long as the finished oil remains unchanged from the time of original approval.

OEM Specifications: Volvo Drain Specifications - 2 (VDS-2)

VDS-2 is the oil quality intended for Volvo Truck engines meeting the 1996 European (Euro 2) emission requirements.

Test Conditions:

Field test to involve a minimum of three trucks.
Test oil shall be minimum ACEA E3 or API CG-4 of viscosity 5W30, 5W40, 10W30, 10W40 or 15W40. Other viscosity grades can be accepted after agreement with Volvo.
Trucks used for the test to be equipped with Volvo TD 123 Series, 12 litre intercooled engine.

Field Test:

Field test to be run for minimum of 300,000 km. with 60,000 km. oil drain intervals.

Oil samples are taken after 15,000, 30,000, 45,000 and 60,000 km. of the drain interval and checked with respect to:

Viscosity at 100°C: (ASTM D445)	To be between 9 cSt. and 140% of the fresh oil value for XW-30 oils, and between 12 cSt. and 140% of the fresh oil value for XW-40 oils.
TBN (ASTM D4739):	≥ 50% of the fresh oil value, or ≥ 4, whichever is the greater.
TAN (ASTM D664):	Report
Pentane Insolubles:	Report
Wear Metals:	Concentration must not increase during the test.
Additive elements:	Report

In addition, oil and fuel consumption are measured during the test, oil consumption must not increase.

Inspection and Evaluation:

Upon completion of the field test, the following engine components are inspected: Pistons, Piston rings, Cylinder liners, Tappets, Camshaft, Rocker arms, Valves, Bearings. Cleanliness of covers and oil sump also inspected.

Limits VDS-2:	Average 2 trucks	Average 3 trucks	Max liner/piston per engine
Piston Cleanliness (1^{st} G + 2^{nd} G + 2^{nd} L)	30 min.	25 min.	-
Ring Riding (max. %)	35 max.	40 max.	40 max.
(avg. %)	20 max.	25 max.	-
Bore Polish (Total, cm^2)	120 max.	140 max.	35 max.

Other:

Read-across to other viscosity grades, base oils or viscosity modifiers are subject to discussion with Volvo.

From January 1st 2012, no new VDS-2 approvals will be issued by Volvo.

Approvals issued before January 1st 2012 will remain valid as long as the finished oil remains unchanged from the time of original approval.

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OEM Specifications: Volvo Drain Specifications - 3 (VDS-3)

VDS-3 is the oil quality intended for Volvo Truck Euro 3 engines.

Engine: D12C (any version > 400 hp) fitted to FH12 or FM12 trucks.

Field Test: European Long Haul Service only, two trucks minimum.

Test Length and Drain Intervals:

GVW up to 44t: 3 x 100,000 km oil drains with oil samples taken at 0, 25,000, 50,000, 75,000 and 100,000 km.

GVW over 44t: 4 x 75,000 km oil drains with oil samples taken at 0, 25,000, 50,000 and 75,000 km.

Field test to commence before engine reaches 50,000 km.

Limits: On completion of the field test, engine parts will be inspected for piston cleanliness, bore polish and ring wear.

Limits VDS-3:	**Average 2 trucks**	**Average 3 trucks**	**Max liner/piston per engine**
Piston Cleanliness (1^{st} G + 2^{nd} G + 2^{nd} L)	40 min.	35 min.	-
Ring Riding (max. %)	25 max.	30 max.	30 max.
(avg. %)	12 max.	15 max.	-
Bore Polish (Total, cm^2)	100 max.	120 max.	30 max.

Other Requirements:

For VDS-3 oils sold in Europe, ACEA E7 or DHD-1 performance to be demonstrated.

For VDS-3 oils sold outside Europe, DHD-1 performance to be demonstrated for global markets or API CI-4 for US market.

T8E limits as per Mack EO-M+ Mack T12 CI-4 limits + Seq. IIIF limits as per API CI-4 specification.

Engine Test Alternative:

The Volvo D12D engine test can now be run, in place of field trials to qualify an oil against the VDS-2 and VDS-3 specifications. The limits are similar, but VDS-3 requires a merit rating of 1250 in the Mack T12 engine test.

Criteria

		VDS-2	**VDS-3**
Piston cleanliness	points	≥ 40	≥ 40
Ring riding	%	Max. 50	Max. 50
Oil Consumption (total and final 100h)	g/h	Max. 35	Max. 35
Bore Polish (based on OM 501 LA Procedure)	cm^2	Max. 150	Max. 150
Other needed criteria	-	ACEA E7	ACEA E7 Merit of 1250 in Mack T12

OEM Specifications: Volvo Drain Specifications - 4 (VDS-4)

Requirements	Limits	
Viscosity grade	SAE 15W-30	SAE 15W-40
	97486-13	97486-15
Viscosity at 100 °C, mm^2/s, (cSt), min. max.	9.3 12.5	12.5 16.3
Viscosity at 40 °C, mm^2/s, (cSt)	Report	Report
Viscosity at 110 °C after shearing (90 cycles), mm^2/s (cSt), min.	9.3	12.5
HTHS after shearing by ASTM D7109 (90 cycles), mPas (cP), min.	3.4	3.9
Base oil viscosity at 100 °C, mm^2/s (cSt), min.	6.2	6.5
Density, kg/m^3	Report	Report
Flash point COC, °C	Report	Report
Pour point, °C	Report	Report
Evaporative loss (NOACK), %, max.	13	13
Sulphated ash, % w/w, max.	1.0	1.0
Phosphorus, % w/w, max.	0.12	0.12
Sulphur, % w/w, max.	0.4	0.4
Foaming tendency/stability		
Sequence I, ml/ml, max.	10/0	10/0
Sequence II, ml/ml, max.	20/0	20/0
Sequence III, ml/ml, max.	10/0	10/0
Corrosion		
Cu, ppm, max.	20	20
Pb, ppm, max.	120	120
Cu strip, max.	3	3

Note:

Grade SAE 10W-30 now allowed for VDS-4 but specifications have not been updated yet.

OEM Specifications: Volvo Drain Specifications - 4 (VDS-4)

Requirements		Limits	
Viscosity grade		SAE 15W-30	SAE 15W-40
Specifications number		97486-13	97486-15
Seal compatibility			
Nitrile			
	Volume, %	+5/-3	+5/-3
	Hardness, points	+7/-5	+7/-5
	Tensile strength, %	+10/-TMC 1006	+10/-TMC 1006
	Elongation at break, %	+10/-TMC 1006	+10/-TMC 1006
Silicone			
	Volume, %	+TMC 1006/-3	+TMC 1006/-3
	Hardness, points	+5/-TMC 1006	+5/-TMC 1006
	Tensile strength, %	+10/-45	+10/-45
	Elongation at break, %	+20/-30	+20/-30
Polyacrylate			
	Volume, %	+5/-3	+5/-3
	Hardness, Points	+8/-5	+8/-5
	Tensile strength, %	+18/-15	+18/-15
	Elongation at break, %	+10/-35	+10/-35
FKM			
	Volume, %	+5/-2	+5/-2
	Hardness, Points	+7/-5	+7/-5
	Tensile strength, %	+10/-TMC 1006	+10/-TMC 1006
	Elongation at break, %	+10/-TMC 1006	+10/-TMC 1006
Vamac G			
	Volume, %	+TMC 1006/-3	+TMC 1006/-3
	Hardness, Points	+5/-TMC 1006	+5/-TMC 1006
	Tensile strength, %	+10/-TMC 1006	+10/-TMC 1006
	Elongation at break, %	+10/-TMC 1006	+10/-TMC 1006

Note:

Grade SAE 10W-30 now allowed for VDS-4 but specifications have not been updated yet.

OEM Specifications: Volvo Drain Specifications - 4 (VDS-4)

Requirements	Limits	
Viscosity grade	SAE 15W-30	SAE 15W-40
Specifications number	97486-13	97486-15
Cummins ISM		
Merit, rating, min	1000	1000
Cross head % wt. loss at 3.9% soot, mg, max.	7.1	7.1
OFDP at 150 hrs, kPa, max	19	19
Avg. engine sludge, merit, min.	8.7	8.7
Avg. VAS % wt. loss at 3.9% soot, mg, max.	45	45
Cummins ISB		
Avg. Slider Tappet % wt. loss, mg, max	100 / 108 / 112	100 / 108 / 112
Avg. Cam Lobe Wear, µm, max.	50 / 53 / 55	50 / 53 / 55
Avg. Crosshead % wt. loss, mg, max.	Rate & Report	Rate & Report
Mack T11 (D7516)		
TGA soot at 4 cSt increase @ 100˚C %, min.	3.5 / 3.4 / 3.3	3.5 / 3.4 / 3.3
TGA soot at 12 cSt increase @ 100˚C %, min.	6.0 / 5.9 / 5.9	6.0 / 5.9 / 5.9
TGA soot at 15 cSt increase @ 100˚C %, min.	6.7 / 6.6 / 6.5	6.7 / 6.6 / 6.5
Mack T11A used MRV TP-1		
180 hr drain MRV, mPas, max.	18,000	18,000
MRV yield stress, Pa, max.	35	35
Mack T12		
Mack Merit rating, min.	1300	1300
Cylinder liner wear, µm, max.	21	21
Top ring weight. loss, mg, max.	105	105
Lead 0-300 hrs, ppm, max.	30	30
Delta Lead 250-300 hrs, ppm, max.	12	12
Oil consumption, g/h, max.	80	80
Caterpillar C13		
Merit rating, min	1000	1000
Delta Oil consumption, g/h, max.	31	31
Avg. Top Land Carbon, demerit, max.	35	35
Avg. Top Groove Carbon, demerit, max.	53	53
2nd Ring Top Face Carbon, demerit, max.	33	33
Sequence IIIG		
EOT KV increase (adjusted), %, max.	150	150
KV40 Increase Parameters		
100 hr (unadjusted) [B], %, max.	Report	Report
80 hr " [C], %	Report	Report
60 hr " [D], %	Report	Report
EOT Ratio [(B-C)/(C-D)], max.	2.5	2.5

Note:

Grade SAE 10W-30 now allowed for VDS-4 but specifications have not been updated yet.

OEM Specifications: Volvo Drain Specifications - 4 (VDS-4)

Requirements	Limits	
Viscosity grade	SAE 15W-30	SAE 15W-40
Specifications number	97486-13	97486-15
Roller Follower Wear Test (D5596)		
Avg. pin wear, µm, max.	7.6 / 8.4 / 9.1	7.6 / 8.4 / 9.1
Engine Oil Aeration Test		
Aeration, % volume, max.	8.0	8.0
Turbocharger Deposits		
Boost pressure loss and/or, %, max.	to be determined	to be determined
Deposit weight, mg, max.	to be determined	to be determined
D12D460		
Piston deposits, merit, min.	40	40
Ring riding, %, max.	50	50
Bore polish, cm^2, max	150	150
Oil consumption (400 h), g/h, max.	35	35
Oil consumption (final 100 h), g/h, max.	35	35
Fuel economy, D12D460, g/kW-h	≥ ref oil	-

Note:

Grade SAE 10W-30 now allowed for VDS-4 but specifications have not been updated yet.

OEM Category: MTU MTL 5044

Laboratory Tests

	Method	Monograde		Multigrade		
				1 to 3		3.1
Viscosity grade	SAE J300	SAE 30	SAE 40	5W-30 10W-30	5W-40 10W-40 15W-40	10W40
Appearance	Visual	Clear & free from insoluble material				
Kinematic viscosity@ 100°C, mm2/s	DIN 51562-1 or ASTM D445	9.3-12.5	12.5-16.3	9.3-12.5	12.5-16.3	12.5-16.3
Kinematic viscosity@ 40°C, mm2/s	DIN 51562-1 or ASTM D445	To be submitted				
Dynamic Viscosity, mPa.s	DIN 51377 or SAE J300	To be submitted				
High Temperature High Shear at 150°C, $10^6 s^{-1}$	CEC-L-36-A-90	-	-	≥ 3.5		
Viscosity Index, VI	ISO 2909 or ASTM D1298	To be submitted				
Specific gravity at 15°C, g/ml	DIN 51757 or ASTM D1298	To be submitted				
Shear Stability, Viscosity on shearing at 100°C, mm2/s	CEC-L-14-A-88, ASTM D6278, ASTM D7109, DIN 51382 30 cycles	-		Oil category 1 and 2 Stay-in-grade		
	ASTM D6278, ASTM D7109, 90 cycles			Oil category 2.1, 3, 3.1 Stay-in-grade		
Pour point, °C	ISO 3016 or ASTM D97	To be submitted				
Flash Point						
COC, °C	ISO 2592 or ASTM D92	≥ 225				
PM, °C	ISO 2719	To be submitted				
Distillation Loss at 250°C, NOACK Method	CEC-L-40-A-93 or DIN 51581	≤ 10		≤ 12		≤ 13
Sulfated Ash, % wt.	DIN 51575 or ASTM D874	1.0 to 2.0		1.0 to 2.0 Oil category 2.1 ≤ 1.0		≤ 1.0
TBN, mg KOH/g	ISO 3771 or ASTM D2896	≥ 8.0		Oil Category 1 and 2 ≥ 8.0 Oil category 2.1 ≥ 7.0 Oil category 3 ≥ 12.0		≥ 7.0
TAN, mg KOH/g	ASTM D664	To be submitted				
Chlorine, ppm	DIN ISO 15597	Less than 150				
Magnesium, % wt.	DIN 51391-3	To be submitted				
Phosphorous, % wt.	DIN 51363-2 DIN 51363-3	To be submitted		To be submitted Oil category 2.1 ≤ 0.12		≤ 0.08
Sulphur, % wt.	DIN 51400-1 DIN EN ISO 14596	To be submitted		To be submitted Oil category 2.1 ≤ 0.4		≤ 0.3

OEM Category: MTU MTL 5044

Laboratory Tests

		Method	Monograde	Multigrade	
				1 to 3	3.1
Calcium, % wt.		DIN 51391-3	To be submitted		
Zinc, % wt.		DIN 51391-3	≥ 0.035		
Nitrogen, % wt.		ASTM D3228 ASTM D5762	To be submitted		
Boron, % wt.		DIN 51443-2	To be submitted		
Molybdenum, % wt.		DIN 51379-2 DIN 51396-1	To be submitted		
Further additive elements, >0,01 %wt.		-	To be submitted		
Elastomer compatibility					
- Standard strip S 2 to Din 53504 -Test material SRE-NBR 28 to DIN 53538-3	Volume Change, %	DIN 53521 (168 +/- 2)h at (100 +/- 1) °C. Test agent volume : 80 * test body volume sealed container	0 to +10		
	Shore A hardness change		0 to -10		
	Tensile strength change, %		max. -20		
	Elongation Rupture Change %		max. -35		
- Standard strip S 2 to Din 53504 -Test material FKM-AK6 (Note1)	Volume Change, %	DIN 53521 (168 +/- 2)h at (150 +/- 2) °C. Test agent volume : 80 * test body volume sealed container	0 to +5		
	Shore A hardness change		-5 to +5		
	Tensile strength change, %		max. -50		
	Elongation Rupture Change %		max. -55		
Mechanical test in the FZG gear rig	Test load stage	DIN 51354-2 or CEC-L-07-A-95	min. 11		
Foaming test at 150°C, ml		ASTM D6082	max. 250-50		
Deposits only for multigrade oils, mg		DIN 51535	-	-	*max. 120

Note:

* Test limit should be the average of two tests, run in two different labs.

OEM Specifications: MTU MTL 5044 Engine Tests

Oil Category	1	2 / 2.1	3 / 3.1
OM 364 LA (1)			
Bore polishing, %	max. 3,5		
Piston cleanliness, merit	min. 40		
Cylinder wear, µm	max. 3,5		
Engine sludge, merit	min. 9,4		
Oil consumption, kg/test	max. 16		
OM 441 LA (1)			
Bore polishing, %	max. 3,0	max. 2,0	max. 2,0
Piston Cleanliness, merit	min. 20	min. 25	min. 40
Cylinder wear, µm	max. 8,0	max. 8,0	max. 8,0
Engine Sludge, merit	min. 9,0	min. 9,0	min. 9,0
Oil consumption, kg/test	max. 100g/h	max. 100g/h	max. 100g/h
Viscosity increase at 40°C, %	-	-	To be submitted
Wear rating, merit	max. 2,5	max. 2,5	max. 2,5
General engine deposit, merit	max. 3,0	max. 3,0	max. 3,0
Oil drain interval, hrs.	200	400	400
OM 501 LA (2)			
Piston cleanliness avg. merit	min. 14,0	min. 17,0	min. 26,0
Ring sticking 2. piston rings, ASF	max. 1,0	max. 1,0	max. 1,0
Engine sludge avg., merit	min. 9,0	min. 9,0	min. 9,4
General engine deposits avg., demerit	max. 3,0	max 2,0	max 2,0
Wear rating (visual) avg., demerit	max. 3,0	max. 3,0	max. 2,0
Bore polishing avg., %	max. 3,0	max. 2,0	max. 1,0
Cylinder wear avg., mm	max. 0,008	max. 0,008	max. 0,008
Turbocharger deposits, demerit	max. 3,0	max. 2,0	max. 2,0
TBN (ASTM D4739) @ end of test, mg KOH/g	Rate & Report	Rate & Report	Rate & Report
TAN (ASTM D664) @ end of test, mg KOH/g	Rate & Report	Rate & Report	Rate & Report
Specific oil consumption, g/hr	max 50,0	max 30,0	max 30,0
OM 611 (300 hrs.)			
Bore polishing, %	max. 4,0	max. 3,5	max. 3,0
Piston cleanliness, merit	min. 23	min. 25	min. 27
Cylinder wear (avg), µm	max. 7,0	max. 7,0	max. 5,2
Cam wear, µm	max. 140 (3) max. 155 (4)	max. 140 3) max. 155 (4)	max. 120 (3) max. 140 (4)
Engine sludge avg., merit	min. 8,0	min. 8,5	min. 9,0
Oil consumption, kg/test	max. 6	max. 6	max. 6
Viscosity increase at 40°C, %	max. 100	max. 100	max. 90

Note:
(1) OM 441 LA test as alternative to the OM 364 LA.
(2) OM 501 LA test as alternative to the OM 441 LA.
(3) Inlet valve.
(4) Outlet valve.

Afton CHEMICAL

OEM Specifications: MTU MTL 5044

Engine Tests

Oil Category	1	2 / 2.1	3 / 3.1
OM 646 DE22LA (CEC-SG-L-099) (5)			
Cam wear inlet (avg. max. wear 8 cams), µm	max. 120	max. 110	max. 100
Cam wear outlet (avg. max. wear 8 cams), µm	max. 155	max. 140	max. 120
Cylinder wear (avg. 4 cylinder), µm	max. 5	max. 5	max. 5
Bore polishing (13 mm) - max. value of 4 cyl., %	max. 4,0	max. 3,5	max. 3,0
Piston cleanliness (avg. 4 pistons), merit	min. 10,0	min. 12,0	min. 14,0
Engine sludge avg., merit	min. 8,5	min. 8,7	min. 9,0
Ring sticking, yes/no	no	no	no
Tappet wear inlet (avg. max. wear 8 cams),µm	Rate & Report	Rate & Report	Rate & Report
Tappet wear outlet (avg. max. wear 8 cams), µm	Rate & Report	Rate & Report	Rate & Report
Bearing wear main / con rod bearing, µm	max. 2,1 / 2,1	max. 2,1 / 2,1	max. 2,1 / 2,1
Piston ring wear axial @ ring 1*, µm	max. 10,4	max. 10,4	max. 8,7
Piston ring wear axial @ ring 2*, µm	max. 6,0	max. 6,0	max. 4,0
Piston ring wear axial @ ring 3*, µm	max. 5,0	max. 5,0	max. 3,0
Piston ring wear radial @ ring 1*, µm	max. 10,0	max. 10,0	max. 10,0
Piston ring wear radial @ ring 2*, µm	max. 12,0	max. 12,0	max. 12,0
Piston ring wear radial @ ring 3*, µm	max. 8,0	max. 8,0	max. 8,0
Timing chain wear (elongation), %	max. 0,4	max. 0,4	max. 0,4
Oil consumption, g/test	max. 7000	max. 7000	max. 7000
Soot, %	max. 4,0-7,0	max. 4,0-7,0	max. 4,0-7,0
Viscosity increase at 100°C, %	max. 100	max. 100	max. 90

Note:

(5) OM 646 DE 22 LA test as alternative to the OM 611.

* The worst result (outlier result) will be replaced by the second worst to calculate the average to control outliers.

OEM Specifications: Scania LDF 1&2 (DM 2004_181 2008-10-07, Issue 6)

Oil Specifications: Quality level must pass one or more of the following specifications ACEA E4, E6, E7, E9, API CJ-4

Number of vehicles: Minimum 3 vehicles with candidate oil to complete the test.

Test Engine Type: Approvals issued based on field testing with Euro III, IV and Euro V engine types

DT12 12, 420 HP and DT12 17, 480 HP both Euro IV engine types

DC13 10, 440 HP Euro V engine type

Scania recommends that engine mileage is not more than 60,000 km before start of test and that the existing oil is analysed to screen for proper operation before switching to the candidate oil.

Test Distance: 2 x 120,000 kms (Total 240,000kms) or 3 x 90,000 kms (Total 270,000 kms) depending on vehicle operation (medium or severe).

Alternatively for Low Ash Oil, 4 x 60,000 kms in severe operation is permitted. In this case, no approvals for LDF, LDF-2 or LDF-3 will be given.

Test Drain Periods: 120,000 ± 5,000 kms, 90,000 ± 5,000 kms or 60,000 ± 2,000 kms

Oil samples: Samples have to be taken at least at 0, 10.000, 30.000, 60.000, 90.000 and 120,000 kms for each drain intervals. For 4 x 60.000 kms samples have to be taken at 0, 10,000, 30,000, 45,000 and 60,000 kms

Component/System	Scania Specification	EURO III	EURO IV	EURO V
		Minimum Piston Rating average		
Piston	LDF-3	38	38	44
	LDF-2	35	35	38
	LDF	32	32	35
	Scania Low Ash	32*	32*	35*
		EOT TBN mg KOH/g ASTM D 4739		
Lubricant	LDF-3	7	7	8
	LDF-2	4	3.5	4
	LDF	3.5	2.5	3.5
	Scania Low Ash	-**	-**	-**
Component/System	**Parameter**	**Method**	**Criteria**	**Remarks**
Valves	Valve head deposit	CRC Manual No 20, p115	Average ≥ 8.0	-
Turbocharger	Deposits on compressor backplate	Scania Turbocharger deposit gauge, see appendix 5	≤ 0.15 mm thickness	-
	Diffuser	Scania Turbocharger deposit gauge, see appendix 5	≤ 0.15 mm thickness	-
Full required parameters and comments are mentioned in the Scania Specifications DM 2004_181, 2008-10-07, Issue 6				

OEM Specifications: Caterpillar

Bench Tests	Cat ECF-1a	Cat ECF-2	Cat ECF-3
	API CH-4 Only	API CI-4, CI-4 + CJ-4 Acceptable	CJ-4
SAE Grade	SAE J300, latest active issue		
Sulfated Ash, % wt. max.	1.5; 2x1P's if > 1.3	1.50	1.0
NOACK, % max (ASTM D5800)	18 (15W-40); 20 (10W-30)	15	13
HTHS Viscosity, mPa.s, min.	Stay-in-grade	3.5	3.5
Sulphur, % wt. max.	-	-	0.4
Phosphorus, % wt. max.	-	-	0.12
Mack T-11A 180 hrs. Used Oil MRV, mPa.s, max.	-	Use if CJ-4	25,000
Mack T-11A 180 hrs. Used Oil Yield Stress, max.	-	-	35
Mack T-10A 75 hrs. Used Oil MRV, mPa.s, max.	-	25,000	-
Mack T-10A 75 hrs. Used Oil Yield Stress, max.	-	35	-
Corrosion (D6594)			
Cu, ppm increase max.	20	20	20
Pb, ppm increase max.	120	120	120
Sn, ppm increase max.	50	50	-
Cu, Strip Rating, max.	3	3	3
Shear Stability (ASTM D7109)	by ASTM D6278	ASTM D6278 or D7109	
100˚C viscosity after 90 cycles, cSt	Stay-in-grade	Stay-in-grade	9.3 (xw30) 12.5 (xw40)
Foaming tendency / stability			
Sequence I (w/o Option A), ml, max.	10 / 0	10 / 0	10 / 0
Sequence II (w/o Option A), ml, max.	20 / 0	20 / 0	20 / 0
Sequence III (w/o Option A), ml, max.	10 / 0	10 / 0	10 / 0
Elastomer Compatibility			
API CJ-4 (D7216) Seal Compatibility	-	Use if CJ-4	Pass
API CJ-4 Seal Compatibility	-	Pass	-

OEM Specifications: Caterpillar

Engine Tests	Cat ECF-1a	Cat ECF-2	Cat ECF-3
	API CH-4 Only	API CI-4, CI-4 + CJ-4 Acceptable	CJ-4
Mack T-12 EGR (1)	-	Use if CJ-4	
Mack Merit Rating, min.	-	1000	1000
Cylinder liner wear, um max.	30.0 / 30.8 / 31.1	-	-
Top Ring % wt. Loss, mg. max.	120 / 132 / 137	-	-
Delta Pb, 250 - 300 hrs, ppm max.	65 / 75 / 79	-	-
Mack T-11 (D7156) (1)		Use if CJ-4 or CI-4+	
Min. TGA % Soot @ 4 cSt Increase, @ 100˚C, min.	-	-	3.5 / 3.4 / 3.3
Min. TGA % Soot @ 12 cSt Increase, @ 100˚C, min.	-	-	6.0 / 5.9 / 5.9
Min. TGA % Soot @ 15 cSt Increase, @ 100˚C, min.	-	-	6.7 / 6.6 / 6.5
Mack T-10 EGR (1)			
Merit Rating, min.	-	1000	-
Avg. Liner Wear, micron, max.	32 / 34 / 35	-	-
Avg. TRWL, mg, max.	150 / 159 / 163	-	-
EOT Used Oil/New Oil Pb Content, ppm max.	-	-	-
Pb Increased 250 - 300 hrs, ppm, max.	50 / 56 / 59	-	-
Avg. Oil Consumption, g/h, max.	-	-	-
Mack T-9 (ASTM D6483)			
Avg. liner wear, microns, max.	25.4 / 26.6 / 27.1	-	-
Avg. Top Ring Weight Loss, mg, max.	120 / 136 / 144	-	-
Pb Increase, ppm, max.	25 / 32 / 36	-	-
Mack T-8E (D5967-96 EXT)			
Relative Viscosity @ 4.8% Soot, cSt, max.	2.1 / 2.2 / 2.3	1.8 / 1.9 / 2.0	-
Viscosity Increase @ 3.8% Soot, cSt, max.	11.5 / 12.5 / 13.0	-	-

Note:

(1) For Cat ECF-1-a run either Mack T9, Mack T10, or Mack 12.
For Cat ECF-2 run either Mack T11 or Mack T12.

OEM Specifications: Caterpillar

Engine Tests	Cat ECF-1a	Cat ECF-2	Cat ECF-3
	API CH-4 Only	API CI-4, CI-4 + CJ-4 Acceptable	CJ-4
Cummins ISM EGR		Use if CJ-4	
Cummins Merit Rating, min.	-	-	1000
Top Ring % wt. Loss, mg max.	-	-	100
Crosshead Wear. Loss, mg max.	-	7.5 / 7.8 / 7.9	-
OFDP @ 150 hrs, kPa max.	-	55 / 67 / 74	-
Avg. Engine Sludge, merit min.	-	8.1 / 8.0 / 8.0	-
Cummins M-11 (D6838)			
Crosshead % wt. Loss, mg, max.	6.5 / 7.5 / 8.0	-	-
OFDP, kPa, max.	79 / 93 / 100	-	-
Sludge rating, merits, min.	8.7 / 8.6 / 8.5	-	-
Cummins M-11 EGR (2)			
Avg Crosshead % wt. Loss, mg, max.	-	20.0 / 21.8 / 22.6	-
Avg Top Ring % wt. Loss, mg, max.	-	Report	-
OFDP at 250 hr, kPa, max.	-	275 / 320 / 341	-
Avg Engine Sludge rating, merits at EOT, min.	-	7.8 / 7.6 / 7.5	-
Cummins ISB			
Avg. Slider Tappet % wt. Loss, mg, max.	-	-	100 / 108 / 112
Avg. Cam Lobe Wear, um. max.	-	-	55 / 59 / 112
Avg. Crosshead % wt. Loss, mg max.	-	-	Report
Caterpillar C13			
Caterpillar Merit Rating, min.	-	1000	1000
Hot stuck piston ring	-	None	None
Caterpillar 1R (3)			
Weighted Total Demerits, max.	-	382 / 396 / 402	-
Top Grove Carbon, Demerits, max.	-	52 / 57 / 59	-
Top Land Carbon, Demerits, max.	-	31 / 35 / 36	-
Initial Oil Consumption, g/hr, max.	-	13.1 / 13.1 / 13.1	-
Final Oil Consumption, g/hr, max.	-	I.O.C. + 1.8	-
Piston ring & liner scuffing, ring sticking	-	None	-
Caterpillar 1P (D6681)	-		
Weighted Total Demerits, max.	350 / 378 / 390	-	-
Top Groove Carbon, %, max.	36 / 39 / 41	-	-
Top Land Carbon, %, max.	40 / 46 / 49	-	-
Avg. Oil Consumption, g/hr, max.	12.4 / 12.4 / 12.4	-	-
Final Oil Consumption, g/hr, max.	14.6 / 14.6 / 14.6	-	-

Note:
(2) For ECF-2 run Cummins ISM or M11 EGR.
(3) For ECF-2, run Caterpillar 1R or 1P.

OEM Specifications: Caterpillar

	Cat ECF-1a	Cat ECF-2	Cat ECF-3
	API CH-4 Only	API CI-4, CI-4 + CJ-4 Acceptable	CJ-4
Caterpillar 1N (5)			
Weighted Demerits, max.	-	286.2 / 311.7 / 323.0	286.2 / 311.7 / 323.0
Top Grove Fill, % max.	-	20 / 23 / 25	20 / 23 / 25
Top Land Heavy Carbon, % max.	-	3 / 4 / 5	3 / 4 / 5
Oil Consumption, g/Kw-h max.)	-	0.5 / 0.5 / 0.5	0.5 / 0.5 / 0.5
Piston/ring/liner scuffing	-	None	None
Piston ring sticking	-	None	None
Caterpillar 1K (5)			
Weighted total demerits, max.	332 / 347 / 353	332 / 347 / 353	-
Top Groove Fill, %, max.	24 / 27 / 29	24 / 27 / 29	-
Top Land Heavy Carbon, % max.	4 / 5 / 5	4 / 5 / 5	-
Avg Oil Consumption, g/bhp-hr, max.	0.5 / 0.5 / 0.5	0.5 / 0.5 / 0.5	-
Piston ring and liner	None	None	-
Sequence IIIF (ASTM D6984)			
EOT KV % Increase @ 40°C, max.	-	275 (MTAC)	275 (MTAC)
Viscosity Increase @ 60 hrs, % max.	295 (MTAC)	-	-
Sequence IIIG (D7320) (4)			
EOT KV % Increased @ 40°C, max.	150 (MTAC)	150 (MTAC)	150 (MTAC)
RFWT (D5596)			
Avg. pin wear, mils max.	-	0.3 / 0.33 / 0.36	0.3 / 0.33 / 0.36
EOAT (D6894)			
Oil aeration volume, % max.	8.0 (MTAC)	8.0 (MTAC)	8.0 (MTAC)

Note:
(4) For Cat ECF-1-a, ECF-2 & ECF-3 run Sequence IIIF or Sequence IIIG.
(5) For Cat ECF-2 run Cat IN or Cat 1K.

OEM Specifications: Cummins

Bench Tests	Cummins 20078 CI-4 / CI-4 +	Cummins 20081 CJ-4
SAE Grade	SAE J300, latest active issue	SAE J300, latest active issue
Sulfated Ash, (D874) % wt. max.	1.85	1.00 / 1.02 / 1.03
TBN, mg KOH/g, m	10	Report
NOACK, (D5800) %, max.	15	13:xW40, 15:xW30
HTHS Viscosity, (D4683) mPa.s, min.	3.5	3.5
Sulphur, % wt. max.	-	0.4
Phosphorus, % wt. max.	-	0.12
Gelation Index (D5133), max.	12	12
Aeration Volume, % max.	8.0	8.0
Mack T-11A 180 hrs. Used Oil MRV, mPa.s, max.	-	18,000
Mack T-11A 180 hrs. Used Oil Yield Stress, max.	-	35
Mack T-10A 75 hrs. Used Oil MRV, mPa.s, max.	25,000	-
Mack T-10A 75 hrs. Used Oil Yield Stress, max.	35	-
Corrosion (D6594)		
Cu, ppm increase, max.	20	20
Pb, ppm increase, max.	120	120
Sn, ppm increase, max.	50	50
Cu strip rating, max.	3	3
Shear Stability (D7109)	by ASTM D6278	
100°C viscosity after 90 cycles, cSt	Stay-in-grade	Stay-in-grade
Foaming (ASTM D892)		
Sequence I (w/o Option A)	10 / 0	10 / 0
Sequence II (w/o Option A)	20 / 0	20 / 0
Sequence III (w/o Option A)	10 / 0	10 / 0
Elastomer Compatibility		
API CJ-4 (D7216) Seal Compatibility	-	Pass
API CI-4 Seal Compatibility	Pass	-
Engine Tests		
Mack T-12 EGR (1)		
Mack Merit rating, min.	-	1300
Avg Liner Wear, um, max.	-	20
Avg Top Ring % wt. Loss, mg, max.	-	105
Delta Pb, 0 - 300 hrs, ppm, max.	-	30
Delta Pb, 250 - 300 hrs, ppm, max.	-	12
Oil Consumption, g/hr, max.	-	80

Note:
(1) For Cummins 20078, run Mack T12 or T10.

OEM Specifications: Cummins

Bench Tests	Cummins 20078	Cummins 20081
	CI-4 / CI-4 +	CJ-4
Mack T-11 (ASTM D7156)		
TGA % Soot @ 4 cSt Increase, at 100˚C, min.	-	3.5
TGA % Soot @ 12 cSt Increase, at 100˚C, min.	-	6.0
TGA % Soot @ 15 cSt Increase, at 100˚C, min.	-	6.7
Mack T-10 EGR ([1])		
Merit Rating, min.	1000	-
Avg. Liner Wear, μm, max.	32	-
Avg. TRWL, mg, max.	158	-
EOT Used Oil/New Oil Pb Content, ppm max.	35	-
Pb Increase 250 - 300 hrs, ppm, max.	14	-
Average oil consumption, g/h, max.	65	
Mack T-8E (D5967-96 EXT)		
Relative Viscosity @ 4.8% Soot, cSt, max.	1.8 max	-
Viscosity increase @ 3.8% Soot, cSt, max.	Report	-
Cummins ISM		
Cummins Merit Rating, min.	-	1000
Crosshead % wt. Loss, mg max.	7.5	7.1
OFDP @ 150 hrs, kPa max.	55	19
Avg. Engine Sludge, merit min.	8.1	8.7
Avg. Adj. Screw % wt. Loss, mg max.	-	45
Cummins M-11 EGR		
Avg. crosshead % wt. Loss, mg, max.	20	-
Top Ring % wt. Loss, mg max.	175	-
OFDP @ 150 hrs, kPa max.	275	-
EOT Sludge Rating, merits, min.	7.8	-
JASO M354-2000		
Cam Lobe Wear, μm, max.	95	-
Cummins ISB EGR		
Avg. Slider Tappet % wt. Loss, mg max.	-	100 / 108 / 112
Avg. Cam Lobe Wear, mm, max.	-	50 / 53 / 55
Avg. Crosshead % wt. Loss, mg max.	-	Report
Caterpillar C13		
Caterpillar Merit Rating, min.	-	Report
Hot stuck piston ring	-	Report
Delta Oil Consumption, g/hr max.	-	Report
Avg. Top Land Carbon, Demerit max.	-	Report
Avg. Top Groove Carbon, Demerit max.	-	Report
2nd Ring Top Carbon, Demerit max.	-	Report

Note:
(1) For Cummins 20078, run Mack T12 or T10.

OEM Specifications: Cummins

Engine Tests	Cummins 20078	Cummins 20081
	CI-4 / CI-4 +	CJ-4
Caterpillar 1R		
Weighted Demerits, max.	382	-
Top Groove Carbon, Demerits, max.	52	-
Top Land Carbon, Demerits, max.	31	-
Initial Oil Consumption, g/h, max.	13.1	-
Final Oil Consumption, g/h, max.	IOC + 1.8	-
Piston ring and liner scuffing, ring sticking	None	-
Caterpillar 1N		
% wt. Demerits, max.	286	286.2
Top Groove Fill, % max.	20	20
Top Land Heavy Carbon, % max.	3	3
Oil Consumption, g/kW-h max.	0.5	0.5
Piston/ring/liner scuffing	None	None
Piston ring sticking	None	None
Caterpillar 1K		
Weighted Total Demerits, max.	332	-
Top Groove Fill, %, max.	24	-
Top Land Heavy Carbon, % max.	4	-
Avg Oil Consumption, g/bhp-hr, max.	0.5	-
Piston ring and liner scuffing	None	-
Sequence IIIF (2) (ASTM D6984)		
EOT KV % Increase @ 40˚C, max.	275	275
Cam + Tappet Wear, µm, max.	20	
Oil Consumption, Litres, max.	5.2	
Sequence IIIG (2)		
EOT KV % Increase @ 40˚C, max.	-	150
RFWT (D5596)		
Avg. pin wear, mils max.	0.3	0.3
EOAT (D6894)		

Note:
(2) For Cummins 20081, run sequence IIIF or sequence IIIG.

OEM Specifications: DDC

Bench Tests	DDC 93K214	DDC 93K215	DDC 93K218
SAE Grade	SAE J300, latest active issue	SAE J300, latest active issue	
Sulfated Ash, % wt. max.	2.0	2.0	1.0
Pour Point, ˚C max.	-25	-25	-25
NOACK, (D5800) % max.	13	18	13
HTHS Viscosity, mPa.s min.	4.2	3.5	Stay-in-grade
Sulphur, % wt. max.	-	-	0.4
Phosphorus, % wt. max.	-	-	0.12
Mack T-11A 180 hr Used Oil MRV, mPa.s, max.	-	-	18,000
Mack T-11A 180 hr Used Oil Yield Stress, max.	-	-	35
Mack T-10A 75 hr Used Oil MRV, mPa.s, max.	25,000	-	-
Mack T-10A 75 hr Used Oil Yield Stress, max.	35	-	-
Corrosion (ASTM D6594)			
Cu, ppm increase max.	20	20	20
Pb, ppm increase max.	120	120	120
Sn, ppm increase max.	50	50	
Cu, strip rating, max.	3	3	3
Shear Stability (ASTM D7109)			
100˚C Viscosity after 90 cycles, cSt	Stay-in-grade	Stay-in-grade	Stay-in-grade
HTHS after 90 cycle shear stability, mPa.s.	3.9	-	3.9
Foaming (ASTM D892)			
Sequence I (w/o Option A)	10 / 0	10 / 0	10 / 0
Sequence II (w/o Option A)	20 / 0	20 / 0	20 / 0
Sequence III (w/o Option A)	10 / 0	10 / 0	10 / 0
Elastomer Compatibility			
Related DBL Elastomer Compatibility	Pass CI-4 Test	-	-
CEC-L-39-T-96	-	Pass	-
API CJ-4 (D7216) Seal Compatibility	Report	-	Pass
API CI-4 Seal Compatibility	Compression Set	Pass	-
Engine Tests			
OM 441 LA Euro 2 (CEC-L-52-T-97)			
Avg Piston Cleanliness, merit min	25.0	25.0	25.0
Bore polishing, % max.	2.0	2.0	2.0
Specific Oil Consumption, kg/test max.	40	40	40
Boost pressure loss at 400 hrs, % max.	4	4	4

OEM Specifications: DDC

Engine Tests	DDC 93K214	DDC 93K215			DDC 93K218		
OM 501 LA Euro 5	-	-			**Pass**		
Piston cleanliness avg., min., merit					17.0		
Ring sticking 2. piston rings, max., ASF					1.0		
Engine sludge avg., min., merit					9.0		
General engine deposits avg., max., demerit					2.0		
Wear rating (visual) avg., max., demerit					2.0		
Bore polishing avg., % max.					2.0		
Cylinder wear avg., mm max.					0,008		
Turbocharger deposits, max., demerit					2,0		
TBN (ASTM D4739) @ end of test, mgKOH/g					Rate & Report		
TAN (ASTM D664) @ end of test, mgKOH/g					Rate & Report		
Specific oil consumption, max., g/hr					30,0		
Mack T-12 EGR(1)							
Mack Merit Rating, min.	1000	1000			1000		
Mack T-11 (ASTM D7156)							
TGA % Soot @ 4 cSt Increase, at 100°C, min.	-	-			3.5	3.4	3.3
TGA % Soot @ 12 cSt Increase, at 100°C, min.	6.00	-			6.0	5.9	5.9
TGA % Soot @ 15 cSt Increase, at 100°C, min.	-	-			6.7	6.6	6.6
Mack T-10 EGR(1)							
Merit Rating, min.	1000	1000			-		
Avg. Liner Wear, μm, max.	32	32	34	35	-		
Avg. Top Ring % wt. loss, mg, max.	158	150	159	163	-		
EOT Used Oil/New Oil Pb Content, ppm, max.	35	50	56	59	-		
Pb Increase 250 - 300 hrs, ppm, max.	14	-			-		
Avg. Oil Consumption, g/hr, max.	65	65			-		
Mack T-8E (D5967-96 EXT)							
Relative Viscosity @ 4.8% Soot, cSt, max.	-	2.1	2.2	2.3	-		
Viscosity Increase @ 3.8% Soot, cSt, max.	-	11.5	12.5	13.0	-		
Cummins ISM							
Cummins Merit Rating, min.	1000	1000			1000		
Crosshead % wt. loss, mg, max.	7.5	7.5			100		
Cummins M-11							
Crosshead % wt. loss, mg, max.	-	6.5	7.5	8.0	-		
OFDP, kPa, max.	-	79	93	100	-		
Sludge rating, merits, min.	-	8.7	8.6	8.5	-		

Note:

(1) For DDC 93K214 & 93K215, run either Mack T12 or T10.

(2) TBD = Limit to be determined.

N.R. = Not Required.

T.B.D. = To Be Determined.

OEM Specifications: DDC

Bench Tests	DDC 93K214	DDC 93K215	DDC 93K218		
Cummins M-11 EGR					
Crosshead % wt. Loss, mg, max.	20.0	-	-		
Top Ring % wt. Loss, mg, max.	175	-	-		
OFDP @ 250 hrs, kPa, max.	275	-	-		
Avg. Engine Sludge Rating, merits, min.	7.8	-	-		
JASO M354-2000					
Avg. Cam Lobe Wear, μm	-	95	-		
Cummins ISB					
Avg. Slider Tappet % wt. Loss, mg, max.	-	-	100	108	112
Avg. Cam Lobe Wear, μm, max.	-	-	55	59	61
Avg. Crosshead % wt. Loss, mg, max.	-	-	Report		

OEM Specifications: DDC

Bench Tests	DDC 93K214	DDC 93K215			DDC 93K218		
Caterpillar C13							
Caterpillar Merit Rating, min.	-	-			1000		
Hot stuck piston ring	-	-			None		
Caterpillar 1R							
Weighted Demerits, max.	382	-			-		
Top Groove Carbon, Demerits, max.	52	-			-		
Top Land Carbon, Demerits, max.	31	-			-		
Initial Oil Consumption, g/h, max.	13.1	-			-		
Final Oil Consumption, g/h, max.	IOC + 1.8	-			-		
Piston ring and liner scuffing, ring sticking	None	-			-		
Caterpillar 1P (D6681)							
Weighted Demerits, max.	-	350	378	390	-		
Top Groove Carbon, %, max.	-	36	39	41	-		
Top Land Carbon, %, max.	-	40	46	49	-		
Avg. Oil Consumption, g/hr, max.	-	12.4	12.4	12.4	-		
Final Oil Consumption, g/hr, max.	-	14.6	14.6	14.6	-		
Piston ring and liner scuffing	-	None			-		
Caterpillar 1N (D6750)							
Weighted Demerits, max.	286.2	-			286.2	311.7	323.0
Top Groove Fill, %, max.	20	-			20	23	25
Top Land Heavy Carbon, %, max.	3	-			3	4	5
Oil Consumption, g/kW-hr, max.	0.5	-			0.5		
Piston/ring/liner scuffing	None	-			None		
Piston ring sticking	None	-			None		
Caterpillar 1K							
Weighted Demerits, max.	332	332	347	353	-		
Top Groove Fill, %, max.	24	24	27	29	-		
Top Land Heavy Carbon, %, max.	4	4	5	5	-		
Avg. Oil Consumption, g/kW-hr, max.	0.5	0.5	0.5	0.5	-		
Piston ring and liner scuffing	None	None			-		
Sequence IIIF[2] (ASTM D6984)							
EOT KV % Increase @ 40˚C, max.	275	-			275		
Viscosity Increase @ 60 hrs, %, max.	-	295			-		
Oil Consumption, litres, max	5.2	-			-		
Sequence IIIG [2]							
EOT KV % Increase @ 40˚C, max.	-	-			150		
RFWT (D5596)							
Avg. pin wear, mils, max.	0.3	0.3	0.33	0.36	0.3	0.33	0.36
EOAT (D6894)							
Oil aeration volume, %, max.	8.0	8.0			8.0		

Note:
(2) For DDC 93K218, run either Sequence IIIF or IIIG.

OEM Specifications: Mack

Bench Tests	Mack EO-N PP 03	Mack EO-O/VDS-4		
SAE Grade	xW-40	15W-40		
Sulfated ash, % wt. max.	-	1.0		
TBN (D4739) min.	10	-		
NOACK, %, max.	13	13		
HTHS Viscosity @ 100˚C, cSt, min.	4.2	3.5		
Base Oil Viscosity, mPa.s	6.8	6.5		
Sulphur, % wt. max.	-	0.4		
Phosphorus, % wt. max.	-	0.12		
Pending CEC Turbo Deposit Test	-	T.B.D[1]		
Mack T-11A 180 hrs. Used Oil MRV, mPa.s	18,000	18,000		
Mack T-11A 180 hrs. Used Oil Yield Stress, max.	35	35		
Corrosion (D6594)				
Cu, ppm increase, max.	20	20		
Pb, ppm increase, max.	120	120		
Sn, ppm increase, max.	50	-		
Cu Strip Rating, max.	3	3		
Shear Stability (ASTM D7109)				
100˚C viscosity after 90 cycles, cSt	Stay-in-grade	Stay-in-grade		
HTHS after 90 cycle shear stability, min. mPa.s	3.9	3.9		
Foaming Tendency Stability				
Sequence I (w/o Option A), ml, max.	10/0	10/0		
Sequence II (w/o option A), ml, max.	20/0	20/0		
Sequence III (w/o Option A), ml, max.	10/0	10/0		
Elastomer Compatibility		-		
Related DBL Elastomer Compatibility	-	Pass		
Vamac API CJ-4 (D7216) Seal Compatibility	Pass	-		
Vamac API CI-4 Seal Compatibility	Pass	-		
HFRR Boundary Trace	Required	-		
Engine Tests				
Mack T-12 EGR				
Mack Merit Rating, min.	-	1300		
Cylinder liner wear, um, max.	-	21		
Top Ring % wt. loss, mg, max.	-	105		
Delta Pb, 0-300 hrs, ppm, max.	-	30		
Delta Pb, 250-300 hrs, ppm, max.	-	12		
Oil Consumption, g/hr, max.	-	80		
Mack T-11 (D7156)				
TGA Soot @ 4 cSt Increase, at 100˚C, %, min.	-	3.5	3.4	3.3
TGA Soot @ 12 cSt Increase, at 100˚C, %, min.	6.0	6.0	5.9	5.9
TGA Soot @ cSt Increase, at 100˚C, %, min.	-	6.7	6.6	6.5

Note:

(1) Limit to be determined.

Grade SAE 10W-30 now allowed for MACK EO-O / VDS-4 but specifications for it have not been updated yet.

OEM Specifications: Mack

<table>
<tr><th>Engine Tests</th><th>Mack EO-N PP 03</th><th colspan="3">Mack EO-O/VDS-4</th></tr>
<tr><td>Mack T-10 EGR</td><td></td><td colspan="3"></td></tr>
<tr><td>Merit Rating, min.</td><td>1500</td><td colspan="3">-</td></tr>
<tr><td>Avg. Liner wear, mm, max.</td><td>26</td><td colspan="3">-</td></tr>
<tr><td>Avg. Top Ring Weight Loss, mg, max.</td><td>120</td><td colspan="3">-</td></tr>
<tr><td>EOT Used Oil/New Oil Pb Content, ppm, max.</td><td>20</td><td colspan="3">-</td></tr>
<tr><td>Pb Increase 200-300 hrs, ppm, max.</td><td>10</td><td colspan="3">-</td></tr>
<tr><td>Pb Increase 250-300 hrs, ppm, max.</td><td>5</td><td colspan="3">-</td></tr>
<tr><td>Avg. Oil Consumption, g/h, max.</td><td>45</td><td colspan="3">-</td></tr>
<tr><td>EOT Oxidation - FTIR. max.</td><td>250</td><td colspan="3">-</td></tr>
<tr><td>Cummins ISM</td><td></td><td colspan="3"></td></tr>
<tr><td>Cummins Merit Rating, min.</td><td>-</td><td colspan="3">1000</td></tr>
<tr><td>Top Ring % wt. loss, mg, max.</td><td>-</td><td colspan="3">100</td></tr>
<tr><td>Crosshead % wt. loss, @ 3.9% soot mg, max.</td><td>-</td><td colspan="3">7.1</td></tr>
<tr><td>OFDP @ 150 hrs, kPa, max.</td><td>-</td><td colspan="3">19</td></tr>
<tr><td>Avg Engine Sludge, merit, min.</td><td>-</td><td colspan="3">8.7</td></tr>
<tr><td>Avg. Adj. Screw % wt. Loss, mg, max.</td><td>-</td><td colspan="3">45</td></tr>
<tr><td>Cummins M-11 EGR</td><td></td><td colspan="3"></td></tr>
<tr><td>Crosshead % wt. loss, mg, max.</td><td>12</td><td colspan="3">-</td></tr>
<tr><td>Top Ring % wt. loss, mg, max.</td><td>175</td><td colspan="3">-</td></tr>
<tr><td>OFDP at 250 hrs, kPa, max.</td><td>275</td><td colspan="3">-</td></tr>
<tr><td>Sludge rating, merits, min.</td><td>7.8</td><td colspan="3">-</td></tr>
<tr><td>Cummins ISB EGR</td><td></td><td colspan="3"></td></tr>
<tr><td>Avg. Slider Tappet % wt. loss, mg, max.</td><td>-</td><td>100</td><td>108</td><td>112</td></tr>
<tr><td>Avg. Cam Lobe Wear, um, max.</td><td>-</td><td>50</td><td>53</td><td>55</td></tr>
<tr><td>Avg. Crosshead % wt. loss, mg, max.</td><td>-</td><td colspan="3">Report</td></tr>
<tr><td>Caterpillar C13</td><td></td><td colspan="3"></td></tr>
<tr><td>Caterpillar Merit rating, min.</td><td>-</td><td colspan="3">1000</td></tr>
<tr><td>Hot stuck piston ring</td><td>-</td><td colspan="3">None</td></tr>
<tr><td>Delta Oil Consumption, g/hr, max.</td><td>-</td><td colspan="3">31</td></tr>
<tr><td>Avg. Top. Land Carbon, Demerit, max.</td><td>-</td><td colspan="3">35</td></tr>
<tr><td>Avg. Top. Groove Carbon, Demerit, max.</td><td>-</td><td colspan="3">53</td></tr>
<tr><td>2nd Ring Top Carbon, Demerit, max.</td><td>-</td><td colspan="3">33</td></tr>
<tr><td>Caterpillar 1R</td><td></td><td colspan="3"></td></tr>
<tr><td>Weighted Demerits, max.</td><td>382</td><td colspan="3">-</td></tr>
<tr><td>Top Groove carbon, Demerits, max.</td><td>52</td><td colspan="3">-</td></tr>
<tr><td>Top Land Carbon, Demerits, max.</td><td>31</td><td colspan="3">-</td></tr>
<tr><td>Initial Oil Consumption, g/hr, max.</td><td>13.1</td><td colspan="3">-</td></tr>
<tr><td>Final Oil Consumption, g/hr, max.</td><td>IOC + 1.8</td><td colspan="3">-</td></tr>
<tr><td>Piston ring and liner scuffing, ring sticking</td><td>None</td><td colspan="3">-</td></tr>
<tr><td>Sequence IIIF (ASTM D6984)</td><td></td><td colspan="3"></td></tr>
<tr><td>EOT KV % Increase @ 40˚C, max.</td><td>80</td><td colspan="3">-</td></tr>
</table>

Note:
Grade SAE 10W-30 now allowed for MACK EO-O / VDS-4 but specifications for it have not been updated yet.

OEM Specifications: Mack

Engine Tests	Mack EO-N PP 03	Mack EO-O/VDS-4		
Sequence IIIG				
EOT KV % Increase @ 40°C, max.	-	150		
KV 40°C Increase parameters				
100 hrs. unadjusted (B), %	-	Report		
80 hrs. unadjusted (C), %	-	Report		
60 hrs. unadjusted (D), %	-	Report		
EOT ratio [(B-C)/(C-D)] max.	-	2.5		
RFWT (D5596)				
Avg. pin wear, mils, max.	0.3	0.3	0.33	0.36
EOAT (D6894)				
Oil aeration volume, %, max.	8.0	8.0		
Volvo D12D460				
Piston Deposits, merit, min.	-	40		
Ring Riding, %, max.	-	50		
Bore Polish. cm^2, max.	-	150		
Oil Consumption (400 hrs.), g/hrs, max.	-	35		
Oil Consumption (final 100 hrs.), g/hrs, max.	-	35		
VD3 Approval	Required	-		

Note:
Grade SAE 10W-30 now allowed for MACK EO-O / VDS-4 but specifications for it have not been updated yet.

European OEM Seal Test Requirements For Automotive Engine Oils

				Test Conditions		Test Limits							
OEM	Specifications	Test Method	Elastomer	Temp (°C)	Time (Hrs.)	Change in Hardness (Shore A)	Tensile Strength at Break (N/mm²)	Change in Tensile Strength at yield (%)	Elongation at break (%)	Change in elongation at break (%)	Volume Change (%)	Weight Change (%)	Cracking
Mercedes Benz	229.1, 229.3, 229.31, 229.5, 229.52, 228.0/1, 228.2/3, 228.31, 228.5, 228.51	VDA 675301	NBR 34	100	168	-8+2	-	-20 max.	-	-35 max.	0/+10	-	-
			AK6	150	168	-5/+5	-	-50 max.	-	-55 max.	0/+5	-	-
			ACM E7503	150	168	-2/+6	-	-30 max.	-	-50 max.	-3/+10	-	-
			EAM D8948-200	150	168	-5/+10	-	-35 max.	-	-50 max.	-5/+15	-	-
Volkswagen	505.00	PV 3344	AK6	150	3 X 94	-	8 min.	-50 max.	160 min.	-50 max.	-	-	No Cracks
	501.01 502 505.01	PV 3344	AK6	150	3 X 94	-	8 min.	-50 max.	160 min.	-50 max.	-	-	No Cracks
			ACM	150	168	-5/+6	-	-30 max.	-	-30 max.	-	-2/+4	-
			VAMAC	150	168	-8/+8	-	-30 max.	-	-30 max.	-	-3/+15	-
	504.00 507.00	PV 3344	AK6	150	168	-	7 min.	-60 max.	160 min.	-50 max.	-	-	No Cracks
			ACM	150	500	-4/+10	-	-40 max.	-	-40 max.	-	-2/+6	-
			VAMAC	150	500	-4/+10	-	-40 max.	-	-40 max.	-	-3/+10	-
MAN	270, 271 M3275 M3277	DIN 53521	NBR 28	100	168	-10 max.	-	-20 max.	-	-30 max.	0/+10	-	-
			AK6	150	168	-5/+5	-	-30 max.	-	-40 max.	-2/+5	-	-

Specification Handbook

Driveline

Contents Driveline

Automotive Gear:

Automatic Transmission Fluids:

API Lubricant Service Designation for Automotive Manual Transmission[1] & Axles

This material was prepared by the Lubricants Service Classification Task Force of the Fuels and Lubricants Committee, Marketing Department, American Petroleum Institute, to assist manufacturers and users of automotive equipment in the selection of transmission and axle lubricants for the operating conditions as described.

In transmissions, and particularly in rear axles, gears of different designs are available for a variety of different service conditions. Selection of a lubricant for specific applications involves careful consideration of the operating conditions and the chemical and physical characteristics of the lubricant to meet these service conditions. Until recently, transmission and differential lubricants were described in qualitative terms and by a variety of designations, each one attempting to describe both the lubricant and the service conditions under which the lubricant must perform. Consideration of these lubricant designations to a minimum number was deemed highly desirable in the light of present day technology. The American Petroleum Institute, therefore, prepared six lubricant service designations for automotive manual transmissions and axles, each designation referring to the performance required of a gear lubricant for a specific type of automotive service. These designations also recognise the possibility that lubricant may be developed for more than one service classification and as a result may be so designated.

In developing the language for the service classifications, a need was recognised to supplement the descriptions for certain gear lubricants, particularly those for hypoid gears, by referring to a series of tests which would serve as a "test language" to provide more detailed information on the performance requirements of such lubricant. This "test language" was developed by Section III of Technical Division B on Automotive Lubricants of ASTM Committee D-2, and reference is made to these test procedures in the API service designations described below.

This system of designations replaced all previous API gear lubricant designations and became effective May 1, 1969. These designations are as follows:-

API GL-1

Designates the type of service characteristic of automotive spiral-bevel and worm-gear axles and some manually operated transmissions operating under such mild conditions of low unit pressures and sliding velocities, that straight mineral oil can be used satisfactorily. Oxidation and rust inhibitors, defoamers, and pour depressants may be utilised to improve the characteristics of lubricants for this service. Frictional modifiers and extreme pressure agents shall not be utilised.

API GL-2

Designates the type of service characteristic of automotive type worm-gear axles operating under such conditions of load temperature and sliding velocities, that lubricants satisfactory for API GL-1 service will not suffice.

API GL-3

Designates the type of service characteristic of manual transmissions and spiral-bevel axles operating under moderately severe conditions of speed and load. These service conditions require a lubricant having load carrying capacities greater than those which will satisfy API GL-1 service, but below the requirements of lubricants satisfying API GL-4 service.

API Lubricant Service Designation

API GL-4

This classification is still used commercially to describe lubricants, but the equipment required for the anti-scoring test procedures to verify lubricant performance is no longer available.

Designates the type of service characteristic of gears, particularly hypoid[(2)] in passenger cars and other automotive type of equipment operated under high-speed, low-torque, and low-speed, high-torque conditions.

Lubricants suitable for this service are those which provide anti-score protection equal to or better than that defined by CRC Reference Gear Oil RGO-105 and have been subjected to the test procedures and provide the performance levels described in ASTM STP-512A, dated March 1987[(3)].

API GL-5

Designates the type of service characteristic of gears, particularly hypoid in passenger cars and other automotive equipment operated under high-speed, shock-load; high-speed, low-torque; and low-speed, high-torque conditions.

Lubricants suitable for this service are those which provide anti-score protection equal to or better than that defined by CRC Reference Gear Oil RGO-110 and have been subjected to the test procedures and provide the performance levels described in ASTM STP-512A dated March 1987[(2)].

API GL-6

This category is obsolete and is listed for historical reference only.
The equipment used to measure performance is no longer available.

Footnotes:

(1) Automatic or semi-automatic transmissions, fluid couplings, torque converters, and tractor hydraulic systems usually require special lubricants. For the proper lubricant to be used, consult the manufacturer or lubricant supplier.

(2) Limited slip differentials generally have special lubricant requirements. The lubricant supplier shall be consulted regarding the suitability of their lubricant for such differentials. Information helpful in evaluating lubricants for this type of service may be found in the latest edition of ASTM & STP-512A.

(3) The complete publication is titled “Laboratory Performance Tests for Automotive Gear Lubricants intended for API GL-5 Service.”

Note:

API GL-4 oils are not suitable for highly-loaded hypoid axles. API GL-4 oils are used in synchronised manual transmissions and transaxles as well as in mild hypoid and spiral bevel axles.

SAE J306 Automotive Gear Viscosity Classifications Axle and Manual Transmission Lubricant Viscosity Classification

		70W	75W	80W	85W	80	85	90	110	140	190	250
Viscosity at 100°C, mm^2/s												
	min.	4.1	4.1	7.0	11.0	7.0	11.0	13.5	18.5	24.0	32.5	41.0
	max.	No requirement				< 11.0	< 13.5	< 18.5	< 24.0	< 32.5	< 41.0	No req
Max. Viscosity of 150,000 mPa.s, at temp °C		-55	-40	-26	-12	No requirement						
20 hr. KRL Shear (CEC L-45-A-99), KV100 after Shear, mm^2/s, min.		4.1	4.1	7.0	11.0	7.0	11.0	13.5	18.5	24.0	32.5	41.0

DEF STAN 91-59/2 Lubricating Oil, Extreme Pressure

Grades 75W and 80W90: Joint Service Designation OEP-38 and OEP-220 Respectively

Property	Limits OEP-38	Limits OEP-220	Test Method
Appearance	Clear homogenous and free from visual impurities		Visual Examination
Kinematic Viscosity mm²/s at 100°C			BS EN ISO 3104 [1]
min.	4.1	13.5	
max.	-	24.0	
Viscosity Index, min.	85	-	ASTM D2270, IP 226
Low Temperature Viscosity: mPa.s			ASTM D2983
at -26°C max.	-	150 000	
at -40°C max.	150 000	-	
Detection of Copper Corrosion			BS 2000 Part 154 or ASTM D130: IP 154 3 hrs at ±120°C
Copper Strip Classification, max.	3		
Condition of Copper Strip	No pitting or etching		
Flash point, °C, min.	150	165	IP36
Detection of Steel Corrosion Appearance of test piece	No rusting or pitting		BS 2000 Part 135 ASTM D665: IP 135 Procedure A (60±1)°C
Foaming tendency and stability characteristics:			BS 2000 Part 146 ASTM D892/IP 146
Sequence I, ml, max.	20/0	20/0	
Sequence II, ml, max.	50/0	50/0	
Sequence III, ml, max.	20/0	20/0	
Additive Elements	See clause 6.1		See clause 6.1
Thermal oxidation stability (TOST)			ASTM D5704 (L-60-1)
Kinematic Viscosity at 100°C increase percent, max.	100		
Change in total acid number mg KOH/g, max.	3.0		
Pentane Insolubles, % m/m, max.	3.0		
Toluene Insolubles, % m/m, max.	2.0		
Carbon Varnish rating, min.	7.5		
Sludge rating, min.	9.4		
High Torque test Condition of Gear Teeth Condition of Half-Shaft and Axle Housing	The performance of the oil shall be superior to that of the CRC reference oil RGO 104		ASTM D6121 (L-37)
High speed/shock load test	The performance of the oil shall be superior to that of the CRC reference oil RGO 114		L-42
Storage Stability			Annex A
Solid, % m/m, max.	0.25		
Liquid % volume, max.	0.50		

Note:

(1) Test facilities for these tests are available at DQA/TS Woolwich.

The above requirements are absolute and not subject to correction for tolerance of test method.
This specification is currently (March 2000) under review.

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MACK GO-H Requirements

Covering SAE 90, SAE 140, SAE 80W-90 and SAE 85W-140 oils

Test	Parameters		Limits
Power Divider Snap Test 5GT11	Condition of cams and divider wedges:		
		Breakage	none
		Chipping	none
		Scoring	none
		Hard snaps during test	none
MIL-L-2105D	Full approval required		
Test for Transmission and Carrier Radial Lip Seal 5 GT 75	Immersion at 93°C for 100 hrs:		
		Appearance	as original
		Blistering	none
		Gum	none
		Tackiness	none
		Brittleness	none
		Swelling	none
Timken Bearing Corrosion 09196	Sample heated for 6 hrs at 150°C. Bearing dipped in sample and drained for 1 hr Bearing placed in humidity cabinet for 3 hrs at 60°C in 100% humidity		
		Rust at end of test, max.	none
Thermal Oxidation Stability	200g/sample in uncovered 400 ml. beaker for 100 hrs. at 150°C in a gravity convection oven		
		Evaporation Loss, max. %	10
		Viscosity Increase at 99°C, max. %	15
		Precipitation Number, max.	0.65
Gear Oil Spalling Test 5 GT 71A	Minimum B 10 life of 50% above the GO-G reference		160 hrs minimum
Transmission Test for Evaluation of Thermally Stable Gear Oils 5 GT 73	No missed shifts and no measurable shifter fork wear at the centre of the pads		Minimum 65,000 cycles

Note:

The lubricant must be a blend from well-refined virgin base stocks (high viscosity index - 95 min.) compounded with load-carrying and lubricity ingredients.
The oil shall be stable and contain no abrasive or corrosive ingredients.

MACK GO-J and GO-J Plus Requirements

	Extended Drain (GO-J Plus)	Standard Drain (GO-J)
Highway (Class A, B)[1]	500,000 Miles or 3 Years	250,000 Miles or 2 Years
Vocational (Class AA, BB, C, CC)[1]	80,000 Miles or 1 Year or 1,200 hrs	40,000 Miles or 1 Year or 1,200 hrs
Off Road (Class D)[1]	6 Months	6 Months

Test	Procedure	Extended Drain Limits	Standard Drain Limits	Comment
Rust Protection	ASTM D7038 (L-33)	(2)	(2)	-
Copper Corrosion	ASTM D130	(2)	(2)	-
Foaming Tendencies	ASTM D892	(2)	(2)	-
Oil Seal Compatibility	ASTM D5662	(2)	(2)	-
PG2 Oil Seal Compatibility	ASTM D5662	(2)	(2)	Section 3.3
Thermal Capability	ASTM D5704 (L-60-1)	100 hr. test	(2)	Section 3.4
SS+C	Fed. Test No. 791C	-	-	-
Storage Stability	Method 3440.1	(2)	(2)	-
Compatibility	Method 3430.2	(2)	(2)	-
Surface Protection	ASTM STP512A (L-42)	(2)	(2)	-
Surface Protection	ASTM D6121 (L-37)	(2)	(2)	-
Cyclic Durability Test	ASTM D5579	1.5 times[2]	(2)	Section 3.5
Power Divider Snap Test	MAT 700 WI	-	-	Section 3.6
Tapered Bearing Shear	DIN 51 350 Part 6, Test C	Stay-in-Grade 17% Max. Change	Stay-in-Grade 17% Max. Change	Section 3.7
Spalling Test	MAT 701 WI	-	-	Section 3.8
Wet Axle Gear Durability	MAT 706 WI (L-37 Modified)	(2)	Not Required	Section 3.9
Field Testing	-	500,000 miles	(2)	Section 3.10
Monitoring Program	-	Required	Required	Section 3.11

Note:
(1) Vehicle classifications as determined for Mack Trucks' vehicle warranty.
(2) ML-PRF-2105E Limits.

MACK TO - A Plus Requirements

	Extended Drain (TO-A Plus)
Highway (Class A,B)(1)	500,000 Miles or 3 Years
Vocational (Class AA, BB, C, CC)(1)	80,000 Miles or 1 Year or 1,200 hrs
Off Road (Class D)	Not Available

Test	Procedure	Extended Drain Limits	Comment
Copper Corrosion	ASTM D130	ASTM D5760 Limits	-
Foaming Tendencies	ASTM D892	ASTM D5760 Limits	-
Oil Seal Compatibility	ASTM D5662	ASTM D5760 Limits	-
Thermal Capability	ASTM D5704	-	Section 3.2
Cyclic Durability	ASTN D5579	1.5 X ASTM D5760 Limits	-
Compatibility	Fed. Test No. 791C Method 3430.2	MIL-PRF-2105E Limits	-
Tapered Bearing Shear	DIN 51 350 Part 6, Test C	Stay in Grade, 17% Max. Change	Section 3.3
Scuffing Resistance (FZG)	ASTM D5182	ASTM D5760 Limit	-
Field Test	-	500,000 miles	Section 3.4
Monitoring Program	-	Required	Section 3.5
Pour Point	ASTM D97	-40°C minimum	-

Note:

(1) Vehicle classifications as determined for Mack Trucks' vehicle warranty.

MAN 341-1 Specifications

Test	Requirement					Test Method
Type	Z1	Z2	Z3	Z4	Z5	
SAE J306 classifications	80W, 80W-85, 80W-90	75W-80, 75W-85, 75W-90, 80W, 80W-85, 80W-90	75W-80	75W-80 75W-85	75W-80	
Density at 15ºC, g/ml	Report					DIN 51757
Brookfield temperature, ºC	-26/-40		-40			DIN 51398
Brookfield viscosity, mPa.s	Report					DIN 51398
Kinematic Viscosity						
at 40ºC, cSt	Report		max. 65			DIN 51562-1
at 100ºC, cSt	min. 8.5		min. 9.0			
Loss of viscosity at 100ºC after 20 hrs shearing	within viscosity grade limits and 10% max. loss					DIN 51350-6 KRL
Flash Point (COC), ºC	Report					DIN EN ISO 2592
Pour Point, ºC	Report					DIN ISO 3016
TBN, mgKOH/g	Report					DIN ISO 3771
TAN, mgKOH/g	Report					ASTM D664
Neutralisation Number, mgKOH/g	Report					DIN 51558-1
Elementals						
Calcium, %	Report					DIN 51391-3
Zinc, %	Report					DIN 51391-3
Magnesium, %	Report					DIN 51391-3
Phosphorus, %	Report					DIN 51363-3
Sulphur, %	Report					E DIN 51400-10
Boron, %	Report					DIN 51443-2
Chlorine, mg/kg	Report					DIN 51577-4
Oxidation Test, 192 hrs [(1)]	150ºC		160ºC			CEC-L-48-A-00-B
Kv 100 increase, %	max. 45		max. 25			DIN 51562-1
Change in TAN, mgKOH/g	max. 4		max. 2			ASTM D664
Sludge	Report		None			

Note:
(1) For SAE 75W-x testing for 384 hrs could also be considered.

MAN 341-1 Specifications - Cont'd

Test	Requirement	Test Method
Steel Corrosion (2)	Procedure A (distilled water), No rust	DIN ISO 7120
Copper Corrosion (2)	2 or better (3 hrs / 120°C)	DIN EN ISO 2160 ASTM D130
Foam		ASTM D892
Sequence I, ml, max.	20/0	
Sequence II, ml, max.	50/0	
Sequence III, ml, max.	20/0	
SRE-NBR 28		VDA 675 301
Hardness change, shore A	-10 to +10	
Tensile strength change, %	-30	
Elongation rupture change, %	-40	
Volume change, %	0 to +10	
AK-6		VDA 675 301
Hardness change, shore A	-5 to +10	
Tensile strength change, %	-40	
Elongation rupture change, %	-50	
Volume change, %	0 to +5	
70 ACM 121 433		VDA 675 301
Hardness change, shore A	-10 to +5	
Tensile strength change, %	-20	
Elongation rupture change, %	-30	
Volume change, %	0 to +5	

Note:
(2) Report metal content in oil at end of test.

MAN 341-2 Specifications

Test	Requirement		Test Method
Type	ZE, VR	MB	
SAE J306 classifications	75W-80	75W-90	
Density at 15°C, g/ml	Report		DIN 51757
Brookfield temperature, °C	-40		DIN 51398
Brookfield Viscosity, mPa.s	max. 150000	max. 60,000	DIN 51398
Kinematic Viscosity			DIN 51562-1
at 40°C, cSt	Report	Report	
at 100°C, cSt	11	13.5	
Loss of viscosity at 100°C after 20 hrs shearing	within viscosity grade limits and 10% max. loss		DIN 51350-6 KRL
Flash point (COC), °C	Report	≥ 200	DIN EN ISO 2592
Pour point, °C	Report	≤ -40	DIN ISO 3016
TBN, mgKOH/g	Report		DIN ISO 3771
TAN, mgKOH/g	Report		ASTM D664
Neutralisation number, mgKOH/g	Report		DIN 51558-1
Elementals			
Calcium, %	Report		DIN 51391-3
Zinc, %	Report		DIN 51391-3
Magnesium, %	Report		DIN 51391-3
Phosphorus, %	Report		DIN 51363-3
Sulphur, %	Report		E DIN 51400-10
Boron, %	Report		DIN 51443-2
Chlorine, mg/kg	max. 100		DIN 51577-4
Oxidation test, 192 hrs (1), 160°C			CEC-L-48-A-00-B
Kv 100 increase, %	max. 25		DIN 51562-1
Change in TAN, mgKOH/g	max. 2		ASTM D664
Sludge	none		
Steel corrosion (2)	Procedure A (distilled water), No rust		DIN ISO 7120
Copper corrosion (2)	2 or better (3h/120°C)		DIN EN ISO 2160 ASTM D130

Note:
(1) Testing for 384 hrs could also be considered.
(2) Report metal content in oil at end of test.

MAN 341-2 Specifications - Cont'd

Test		Requirement	Test Method
Foam			ASTM D892
	Sequence I, ml, max.	20/0	
	Sequence II, ml, max.	50/0	
	Sequence III, ml, max.	20/0	
SRE-NBR 28			VDA 675 301
	Hardness change, shore A	-10 to +10	
	Tensile strength change, %	-30	
	Elongation rupture change, %	-40	
	Volume change, %	0 to +10	
AK-6			VDA 675 301
	Hardness change, shore A	-5 to +10	
	Tensile strength change, %	-40	
	Elongation rupture change, %	-50	
	Volume change, %	0 to +5	
70 ACM 121 433			VDA 675 301
	Hardness change, shore A	-10 to +5	
	Tensile strength change, %	-20	
	Elongation rupture change, %	-30	
	Volume change, %	0 to +5	

MAN 342 Specifications

Type	M1, M2 and M3				S1, S2
SAE Viscosity Class	80W	80W-90	85W-90	90	75W-90
Density at 15°C, g/ml	Report	Report	Report	Report	Report
Max. Temperature at which the Brookfield Viscosity is 150,000 mPa.s,°C	-26	-26	-12	-	-40
Kinematic Viscosity at 40°C, mm²/s	Report	Report	Report	Report	Report
Kinematic Viscosity at 100°C, mm²/s	7.0 min.	13.5 min.	13.5 min.	13.5 min.	13.5 min.
Viscosity at 100°C after Shear (20 hr KRL), mm²/s	Stay-in-grade (max. 10% loss)				
Flash Point, °C	190 min.	190 min.	200 min.	200 min.	200 min.
Pour Point, °C	-27 max.	-27 max.	-21 max.	-	-40 max.
Total Acid No., mg KOH/g	Report	Report	Report	Report	Report
Calcium, Magnesium, Zinc mg/kg	Report	Report	Report	Report	Report
Boron Content, mg/kg	Report	Report	Report	Report	Report
Phosphorus, % mass	Report	Report	Report	Report	Report
Sulphur, % mass	Report	Report	Report	Report	Report
Chlorine, mg/kg	100 max.	100 max.	100 max.	100 max.	100 max.
Oxidation Stability CEC-L-48-A-00 (B)	192 hrs at 150°C				192 hrs at 160°C
Viscosity Increase at 100°C, %	130 max.	130 max.	130 max.	130 max.	130 max.
Change in TAN, mg KOH/g	10 max.	10 max.	10 max.	10 max.	10 max.
Sludge Formation	Report	Report	Report	Report	None
Steel Corrosion (DIN ISO 7120 Method A) - Metallic elements in oil after test to be reported	no rust	no rust	no rust	no rust	no rust
Copper Corrosion (3 hrs at 120°C) ASTM D130 - Copper in oil after test to be reported	2 max	2 max	2 max	2 max	2 max
Foaming Tendency/Stability, ml, max.					
Sequence I	20/0	20/0	20/0	20/0	20/0
Sequence II	50/0	50/0	50/0	50/0	50/0
Sequence III	20/0	20/0	20/0	20/0	20/0
MAN Seal Tests (168 hrs: 100°C NBR-28, 150°C AK6 & ACM 121433)	Pass	Pass	Pass	Pass	Pass

Testing Required for new Additive Technologies	
API GL-5 and MIL-L-2105D Performance	Meet
FZG Pitting (C/8.3/90), 3 Runs, Hrs	M1, M2, M3: 90 min. - S1, S2: 250 min.
FZG Sprung S-A 10/16, 6R/90, Pass Load Stage	10 min.
FZG A/8, 3/90 on used oil after DKA oxidation, Pass Load Stage	10 min. (1)
FZG wear C/0.05/90/10 and C/0.05/90/12, wear, mg	Max 400mg in 120 hrs
Dynamic Seals Test: 240 hrs at 120°C (10 cycles): 75 FPM 595 and FKM 585	Pass (1)
Bearing wear test - DIN 51819-3	Report results

Note: (1) Only required for S1, S2. (2) Only required for M3 and SI, S2.

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MAN 3343 Specifications

Type	M		S
SAE Viscosity Class	80W-90	85W-90	75W-90
Density at 15°C, g/ml	Report	Report	Report
Max. Temperature at which the Brookfield Viscosity is 150,000 mPa.s,°C	-26	-12	-40
Kinematic Viscosity at 40°C, mm²/s	Report	Report	Report
Kinematic Viscosity at 100°C, mm²/s	13.5 min.	13.5 min.	13.5 min.
Viscosity at 100°C after Shear (20 hr KRL), mm²/s	Stay-in-grade		
Flash Point, °C	190 min.	200 min.	200 min.
Pour Point, °C	<-27 max.	<-21 max.	<-40 max.
Total Acid No., mg KOH/g	Report	Report	Report
Calcium, Magnesium, Zinc, Barium, mg/kg	Report	Report	Report
Phosphorus, % mass	Report	Report	Report
Chlorine, mg/kg	100 max.	100 max.	100 max.
Oxidation Stability (for 192 hrs) - CEC-L-48-A-00 (B)	at 150°C		at 160°C
Viscosity Increase at 100°C, mm²/s	130 max.	130 max.	130 max.
Change in Total Acid Number, mg KOH/g	10 max.	10 max.	10 max.
Sludge Formation	Report	Report	None
Steel Corrosion (DIN ISO 7120 Method A) - Metallic elements in oil after test to be reported	no rust	no rust	no rust
Copper Corrosion (3 hrs ar 120°C) ASTM D130 - Copper in oil after test to be reported	2 max.	2 max.	2 max.
Foaming Tendency / Stability			
Sequence I	20/0	20/0	20/0
Sequence II	50/0	50/0	50/0
Sequence III	20/0	20/0	20/0
MAN Static Seal Tests (168 hrs: 100°C NBR-28, 150°C AK6 & ACM 121433)	Pass	Pass	Pass

Testing Required for new Additive Technologies	
API GL-5 MIL-L-2105D Performance	Meet
FZG Pitting (C/8.3/90), 3 Runs, Hrs	M: 90 min - S: 250 min
FZG Sprung S-A 10/16,6R/90, Pass Load Stage	10 min.
FZG wear C/0.05/90/10 and C/0.05/90/12, wear, mg	Max 400 mg in 120 hrs
Dynamic Seals Test: 240 hrs at 120°C (10 cycles): 75 FPM 595 and FKM 585	Pass (1)
Field Test for S Grades (half with retarders)	400,000 km

Note: (1) Only required for S.

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Performance Requirements For MIL-L-2105D (GL-5) Lubricants

SAE Viscosity Grade		75W	80W-90	85W-140
ASTM D5704 (formerly CRC L-60-1 or L-60)				
Thermal Oxidation Stability	100°C Viscosity Increase at 50 hrs, max. %	100	100	100
	Pentane Insolubles, max. %	3	3	3
	Toluene Insolubles, max. %	2	2	2
ASTM D7038 (formerly CRC L-33-1)				
Moisture Corrosion	Final rust merit rating, min	9	9	9
ASTM D6121 (formerly CRC L-37)				
Low Speed - High Torque	"Green" Gears	Pass	Pass	NR
CRC L-42				
High Speed-Shock Loading Axle Test	Ring & Pinion Tooth Scoring, max. %	Equal to or better than Passing reference oil		NR
ASTM D130 (3 hrs @ 121°C)				
Copper Strip Corrosion	Strip Rating, max.	3	3	3
ASTM D892				
Foam Tendency max.	Sequence I	20	20	20
	Sequence II	50	50	50
	Sequence III	50	50	50

Note:
NR: Not Required, if 80W90 passes in the same base stock. Lower L-37 and L-42 test temperatures are required for 75W oils often referred to as Canadian versions.

Performance Requirements For SAE J2360 (formerly MIL-PRF-2105E) November 1998

SAE Viscosity Grade		75W	80W-90	85W-140
Viscosity at 100°C, mm^2/s				
min.		4.1	13.5	24.0
max.		-	18.5	32.5
Viscosity at 150,000 mPa.s, max temp °C		-40	-26	-12
Channel Point, min, °C		-45	-35	-20
Flash Point, min, °C		150	165	180
ASTM D5704 (formerly CRCL-60-1)				
Thermal Oxidation Stability	100°C Viscosity Increase at 50 hrs, max. %	100	100	100
	Pentane Insolubles, max. %	3	3	3
	Toluene Insolubles, max. %	2	2	2
	Carbon Varnish, min, Rating	7.5	7.5	7.5
	Sludge, max. Rating	9.4	9.4	9.4
ASTM D7038 (formerly CRC L-33-1)				
Moisture Corrosion	Rust on Gear Teeth Bearings and Cover plate, Rating, min	9.0	9.0	9.0
ASTM D6121 (formerly CRC L-37)				
High Speed - Low Torque	"Green Gears"	Pass	Pass	NR
High Torque - Low Speed	"Lubrited" Gears	Pass	Pass	NR
CRC L-42				
High Speed-Shock Loading Axle Test	Ring and Pinion Tooth Scoring, max., %	Equal to or better than passing reference oil		NR
Cycle Durability (ASTM D5579)				
MACK Cycling Test	No. of Cycles	Equal to or better than average of past 5 reference runs.		
ASTM D130				
Copper Corrosion/3 hrs at 121°C	Strip Rating, max.	3	3	3
Elastomer Compatibility (ASTM D5662)		Polyacrylate	Fluoroelastomer	Nitrile
Polyacrylate + Fluoroelastomer	Elongation Change, min, %	-60	-75	-60
at-150°C for 240 hrs	Hardness Change, Points	-25 to + 5	-5 to + 10	-10 to + 5
Nitrile at 100°C for 240 hrs	Volume Change, %	-5 to + 30	-5 to + 15	-5 to + 20
ASTM D892				
Foam Tendency/Stability, ml, max.	Sequence I	20/0	20/0	20/0
	Sequence II	50/0	50/0	50/0
	Sequence III	20/0	20/0	20/0
SS&C FTM 791				
Storage Stability & Compatibility	Method 3340	Pass	Pass	Pass

Note:
NR: Not required, if 80W-90 passes in the same base stock. Lower L-37 and L-42 Test Temperatures are required for 75W oils.

MT-1 Category Tests and Acceptance Criteria

Test		Minimum	Maximum
Test method for Evaluation of the Thermal and Oxidative Stability of Lubricants used for Manual Transmissions and Final Drive Axles L-60-1(ASTM D5704)			
	Viscosity Increase, %	-	100
	Pentane Insolubles, %	-	3.0
	Toluene Insolubles, %	-	2.0
	Carbon/Varnish Rating	7.5	-
	Sludge Rating	9.4	-
Test method for determining Automotive Gear Oil compatibility with Typical Oil Seal Elastomers (ASTM D5662)			
Polyacrylate at 150°C, 240 hrs			
	Elongation change, %	No limits	-60
	Hardness change, points	+5.0	-35
	Volume change, %	+30	-5
Fluoroelastomer at 150°C, 240 hrs			
	Elongation change, %	No limits	-75
	Hardness change, points	+10	-5
	Volume change, %	+15	-5
Test method for evaluating the thermal stability of manual transmission lubricants in a Cyclic Durability Test Cycles to fail (ASTM D5579)		Better than passing reference oil	-
Test method D130 for detection of copper corrosion from petroleum products by the Copper Strip Tarnish Test, 121°C, 3 hrs		-	2a
Test Method D5182 for evaluating the scuffing (scoring) load capacity of oils Failing load stage		11	-
Test Method D892 for foaming characteristics of lubricating oils (tendency only)			
	Sequence I, ml	-	20
	Sequence II, ml	-	50
	Sequence III, ml	-	20
Federal Test Method 791C, Method 3430.2, for compatability characteristics of Universal Gear Lubricant		Compatible with MIL-L-2105D oils(1)	-
Federal Test Method 791C, Method 3440.1, for storage solubility characteristics of Universal Gear Lubricant		Pass(2)	-

Note:

(1) Shall be compatible with specific reference oils when tested in accordance with Federal Test Method 3430.2. Reference oils may be obtained from SAE, 400 Commonwealth Drive, Warrendale, Pennsylvania, 15096.

(2) Shall pass the performance requirements as specified in the MIL-L-2105D specifications when tested in accordance with Federal Test Method 3440.1.

Scania STO 1:0

Type	Requirement	Limits
Gear Oil	API	GL-5
STO [1] 1:0	API	GL-5
	Shear Stability	
	20 hr KRL Shear (CEC-L-45-A-99)	Viscosity change (%) less than or equal to RL181
	Filterability	Minimum 90% in stage 2 of ISO 13357-2 using 5mm filter and 1.0 bar pressure
	Thermal and Oxidation Stability, ASTM D5704 (L-60-1) [2]	Carbon varnish = 7.5 min. (on large gear only) Sludge = 9.4 min. (on both gears)

Note:

(1) Scania Gear Oil.

(2) MIL-PRF-2105E (SAE J2360) Limits.

Volvo Transmission Oil Specifications 1273.07

Test	Limits	Test Method
Density, kg/m³	To be stated	ASTM D1298
Flash Point, COC, min, °C	200	ASTM D92
Pour Point, max. °C	-48	ASTM D97
Viscosity at 100°C, mm²/s		ASTM D445
min.	9	
max.	12	
Viscosity Loss after Shearing, 20 hrs, max. %	5	ASTM D445 CEC L-45-A-99
Viscosity at -40°C, mPa.s, max.	150,000	ASTM D2983
Oxidation Stability after 160°C/192 hrs		CEC L-48-A-95B
Viscosity Increase, 100°C, max. %	10	
Tan Increase, mg KOH/mg, max.	1.0	
Copper Corrosion, 3 hrs, max. 150°C	1B	ASTM D130
Rust Protection 24 hrs	No rust	ASTM D665 A
Rust Protection after Oxidation	No rust	ASTM D665 A CEC L-48-A-95
Foaming Tendency, ml/ml		ASTM D892
Sequence I/II/III, max.	50/0	
Water Content, ppm, max.	200	ASTM D1744
Solid Particles, code, max.	18/13	ISO 4406
Synchronization Properties	(1)	
Seal Compatibility	Pass	VTM-02-95(2)
Load Carrying Capacity, load stage, min.	12 +	CEC L-07-A-95
Surface Fatigue, gears	50% better than reference oil	VTM-01-96(2)
Field Tests	400,000 km	VTM-03-95(2)

Note:

(1) The oil shall be tested in the Volvo test rig with approved results after 300,000 engagements.

(2) Volvo Test Method.

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Volvo Transmission Oil Specifications 1273.12

Test	Limits	Test Method
Density, kg/m^3	To be stated	ASTM D1298
Flash Point, COC, min, °C	200	ASTM D92
Pour Point, max. °C	-48	ASTM D97
Viscosity at 100°C, mm^2/s		ASTM D445
min.	13.5	
max.	18	
Viscosity Loss after Shearing, 20 hrs, max. %	5	ASTM D445 CEC L-45-A-99
Viscosity at -40°C, mPa.s max.	150,000	ASTM D2983
Oxidation Stability after 120°C/192 hrs		CEC L-48-A-95B
Viscosity Increase, 100°C, max. %	10	
Tan Increase, mg KOH/mg, max.	1.0	
Copper Corrosion, 3 hrs, max. 120°C	1B	ASTM D130
Rust Protection 24 hrs	No rust	ASTM D665 A
Rust Protection after Oxidation	No rust	ASTM D665 A CEC L-48-A-95
Foaming Tendency, ml/ml		ASTM D892
Sequence I/II/III, max.	50/0	
Water Content, ppm, max.	200	ASTM D1744
Solid Particles, code, max.	18/13	ISO 4406
API	GL-5	
Seal Compatibility	Pass	VTM-02-95[1]
Surface Fatigue, gears	30% better than reference oil	VTM-01-96[1]
Field Tests	400,000 km	VTM-03-95[1]

Note:
(1) Volvo Test Method.

ZF Specifications: Master List

Description	ZF List	Notes	Viscosity Grades
TE-ML 01 Manual synchronised transmissions for commercial vehicles	Class 01E Class 01L	Requires ZF TE-ML 02E	SAE 75W-80
		Requires ZF TE-ML 02L	SAE 75W-80
TE-ML 02 Manual and automatic transmissions for trucks and buses	Class 02A (1)	Gear oils of API GL-4, MIL-L-2105 quality - not applicable for intarder	SAE 80W / SAE 75W-80 / 80W-85W / 80W-90
	Class 02B	Gear oils - not applicable for intarder	SAE 80W / 80W-85 / 80W-90 / SAE 90 /75W-80 / 75W-85 / 75W-90
	Class 02C (1)	Monograde engine oils - mineral oil based - applicable for intarder	SAE 30
	Class 02D (1)	Semi-synthetic gear oils - applicable for intarder	SAE 75W-80
	Class 02E	Gear oil - Synthetic gear oil applicable for intarder	SAE 75W-80
	Class 02F	ATF (Automatic Transmission Fluid)	
	Class 02G (1)	Gear oil - mineral based, not applicable for intarder	SAE 75W
	Class 02H	Monograde engine oils (mineral based) - applicable for in tarder	SAE 30, SAE 40 80W / 80W-85W / 80W90 / 85W-90 / 90
	Class 02K	Hydraulic oil	
	Class 02L	Semi-synthetic gear oil - applicable for intarder	SAE 75W-80
TE-ML 03 Torque convertor transmissions for off-road vehicles and machinery (construction plant, special vehicles, lift trucks)	Class 03A	Mineral based engine oil in accordance with Group Standard	SAE 10W-30 / 10W-40 SAE 15W-30 / 5W-40 SAE 20W-20 & 30 grade / 20W-40
	Class 03B	Mineral based engine oil in accordance with Group Standard	SAE 10W / 5W-30 / 5W-40
	Class 03C	Off highway lubricants	SAE 5W-30 / 5W-40 / 10W / 10W-30 / 10W-40 / 15W-30 / 15W-40 / 20W-20 / 20W-40 / SAE 30
	Class 3D	ATF	
	Class 03E	Universal Tractor transmission oils (UTTO) for converter transmissions for off-road equipment	
	Class 03F	Universal Tractor transmission oils (UTTO) for use at outside temperatures below -10ºC	
	Class 03G	Universal construction machinery oil	
TE-ML 04 Marine	Class 04A	Monograde engine oils - API CD / CE / CF-4 / CF / SF / SG / SH / SJ or ACEA categories A / B / E	SAE 30 (SAE 40 in hot countries)
	Class 04B	Monograde engine oils	
	Class 04C	Multigrade engine oils	SAE 5W-40, 10W-40, 15W-40
	Class 04D	ATF	
	Class 04E	Monograde engine oils (API CD / CE /CF-4 / CG-4 / CH-4 / CI-4 / SF / SG / SH / SJ / SL or ACEA categories A / B / C	SAE 50
	Class 04F	Oil CLP 220 in accordance with DIN 51517 -3	ISO VG 220

Note:
(1) Now obsolete: Class 02A, 02C, 02D, 02G.

ZF Specifications: Master List

Description	ZF List	Required Performance	Viscosity Grades
TE-ML 05 Axles for off-road vehicles	Class 05A	Mineral oil based & semi-synthetic gear oils	SAE 75W-90 / 75W-110 / 75W-140 / 80W-90 / 80W-110 / 80W-140 / 85W-90 / 85W-110 / 85W-140 / 90
	Class 05B	Synthetic gear oils	SAE 75W-90 / 75W-110 / 75W-140 / 80W-90 / 80W-110 / 80W-140 / 85W-90 / 85W-110 / 85W-140 / 90
	Class 05C	Mineral oil based gear oils with limited slip additives	SAE 75W-90 / 75W-110 / 75W-140 / 80W-90 / 80W-110 / 80W-140 / 85W-90 / 85W-110 / 85W-140 / 90
	Class 05D	Synthetic gear oils with limited slip additives	SAE 75W-90 / 75W-110 / 75W-140 / 80W-90 / 80W-110 / 80W-140 / 85W-90 / 85W-110 / 85W-140 / 90
No longer active	Class 05E	Universal Tractor Transmission Oils (UTTO)	SAE 20W-40
	Class 05F	Universal Tractor Transmission Oils (UTTO) as service oil for ZF axles in off-road vehicles with and without wet breaks and/or differential	
	Class 05G	Universal construction machinery oil	
	Class 05H	Bio-degradeable lubricant	SAE 75W-80
	Class 05K	Engine oil in accordance with API CD / CE / CF-4 / CG-4 / CH-4 / CI-4 or SF / SG / SH / SJ / SL or ACEA Catagories A / B / C	SAE 10-W, 10W-30, 10W-40
	Class 05L	Mineral ATF in accordance with General Motors	
TE-ML 06 Tractor transmissions and hydraulic lifts	Class 06A	Engine oils - API CD / CE / CF-4 / CF / SF / SG / SH / SJ or ACEA categories A / B / E	SAE 20W-20
	Class 06B	STOU (Super Tractor Oil Universal) braking test	SAE 10W-30 / 10W-40 / 15W-30 / 15W-40 / 20W-40
	Class 06C	STOU (Super Tractor Oil Universal)	SAE 10W-30 / 10W-40 / 15W-30 / 15W-40 / 20W-40
	Class 06D	STOU (Super Tractor Oil Universal)	SAE 10W-30
	Class 06E	Universal Tractor Transmission Oil (UTTO)	
	Class 06F	Super Tractor Oil Universal (STOU) and Universal Tractor Transmission Oil (UTTO)	SAE 10W-30 / 10W-40 / 15W-30 / 15W-40
	Class 06G	Biodegradeable lubricant with environmental labels RAL-UZ 79 (Blue Angel), Vamil-regeling	SAE 75W-80
	Class 06H	Tractor oils	SAE 10W-30 / 10W-40
	Class 06K	Universal Tractor Transmission Oil (UTTO)	
	Class 06L	Gear oils GL-4 and Mil 2105	SAE 75W-80 / 75W-85 / 80W / 80W-85
	Class 06M	Tractor oils	SAE 10W-30 / 10W-40 / 15W-30 / 15W-40
	Class 06Q	Tractor oils	SAE 15W-40
TE-ML 07 Hydrostatic & mechanical drives and electric drive systems	Class 07A	Gear oils	SAE 75W-90 / 75W-110 / 75W-140 / 80W-85 / 80W-90 / 80W-110 / 80W-140 / 85W-90 / 85W-140 / 85W-110 / 90
	Class 07B	STOU (Super Tractor Oil Universal)	SAE 10W-30 / 10W-40 / 15W-30 / 15W-40 / 20W-40
	Class 07C	Engine oil	SAE 5W-40 / 10W-40 / 15W-40
	Class 07D	Engine oils - API CD / CE / CF-4 / CF / CG-4 / CH-4 / CI-4 / SF / SG / SH / SJ / SL or ACEA categories A / B / E	SAE 20W-20 / 30 / 5W-30 / 5W-40 / 10W-30 / 10W-40 / 15W-30 / 15W-40 for powershift transmissions SAE 10W-40 / 15W-40 for Mobile mixer drives
	Class 07E	Biodegradeable lubricant Environmental labels RAL-UZ 79 (Blue Angel) Vamil-regeling	SAE 75W-80
	Class 07F	Off highway lubricants	SAE 30
	Class 07G	Biodegradeable lubricant with environmental labels RAL-UZ 79 (Blue Angel), Vamil-regeling and Swedish standard 15 54 34	ISO VG 46 / 68
	Class 07H	Mineral based hydraulic oil HLP or HVLP in accordance with DIN 51524-2	ISO VG 46 / 68

ZF Specifications: Master List

Description	ZF List	Required Performance	Viscosity Grades
TE-ML 08 Steering systems (non-power assisted) for cars, commercial vehicles and off road vehicles		Gear oils (API GL-4, MIL-L-2105)	SAE 75W-80 / 75W-85 / 75W-90 / 80W / 80W-85 / 80W-90
		Gear oils (API GL-5, MIL-L-2105D, MIL-PRF-2105E, SAE J2360)	SAE 75W-90 / 75W-110 / 75W-140 / 80W-90 / 80W-110 / 80W-140 / 85W-90 / 85W-140 / 90
TE-ML 09 Steering systems and oil pumps for cars, commercial vehicles and off road vehicles	Class 09X	Special approvals	
TE-ML 11 Manual transmissions, double clutch transmissions and automatic transmissions for cars	Class 11A	Automatic transmission fluid (ATF)	
	Class 11B	Automatic transmission fluid (ATF)	
TE-ML 12 Axles for cars, commercial vehicles and buses Axles, differentials, wheel heads and wheel hubs - 12B,12C,12D,12E Axles and differentials with multi disc self locking differentials - 12C & 12D	Class 12B	Synthetic gear oils - subject to intensified wear protection requirements	SAE 75W-90 / 75W-110 / 75W-140
	Class 12C	Mineral oil based gear oils with limited slip additives	SAE 80W-90 / 80W-140 / 80W-110 / 85W-90 / 85W-110 / 85W-140 / 90
	Class 12D	Synthetic gear oils with limited slip additives	SAE 75W-90 / 75W-110 / 75W-140
	Class 12E	Mineral oil & semi-synthetic gear oil - subject to intensified wear protection requirements	SAE 75W-90 / 75W-110 / 75W-140 / 80W-90 / 80W-110 / 80W-140 / 85W-90 / 85W-110 / 85W-140 / 90
TE-ML 13 ZF assemblies in special purpose vehicles			
TE-ML 14 Powershift transmissions, type Ecomat, for buses, trucks and special vehicles	Class 14A	Mineral oil based ATFs	
	Class 14B	Semi-synthetic ATFs	
	Class 14C	Synthetic ATF	
	Class 14E	Fully synthetic ATF	
TE-ML 15 Brake systems for special vehicles			

ZF Specifications: Master List

Description	ZF List	Required Performance	Viscosity Grades
TE-ML 16 Transmissions for rail vehicles	Class 16A	Gear oil - Mineral oil based & semi-synthetic	SAE 80W-90 / 85W-90 / 90
	Class 16B	Gear oil - Mineral oil based & semi-synthetic	SAE 75W-90 / 80W-90 / 85W-90 / 90
	Class 16C	Gear oil - Mineral oil based & semi-synthetic	SAE 80W-90 / 80W-110 / 80W-140 / 85W-90 / 85W-110 / 85W-140 / 90
	Class 16D	Gear oil - Mineral oil based & semi-synthetic	SAE 80W-140 / 85W-140 / 140
	Class 16E	Gear oil with limited slip additives - Mineral oil based	SAE 80W-90 / 80W-110 / 80W-140 / 85W-90 / 85W-110 / 85W-140 / 90
	Class 16F	Gear oil - Synthetic	SAE 75W-90 / 75W-110 / 75W-140 / 80W-110 / 85W-110
	Class 16G	Gear oil with limited slip additives - Synthetic	SAE 75W-90 / 75W-110 / 75W-140
	Class 16K	Gear oil of viscosity grade 75W85 (synthetic, suitable for intarder)	SAE 75W-80
	Class 16L	Semi-synthetics ATFs	
	Class 16M	Synthetic ATFs	
	Class 16N	Synthetic ATFs	
	Class 16P	Synthetic gear oil suitable for intarder	SAE 75W-80
TE-ML 17 Transmissions and axles for lift-trucks	Class 17A	Gear oil in accordance with API GL-4, MIL-2105	SAE 75W-80 / 75W-85 / 75W-90 / 80W / 80W-85 / 80W-90 / 85W-90 / 90
	Class 17B	Gear oil	SAE 75W-80 / 75W-85 / 75W-90 / 80W / 80W-85 / 80W-90 / 85W-90 / 90
	Class 17C	ATF and special requirements	
	Class 17D special approvals		
	Class 17E		
	Class 17F		
TE-ML 18 Axles for cars			
TE-ML 19 Transfer and offset transmissions for commercial vehicles	Class 19A	Gear oil	SAE 80W-90 / 85W-90 / 90
	Class 19B	Mineral oil-based and semi-synthetic gear oil	SAE 75W-90 / 75W-110 / 75W-140 / 80W-90 / 85W-90 / 90
	Class 19C	Synthetic gear oil	SAE 75W-90 / 75W-110 / 75W-140
TE-ML 20 Powershift transmissions type Ecolife, for buses	Class 20E		
	Class 20E		
TE-ML 21 Tractor front axles, transmissions for harvesters and final drives	Class 21A	Gear oil	SAE 75W-90 / 75W-110 / 75W-140 / 80W-90 / 80W-110 / 80W-140 / 85W-90 / 85W-110 / 85W-140 / 90
	Class 21B	Gear oil	SAE 75W-90 / 75W-110 / 75W-140 / 80W-90 / 80W-110 / 80W-140 / 85W-90 / 85W-110 / 85W-140 / 90
	Class 21C	Gear oil with limited slip additives	SAE 75W-90 / 75W-110 / 75W-140 / 80W-90 / 80W-110 / 80W-140 / 85W-90 / 85W-110 / 85W-140 / 90
	Class 21D	Gear oil with limited slip additives	SAE 75W-90 / 75W-110 / 75W-140 / 80W-90 / 80W-110 / 80W-140 / 85W-90 / 85W-110 / 85W-140 / 90

Ford Specifications

Test	Method	MERCON® V	FORD
Miscibility	FORD Appendix 1	No separation	No separation
Viscosity			
at 100°C	ASTM D445	6.8 mm^2/s, min.	6.8 mm^2/s, min.
at -20°C	ASTM D2983	1,500 mPa.s, max.	1,500 mPa.s, max.
at -40°C	ASTM D2983	13,000 mPa.s, max.	20,000 mPa.s, max.
Shear Stability			
Degraded 100°C	ASTM D445/KRL 20 hrs	6.0 mm^2/s, min.	
Apparent Vis at 150°C	ASTM D4683		
ULSV	40 passes FISST	Read & Report	
UHSV	(D5275)	Read & Report	
DLSV		Read & Report	
DHSV		2.6 mPa.s, min.	
Apparent Vis at 100°C	ASTM D4683		
DHSV		5.4 mPa.s, min.	
Vis after mod. NOACK at -40°C Evaporation Loss	ASTM D2983 Modified NOACK (150°C, 2 hrs)	ASTM D2983 10% maximum change	2,000 mPa.s maximum change 10% maximum change
Flash Point	ASTM D92	180°C, min.	177°C, min.
Copper Strip	ASTM D130	1b, max.	1b, max
Non-Corrosion and Non-Rusting Properties	ASTM D665 A	No visible rust	No visible rust
Colour	ASTM D1500 Red	6.0 - 8.0	6.0 - 8.0
Vane Pump Wear Test	ASTM D2882	10mg, max.	10mg, max.
FZG Wear Test	ASTM D5182, 1450 rpm, 15 min. at 150°C	11 Load Stage Pass	
Four Ball Wear	ASTM D4172 600rpm, 100°C 600rpm, 150°C	Average scar diameter of two runs 0.61 mm max. 0.61 mm max.	
Falex EP Test Method B	ASTM D3233 No seizure at 100°C No seizure at 150°C	 Average of 750 lbs. min. Average of 750 lbs. min.	
FORD Timken	ASTM D2782 9lb. Load, 150°C, 10 min.	No scoring Average 0.60 mm max.	

Ford Specifications - Cont'd

Test	Method	MERCON® V	FORD
Anti-shudder Evaluation	MERCON® V Appendix 4	Candidate Fluid Equivalent to Reference	
Clutch Friction Evaluation and Durability	MERCON® V Appendix 5 20K Friction Durability	SD 1777	
		Midpoint Coeff. , 0.140 - 0.170	Midpoint Coeff. , 0.13 - 0.16
		Low Speed Dynamic, 0.135 - 0.160	Low Speed Dynamic, 0.12 - 0.16
		Stop Time, s 0.70 - 0.90	Engagement time, s 0.75 - 1.0
		E/M (S1/D) Ratio, 0.85 - 1.07	E/M (S1/D) Ratio, 0.90 - 1.0
		Static Breakaway, 0.100 - 0.155	Static Breakaway, 0.10 - 0.15
			S2/D Ratio, Rate & Report
Anti-foaming Properties	ASTM D892	Tendency/Stability	Tendency/Stability
		Sequence 1: 50/0 max.	Sequence 1: 100/0 max.
		Sequence 2: 50/0 max.	Sequence 2: 100/0 max.
		Sequence 3: 50/0 max.	Sequence 3: 100/0 max.
		Sequence 4: 100/0 max.	Sequence 4: 100/0 max.
Elastomer Compatibility (Volume Change/Hardness Change)	MERCON® V Appendix 7 Volume/Hardness	ATRR 101, -3 to +4% / 0 to +10	ATRR 101, -1 to +6% / ±7
		ATRR 201, 0 to +6% / ±5	ATRR 201, 0 to +6% / ±5
		ATRR 300, +20 to +48% / -15 to -40	ATRR 300, +20 to +48% / -15 to -40
		ATRR 400, 0 to +4% / ±8	ATRR 400, 0 to +4% / ±5
		ATRR 500, +5 to +15% / ±5	ATRR 500, -10 to +20% / -10 to 0
		ATRR 600, +5 to +35% / -30 to 0	ATRR 600, +20 to +50% / -40 to -10
		ATRR 700, -2 to +4% / 0 to +5	ATRR 700, -2 to +4% / ±5
Aluminum Beaker Oxidation Test	MERCON® V Appendix 8	Pentane Insolubles <0.35%	Pentane Insolubles <1%
		Delta TAN, 3.5 max.	Delta TAN, 4.0 max.
		Delta IR, 30 max.	Delta IR, 40 max.
		Visc. Inc. at 40°C, 25% max.	Visc. Inc. at 40°C, 40% max.
		Cu Strip Rating, 3b max.	Cu Strip Rating, 3b max
		Al Strip Rating, No Varnish	Al Strip Rating, No Varnish
		Sludge, No Sludge	Sludge, No Sludge
		Viscosity at -40°C, Rate & Report	Viscosity at -40°C, Rate & Report
		Calculated % wt. loss, Rate & Report	Calculated % wt. loss, Rate & Report
Cycling Test	GM-6297-M plus post test viscosity limits	Pass GM cycling test	Pass GM cycling test
	20K cycle used oil vis at 100°C	6.0 mm^2/s, min.	
	20K cycle used oil vis at 40°C	Rate & Report	
	20K cycle used oil vis at -40°C	Rate & Report	
Shift Feel	MERCON® V	Candidate Fluid Equivalent to Reference	Candidate Fluid Equivalent to Reference

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Allison Transmission Division General Motors

C-4 Heavy Duty Transmission Fluid Specifications

Test	Requirements	Test Method
Chemical Analysis		
Metals Content		
Barium	Report	Emission spectroscopy: ICP
Boron	Report	Emission spectroscopy: ICP
Calcium	Report	Emission spectroscopy: ICP
Magnesium	Report	Emission spectroscopy: ICP
Phosphorus	Report	Emission spectroscopy: ICP
Silicon	Report	Emission spectroscopy: ICP
Sodium	Report	Emission spectroscopy: ICP
Zinc	Report	Emission spectroscopy: ICP
Non Metals Content		
Chlorine	Report	ASTM D808
Nitrogen	Report	ASTM D3228
Sulphur	Report	ASTM D4951 or ASTM D129
Total Acid Number	Report	ASTM D664
Total Base Number	Report	ASTM D4739 or D2896
Infrared Spectrum	Report	ASTM E168
Physical Properties		
Flash Point, °C min.	170	ASTM D92
Fire Point, °C min.	185	ASTM D92
Viscosity Characteristics		
Kinematic Viscosity at 40°C	Report (1)	ASTM D445
Kinematic Viscosity at 100°C	Report (1)	ASTM D445
Apparent Viscosity	Report (1)	ASTM D2602
Brookfield Viscosity	Report Temperature at 3500 mPa.s	ASTM D2983
Stable Pour Point	Report (1)	ASTM D97

Note:
(1) Fluids shall meet SAE J300 Viscosity grades and in addition ATFs must meet General Motors and Ford requirements.

Test		Requirements	Test Method
Bench Tests			GM 6297-M,Test M (Appendix A)
Foaming Tendency			
	Foam at 95°C, max.	Nil	
	Foam at 135°C, mm max.	10	
	Break time at 135°C, secs. max.	23	
Copper Corrosion		No blackening or flaking	ASTM D130, 3 hrs at 150°C
Corrosion/Rust Protection		No visible rust on test pins	ASTM D665, procedure "A" for 24 hrs
Rust Protection		No rust or corrosion on any test surface	ASTM D1748, 98% humidity, 50 hrs at 40°C
Elastomer Compatibility		Limits are adjusted for each new elastomer batch	GM 6137-M (Appendix B)
V1	Volume difference, %	0 to 20	
	Hardness difference, points	-15 to 0	
V2	Volume difference, %	0 to 12	
	Hardness difference, points	-7 to +3	
V3	Volume difference, %	0 to 22	
	Hardness difference, points	- 14 to 0	
P1	Volume difference, %	0 to 8	
	Hardness difference, points	-10 to 0	
P2	Volume difference %	0 to 8	
	Hardness change, points	-11 to +3	
P3	Volume difference %	0 to 4	
	Hardness change, points	-8 to +4	
F1	Volume difference %	0 to 3	
	Hardness change, points	-5 to +4	
F2	Volume difference %	0 to 4	
	Hardness change, points	-2 to +5	
N1	Volume difference %	0 to 5	
	Hardness change, points	-12 to +12	
N2	Volume difference %	0 to 6	

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Allison Transmission Division General Motors - Cont'd C-4 Heavy Duty Transmission Fluid Specifications

Test	Requirements	Test Method
Oxidation Stability, C-4 Oxidation Test (THOT)	Satisfactory operation for 300 hrs	GM 6297-M (Appendix E)
Viscosity Increase, 40°C, %, max.	100	
Viscosity Increase, 100°C, %, max.	60	
TAN Increase, max.	4.0	
Carbonyl Absorbance, max.	0.75	
Wear protection C-4 Vane Pump Wear Test, Total Weight Loss, mg, max.	30	ASTM D2882 mod. (a) 80 ± 3°C (b) 6.9 Mpa
Clutch Frictional Characteristics		
C-4 Graphite Clutch Test	Mid-point dynamic coefficient and slip time must surpass limits set with minimum performance reference oil	Allison C-4 graphite clutch friction test
C-4 Paper Clutch Friction Test		Allison C-4 paper clutch friction test

Allison TES 439

Test	Requirements	Test Method
SAE Grades	0W-30, 0W-40, 30, 5W-40, 10W-40, 15W-40, 40	SAE J300
Chemical Analysis	Report (ppm): Al, Ba, B, Ca, Cr, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Si, Ag, Na, S, Sn, Ti, V and Zn	ASTM D5185
Total Acid Number	Report	ASTM D664
Physical Properties		
Flash Point, °C min.	170	ASTM D92
Viscosity Characteristics		
Kinematic Viscosity at 100°C	Report (1)	ASTM D445
Low Temperature Cranking Viscosity, cP	Report (1)	ASTM D5293
Low Temperature Pumping Viscosity, cP	Report (1)	ASTM D4684
High Temperature Shear Rate (HTHS), 150°C, cSt	Report (1)	ASTM D4683, CEC-L-36-A-90 or ASTM D5481
Glycol Response	Report (negative, trace or positive)	ASTM D2982
Bench Tests		
Foaming Tendency		ASTM D892
Seq I	10/0	
Seq II	20/0	
Seq III	10/0	
Copper Corrosion	1b	ASTM D130, 3 hrs at 150°C
Corrosion / Rust Protection	Pass	ASTM D665, procedure “A”
Rust Protection, Elongation rupture change, %	No rust or corrosion permissible on 3 of 4 surfaces	ASTM D1748, (sandblasted surface, 50°C, 50hrs)

Note:
(1) Fluids shall meet SAE J300 Viscosity grades.

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Allison TES 439 - Cont'd

Test		Requirements	Test Method
FZG Wear Test (not required if API CI-4 or API CJ-4 approved)		Failure load stage >12 EOT total weight loss <0.12g	ASTM D5182
Seals Compatibility Test		Not required if API CI-4 or CJ-4 approved	ASTM D7216
Nitrile	Volume change, %	+5 to -3	
	Hardness change, shore A	+7 to -5	
	Tensile strength change, %	+10 to - TMC 1006	
	Elongation rupture change, %	+10 to -TMC 1006	
Polyacrylate	Volume change, %	+5 to -3	
	Hardness change, shore A	+8 to -5	
	Tensile strength change, %	+18 to -15	
	Elongation rupture change, %	+10 to -35	
FKM	Volume change, %	+5 to -2	
	Hardness change, shore A	+7 to -5	
	Tensile strength change, %	+10 to -TMC 1006	
	Elongation rupture change, %	+10 to -TMC 1006	
Vamac G	Volume change, %	+TMC 1006 to -3	
	Hardness change, shore A	+5 to -TMC 1006	
	Tensile strength change, %	+10 to -TMC 1006	
	Elongation rupture change, %	+10 to -TMC 1006	
Seal Compatibility Test (TMS-22630 Material)		Elongation to first crack after first heat soak shall be ≥ 65%	TES-439 (Appendix A)
Oxidation Stability [1]		Satisfactory operation for 300 hrs	TES-439 (Appendix B)
Viscosity Increase, 40°C, %, max.		25	
Viscosity Increase, 100°C, %, max.		25	
TAN Increase, max.		2.5	
Copper Smp Corrosion, max.		4a	
Clutch Frictional Characteristics			
Graphite Clutch Test		Mid-point dynamic coefficient and slip time must surpass limits set with minimum performance reference oil	TES-439 (Appendix C)

Note:
(1) Oxidation test similar to Ford Aluminium Beaker Oxidation test (ABOT).

A Comparison of GM Specifications Requirements

General Motors ATF Specifications GM 6137-M		GM	GM	GM
Test	**Method**	**Requirement**	**Requirement**	**Requirement**
Colour	ASTM D1500	Not required	6.0 - 8.0	6.0 - 8.0
Elemental Analysis	ASTM D4951	Not required	Report ppm: Ba, B, Ca, Mg, P Si, Na, Zn, Cu, Al, Fe, Pb	Report ppm: Ba, B, Ca, Mg, P, Si, Na, Zn, Cu, Al, Fe, Pb
	ASTM D808	Not required	Report, ppm: Cl	Report, ppm: Cl
	ASTM D3228	Not required	Report, ppm: N	Report, ppm: N
	ASTM D129 OR D 4951	Not required	Report, ppm: S	Report, ppm: S
Infrared Spectrum	ASTM E168	Not required	Report	Report
Miscibility	FTM 791C Method 3470.1	No separation or colour change at end of test	No separation or colour change at end of test using reference fluid	No separation or colour change at end of test using reference fluid
Kinematic Viscosity			Report	Report
at 40°C	ASTM D445	Not Required		
at 100°C		5.5 cSt min during and at end of oxidation and cycling tests		
Flash Point	ASTM D92	160°C min.	160°C min.	170°C min.
Fire Point	ASTM D92	175°C min.	175°C min.	195°C min.
Brookfield Viscosity	ASTM D2983	4000 mPa.s (4.0 Pa.s) max. at -23.3°C	Report Viscosity, mPa.s at -10°C 1,500 mPa.s max. at -20°C	Report, mPa.s at -10°C 1,500 mPa.s max. at -20°C
		50,000 mPa.s (50.0 Pa.s) max. at -40°C	5,000 mPa.s max. at -30°C 20,000 mPa.s max. at -40°C	5,000 mPa.s max. at -30°C 20,000 mPa.s max. at -40°C

A Comparison of GM Specifications Requirements - Cont'd

General Motors ATF Specifications GM 6137-M		GM	GM			GM		
Test	**Method**	**Requirement**	**Requirement**			**Requirement**		
Copper Strip Test	ASTM D130 Mod 3 hrs at 150°C	No blackening with flaking	No blackening with flaking			1b		
Corrosion Test	ASTM D665 Procedure A	No rust on test pins	Pass			Pass		
Rust Protection	ASTM D1748 Mod Sandblasted Surface Temp. at 40°C Test time of 50 hrs	No rust or corrosion on test panels	No rust or corrosion on any test surface			No rust or corrosion on any test surface		
Foam Test	GM	No foam at 95°C	No foam at 95°C			No foam at 95°C		
		10mm max. at 135°C	6mm at 135°C			5mm max. height at 135°C		
		23 s max. break-time at 135°C	15 s max. break-time at 135°C			15 s max. collapse time at 135°C		
Fluid Effect on Seals	GM Method	Elastomers:	Procedure 1 - Total Immersion			Procedure 1 - Total Immersion[1]		
		Nitrile	Change in:			Change in:		
		Polyacrylate	Elastomer	Vol, %	Hardness pts.	Elastomer	Vol,%	Hardness pts.
		Silicone	A (Polyacrylate)	+5 to +12	-8 to +1	A (Polyacrylate)	+5 to +12	-8 to +1
			B (Nitrile)	+0.5 to +5	-3 to +6	B (Nitrile)	+1 to +6	-3 to +6
		The limits are assigned	C (Polyacrylate)	+2 to +7	-4 to +4	C (Polyacrylate)	+2 to +7	-4 to +4
		by GM for each batch	H (Fluorinated)	+0.5 to +5	-5 to +6	H (Fluorinated)	+0.5 to +5	-5 to +6
		of elastomer	J (Silicone)	+23 to +45	-30 to -13	J (Silicone)	+23 to +45	-30 to -13
			R (Ethylene/ Acrylic)	+13 to +27	-17 to -7	R (Ethylene/ Acrylic)	+13 to +27	-17 to - 7

Note:
(1) Tensile strength and elongation are now required to be reported but no limits have been set yet.

A Comparison of GM Specifications Requirements - Cont'd

General Motors ATF Specifications GM 6137-M		GM	GM	GM
Test	**Method**	**Requirement**	**Requirement**	**Requirement**
Saginaw Power Steering Pump Test	GM Method	Parts condition to be equal to or better than that obtained with reference fluid		
Vane Pump Wear Test	ASTM D2882 Mod 80+/-3°C 6.9 MPa		weight loss < 15mg	weight loss < 15mg
HEFCAD - Plate Clutch Test	GM Method	Satisfactory operation for 100 hrs	Satisfactory operation for 100 hrs	Satisfactory operation for 100 hrs
	GM uses SD-715 Clutch Plates	No unusual clutch plate wear or flaking	No unusual wear or flaking on test parts	No unusual wear or flaking on test parts
	GM uses D-1777 Clutch Plates GM uses SD-1777 Clutch Plates	Between 24 and 100 hrs of operation:- Midpoint of Dynamic Torque 115 - 175Nm Delta Torque < 14Nm Clutch Engagement time 0.45s - 0.75s	Between 20 and 100 hrs of operation:- Midpoint of Dynamic Torque 150 - 180Nm Maximum Torque > 150Nm Delta Torque < 30Nm Stop time between 0.4s - 0.6s Report End Torque Nm	Between 10 and 100 hrs of operation:- Midpoint of Dynamic Torque 150 - 180Nm Maximum Torque > 150Nm DeltaTorque < 30Nm Stop time between 0.5s - 0.6s Report End Torque Nm

A Comparison of GM Specifications Requirements - Cont'd

General Motors ATF Specifications GM 6137-M		GM	GM	GM
Test	**Method**	**Requirement**	**Requirement**	**Requirement**
Band Clutch Test	GM Method Uses 3T40 Band & Drum	Not Required	Satisfactory operation for 100 hrs	Satisfactory operation for 100 hrs
			No unusual wear or flaking on test parts	No unusual wear or flaking on test parts
			Between 20 and 100 hrs of operation:- 145Nm < Midpoint Dynamic Torque < 220Nm End Torque > 170Nm Delta Torque < 80Nm Stop time between 0.4s - 0.6s Report Maximum Torque, Nm	Between 10 and 100 hrs of operation:- 180Nm < Midpoint Dynamic Torque < 225Nm End Torque > 170Nm Delta Torque < 80Nm Stop time between 0.35 and 0.55 s Report Maximum Torque, Nm
THOT - Oxidation Test	GM Method THM-350 GM uses Transmission GM uses Hydra-matic 4L60 Transmission	Satisfactory operation for 300 hrs	Satisfactory operation for 300 hrs.	Satisfactory operation for 300 hrs
		Transmission parts cleanliness and physical condition must be equal to or better than that obtained with Reference Fluid	Transmission parts cleanliness and physical condition must be equal to or better than that obtained with Reference Fluid	Transmission parts condition must be equal to or better than that obtained with Reference Fluid
		Total Acid Number Increase, 7.0 max.	Total Acid Number Increase < 4.5	Total Acid Number Increase < 3.25
		Carbonyl Absorbance Increase, 0.8 max.	Carbonyl Absorbance Increase < 0.55	Carbonyl Absorbance Increase < 0.45
		Min. O_2 content of transmission effluent gas 2%	Min. O_2 content of transmission effluent gas 4%	Report effluent gas O_2 content
		Used Fluid Viscosity at - 23.3°C 6000mPa.s max;- 40°C Report	Used Fluid Viscosity at -20°C < 3,000 mPa.s	Used Fluid Viscosity at -20°C < 2000 mPa.s
		Used Fluid Viscosity at 100°C, 5.5 mm^2/s min.	Used Fluid Viscosity at 100°C > 5.5 mm^2/s	Used Fluid Viscosity at 100°C > 5.5 mm^2/s
		Cooler braze alloy condition shall be acceptable	No cooler braze alloy corrosion	No cooler braze alloy corrosion
				No expulsion of ATF from Vent

A Comparison of GM Specifications Requirements - Cont'd

General Motors ATF Specifications GM 6137-M		GM	GM	GM
Test	**Method**	**Requirement**	**Requirement**	**Requirement**
THCT - Cycling Test	GM Method	Satisfactory operation for 20,000 cycles	Satisfactory operation for 20,000 cycles	Satisfactory operation for 20,000 cycles
	GM uses THM 350 transmission	Transmission parts cleanliness & physical condition must be equal to or better than that obtained with the Reference Fluid	Condition of transmission parts must be equal to or better than that obtained with the Reference Fluid	Condition of transmission parts must be equal to or better than that obtained with the Reference Fluid
	GM uses	0.35s < 1-2 Shift Time < 0.70s	Total Acid Number Increase < 2.50	Total Acid Number Increase < 2.0
	Hydra-matic 4L60	0.20s < 2-3 Shift Time < 0.55s	Carbonyl Absorbance Increase < 0.35	Carbonyl Absorbance Increase < 0.30
	transmission	Total Acid Number Increase, 6.0 max.	1-2 Shift Time between 0.35 and 0.75s	1-2 Shift Time between 0.30 and 0.75s
		Carbonyl Absorbance Increase, 0.7 max.	2-3 Shift Time between 0.30 and 0.75s	2-3 Shift Time between 0.30 and 0.75s
		Used Fluid Viscosity at 100°C 5.5 mm^2/s min. during and at end of test	Report 3-4 Shift Time, s	Report 3-4 Shift Time, s
			Used Fluid Viscosity at 100°C, > 5.0 mm^2/s	Used Fluid Viscosity at 100°C, > 5.0 mm^2/s
			Used Fluid Viscosity at -20°C < 2000 mPa.s	Used Fluid Viscosity at -20°C < 2000 mPa.s
				No expulsion of ATF from Vent
Vehicle Performance Test	GM Method	Shift performance essentially equal to that obtained with the Reference Fluid	Shift performance essentially equal to that obtained with the Reference Fluid	Shift performance essentially equal to that obtained with the Reference Fluid
ECCC Vehicle Performance Test	GM Method	Not Required	Not Required	Equal to or better than Reference Fluid
Sprag Wear Test	GM Method	Not Required	Not Required	60mg maximum weight loss

GM, H Revision [GMN 10055]

Test	Method	Requirement		
Colour	ASTM D1500	6.0-8.0		
Elemental Analysis	ASTM D5185	Report, ppm: Al, Ba, B, Ca, Cr, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Si, Ag, Na, S, Sn, Ti, V, Zn		
	UOP 975	Report, ppm: F		
	ASTM D6443	Report, ppm: Cl		
	ASTM D4629	Report, ppm: N		
Fluid Profile	Proprietary GM Test	Report		
Miscibility	FTM 791C: Method 3470.1	No separation or colour change at end of test using Reference Fluid		
Kinematic Viscosity				
at 40°C	ASTM D445	Report		
at 100°C				
at 150°C				
Flash Point	ASTM D92	> 170°C		
Fire Point	ASTM D92	> 195°C		
Brookfield Viscosity	ASTM D2983	Report, cP at -10°C		
		< 1500 cP at -20°C		
		< 5000 cP at -30°C		
		< 20000 cP at -40°C		
Cu Corrosion Test	ASTM D130 Modified: 3 hrs at 150°C	1B		
Corrosion Test	ASTM D665: Procedure A	Pass		
Rust Protection Test	ASTM D1748 Sandblasted surface, 40°C, 50hrs	No rust or corrosion on any test surface		
Wear Test	ASTM D2882-00 Modified: 80 ±3°C, 6.9 MPa, 3 gal canister, Conestoga pump parts	< 10mg weight loss		
Foam Test	Appendix A	No Foam at 95°C		
		< 5mm height at 135°C		
		< 15s collapse height at 135°C		
Elastomer Test	Appendix B	Elast	%Vol.	Hard
		V1	+7 to +20	-15 to -2
		V2	+2 to +12	-7 to +3
		V3	+7 to +22	-14 to -2
		P1	0.00 to +8	-10 to 0
		P2	0.00 to +8	-11 to +3
		P3	0.00 to +4	-8 to +4
		F1	0.00 to +4	-5 to +4
		F2	0.00 to +4	-2 to +5
		N1	0.00 to +5	-12 to +12
		N2	0.00 to +6	-9 to +5

Afton CHEMICAL

GM, H Revision [GMN 10055] - Cont'd

Test	Method	Requirement
Plate Friction Test	Appendix C	Satisfactory operation for 150 h with 3T40 clutch plates
		No unusual wear or flaking on test parts
		From 10-150 hrs of operation:
		Midpoint dynamic torque, 150-180 Nm
		Max. Torque > 150 Nm
		Delta Torque < 30 Nm
		Stop Time, 0.5-0.6s
		Report End Torque, Nm
Band Friction Test	Appendix D	Satisfactory operation for 100 hrs on 3T40 GM Racing drums with 1473-2, Batch 00-12, Friction Material band
		No unusual wear or flaking on test parts
		From 10-100 hrs of operation:
		Midpoint Torque, 180-225 Nm
		End Torque > 170 Nm
		Delta Torque < 80 Nm
		Stop Time, 0.35-0.55 s
		Report Max Torque, Nm
Oxidation Test	Appendix E	Satisfactory operation for 450 hrs
		Condition of transmission parts must be equal to or better than that obtained with the Reference Fluid
		TAN increase < 3.25
		Carbonyl Absorbance increase < 0.45
		Used fluid viscosity at 100°C > 5.5 cSt
		Used fluid viscosity at -20°C < 2000 cP
		No cooler braze alloy corrosion
		No expulsion of ATF from vent
		pDSC (Report)
Cycling Test	Appendix F	Satisfactory operation for 32,000 cycles
		Condition of transmission parts must be equal to or better than that obtained with the Reference Fluid
		TAN Increase < 2.0
		Carbonyl Absorbance increase < 0.30
		Used fluid viscosity at 100°C > 5.0 cSt
		Used fluid viscosity at -20°C < 2000 cP
		1-2 shift time, 0.30-0.75s
		2-3 shift time, 0.30-0.75s
		3-4 shift time, s (Report)
		No expulsion of ATF from vent
		Used fluid viscosity at -40°C (Report, cP)
Vehicle Perf. Test	Appendix G	Shift performance essentially equal to that obtained with the Reference Fluid
ECCC Vehicle Performance Test	Appendix H	Equal to or better than Reference Fluid
Sprag Wear Test	Appendix I	< 60 mg weight loss
Low-Speed Carbon Fiber Friction Test	Appendix J	New and used fluid from Cycling Test (Report)
Aeration Test	Appendix K	New and used fluid from Cycling Test (Report)

DEXRON® VI [GMN 10060]

Test	Method	Requirement		
Colour	ASTM D1500	6.0 - 8.0		
Elemental Analysis	ASTM D5185	Report, ppm: Al, Ba, B, Ca, Cr, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Si, Ag, Na, S, Sn, Ti, V, Zn		
	ASTM D4927	Report, ppm: S		
	ASTM D6443	Report, ppm: Cl		
	ASTM D4629	Report, ppm: N		
Fluid Profile	Proprietary GM Test	Report		
Miscibility	FED-ST D791: Method 3470.1	No separation or color change during or at completion of test using reference fluid		
Density	ASTM D4052 : at 15°C	Report		
Kinematic Viscosity	ASTM D445	32 cSt at 40°C max. 6.4 cSt at 100°C max. 150°C (Report) 4.5 cSt at 100°C min. (base oil mix)		
Viscosity Index	ASTM D2270	145 min.		
Flash Point	ASTM D92	180°C min.		
Fire Point	ASTM D92	195°C min.		
Brookfield Viscosity	ASTM D2983	Report, cP at -10°C		
		< 1,500 cP at -20°C		
		< 5,000 cP at -30°C		
		< 15,000 cP at -40°C		
Copper Corrosion Test	ASTM D130 Modified: 3 hrs at 150°C	1b		
Corrosion Test	ASTM D665: Procedure A	Pass		
Rust Protection Test	ASTM D1748 a) Sandblasted surface b) 40°C c) 50 hrs	No rust or corrosion on any test surface		
Wear Test	ASTM D2882-00 Modified: a) 80 ± 3°C b) 6.9 MPa c) 3 gal canister d) Conestoga pump parts	< 10 mg weight loss		
Cold Crank Simulation	ASTM D5293 -30°C	3,200 cP max.		
High Temperature High Shear	ASTM D4683 150°C	2.00 cP min.		
Noack Evaporation	ASTM D5800	10% evaporation max., 1 hr at 200°C		
Film Thickness	EHDPROC_11 at Imperial College	Equal to or better than reference fluid		
Taper Bearing Roller Shear	CEC L-45-A-99 Modified 40 hrs	1) KV100, 5.5 cSt min. 2) 10% KV100 decrease max. 3) (BOV+EOTV)/2 > 5.0 cSt at 100°C		
Foam Test	Appendix A ASTM D892 Modified		New	Used
		Seq I	50/0	50/0
		Seq II	50/0	50/0
		Seq III	50/0	50/0
		Seq I (150°C)	50/0	150/0

DEXRON® VI [GMN 10060] - Cont’d

<table>
<tr><th>Test</th><th>Method</th><th colspan="3">Requirement</th></tr>
<tr><td rowspan="11">Elastomer Test</td><td rowspan="11">Appendix B</td><td>Elastomer</td><td>% Vol</td><td>Hardness</td></tr>
<tr><td>V1</td><td>+7 to +20</td><td>-15 to -2</td></tr>
<tr><td>V2</td><td>+2 to +12</td><td>-7 to + 3</td></tr>
<tr><td>V3</td><td>+7 to +22</td><td>-14 to -2</td></tr>
<tr><td>P1</td><td>0 to +8</td><td>-10 to 0</td></tr>
<tr><td>P2</td><td>0 to +8</td><td>-11 to +3</td></tr>
<tr><td>P3</td><td>0 to +4</td><td>-8 to +4</td></tr>
<tr><td>F1</td><td>0 to +4</td><td>-5 to +4</td></tr>
<tr><td>F2</td><td>0 to +4</td><td>-2 to +5</td></tr>
<tr><td>N1</td><td>0 to +5</td><td>-12 to +12</td></tr>
<tr><td>N2</td><td>0 to +6</td><td>-9 to +5</td></tr>
<tr><td>Plate Friction Test</td><td>Appendix C</td><td colspan="3">1) Satisfactory operation for 200 hrs
2) No unusual wear or flaking on test parts
3) Between 10 and 200 hrs of operation:
a) Midpoint dynamic torque between 135 and 175 N·m
b) Max. Torque > 150 N·m
c) Delta Torque < 40 N·m
d) Stop Time between 0.5 and 0.65 s
e) Report End Torque, N·m</td></tr>
<tr><td>Band Friction Test</td><td>Appendix D</td><td colspan="3">1) Satisfactory operation for 150 hrs
2) No unusual wear or flaking on test parts
3) Between 10 and 150 hrs of operation:
a) Midpoint dynamic torque between 180 and 290 N·m
b) End Torque > 200 N·m
c) Delta Torque < 120 N·m
d) Stop Time between 0.35 and 0.55 s
e) Report Max. Torque, N·m</td></tr>
<tr><td>Oxidation Test</td><td>Appendix E</td><td colspan="3">1) Satisfactory operation for 450 hrs
2) Condition of transmission parts must be equal to or better than that obtained with the Reference Fluid
3) TAN Increase < 2.00
4) Carbonyl Absorbance Increase < 0.45
5) Used Fluid viscosity at 100°C > 5.0 cSt
6) Used fluid viscosity at -20°C < 2,000 cP
7) Used fluid viscosity at -40°C < 15,000 cP
8) No expulsion of ATF from vent</td></tr>
<tr><td>Cycling Test</td><td>Appendix F</td><td colspan="3">1) Satisfactory operation for 42,000 cycles
2) Condition of transmission parts must be equal to or better than that obtained with the Reference Fluid
3) TAN Increase < 2.0
4) Carbonyl Absorbance Increase < 0.30
5) Used Fluid viscosity at 100°C > 5.0 cSt
6) Used fluid viscosity at -20°C < 2,000 cP
7) Used fluid viscosity at -40°C < 15,000 cP
8) 1-2 shift time between 0.30 and 0.75 s
9) 2-3 shift time between 0.30 and 0.75 s
10) Report 3-4 shift time, s
11) No expulsion of ATF from vent</td></tr>
</table>

DEXRON® VI [GMN 10060] - Cont'd

Test	Method	Requirement
Vehicle Performance Test	Appendix G	Shift performance essentially equal to that obtained with the Reference Fluid
ECCC Vehicle Performance Test	Appendix H	Equal to or better than Reference Fluid
Sprag Wear Test	Appendix I	50 mg weight loss (max)
Low-speed Carbon Fibre Friction Test	Appendix J	New and used fluid from Cycling Test must be equal to or better than Reference Fluid
Aeration Test	Appendix K	New and used fluid from Cycling Test must be equal to or better than Reference Fluid

DEXRON® VI Approved Chemistry Combinations

Company	Chemistry Name	Treat Rate (% wt.)
Afton Chemical Corp.	HiTEC® 3491K	7.18
Afton Chemical Corp.	HiTEC® 5738	1 to 5

DEXRON® VI Additional Test Methods and Requirements for New Additive Chemistries

Test	Method	Requirement
Hunting Behaviour	LR4 4.8L 4L60-E	No Hunting
Pitting	CEC L-07-A-85 C/8.3/90 (x3)	Equal to or better than Reference Fluid
Carbon Fibre Durability	FORD SP Proc. 3.14 Modified: Low Speed Carbon Fibre plates	Equal to or better than Reference Fluid
Fleet Test	GM ATF Committee	150,000 km
Additional Tests	GM ATF Committee	At the discretion of the committee

Note:
New DEXRON® VI additive chemistry combinations are required to:-

1. Successfully complete a DEXRON® VI qualification program.
2. Successfully complete a DEXRON® VI qualification program using a 75% candidate, 25% reference fluid mix.
3. Successfully complete a DEXRON® VI qualification program using a 50% candidate, 50% reference fluid mix.
4. Successfully complete a DEXRON® VI qualification program using a 25% candidate, 75% reference fluid mix.
5. Successfully complete the tests listed in the above table.

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AIST Hydraulic Standards 126 & 127

February 1997

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<tr><th>Specifications</th><th colspan="4">126</th><th colspan="4">127</th><th>ASTM Test Method</th></tr>
<tr><td>Viscosity</td><td colspan="4">32, 46, 68</td><td colspan="4">32, 46, 68</td><td>D88 & D445</td></tr>
<tr><td>Viscosity Index</td><td colspan="4">80 min.</td><td colspan="4"></td><td>D567</td></tr>
<tr><td>Hydraulic Pump Test (100 hrs at 2000psi), 150°F</td><td colspan="4">0.05% Total wear (by weight)</td><td colspan="4">50 mg max.</td><td>D2882</td></tr>
<tr><td>Four-Ball Wear Test (40 Kg, 1800 rpm, 130°F, 1 hr)</td><td colspan="4">0.80 mm scar diameter max.</td><td colspan="4">0.50 mm scar diameter max.</td><td>D4172 (MOD)</td></tr>
<tr><td>RPVOT</td><td colspan="4">120 mins., min.</td><td colspan="4">120 mins., min.</td><td>D2272</td></tr>
<tr><td>Low Temp Cycling Test (U.S. Steel method)</td><td colspan="4">Pass OK at 15°F</td><td colspan="4">Pass OK at 15°F</td><td>N/A</td></tr>
<tr><td rowspan="2">Water Emulsion Test, D1401 at 130°F</td><td>ml oil</td><td>ml water</td><td>ml emulsion</td><td>minutes</td><td>ml oil</td><td>ml water</td><td>ml emulsion</td><td>minutes</td><td></td></tr>
<tr><td>40</td><td>37</td><td>3</td><td>≤ 30</td><td>40</td><td>37</td><td>3</td><td>≤ 30</td><td>D1401</td></tr>
<tr><td>Rust Prevention Test, D665A</td><td colspan="4">Pass</td><td colspan="4">Pass</td><td>D665A</td></tr>
</table>

ASTM D6158 Standard Requirements for Mineral Hydraulic Oils 2010

Test									ASTM Test Method
ISO Viscosity grade	10	15	22	32	46	68	100	150	D2422
Kinematic Viscosity at 40°C, cSt	9.0-11.0	13.5-16.5	19.8-24.2	28.8-35.2	41.4-50.6	61.2-74.8	90.0-110	135-165	D445
Viscosity ≤ 750 cP °C, max.	-33	-23	-15	(-8)	-2	4	10	16	D2983
Viscosity index, min.	90								D2270
Gravity (specific)	Report								D1298
Appearance, visual, at 20°C	Clear & Bright								
Flash point °C, min.	125	145	165	175	185	195	205	215	D92
Pour Point °C, max.	-33	-24	-21	-18	-15	-12	-12	-12	D97
Acid Number mg KOH/g, max.	Report								D974 / D664
Rust prevention, 24 hrs	Pass								D665A and D665B
Copper corrosion, 3 hrs at 100°C, max.	2								D130
Water separability									D1401
time (mins) to 3ml emulsion max. at 54°C	30	30	30	30	30	30	-	-	
time (mins) to 3ml emulsion at 82°C	-	-	-	-	-	-	60	60	
Elastomer compatibility 100 ± 1°C/288 ± 2h, SRE-NBR 1 Elastomer (DIN53 538, Part 2 or AAMA 524, Part 2)									D471
Relative volume change, %[1]	Report	Report	0 to 15	0 to 12	0 to 12	0 to 10	0 to 10	0 to 10	
Change in Shore A hardness, rating[1]	Report	Report	0 to -8	0 to -7	0 to -7	0 to -6	0 to -6	0 to -6	
Foam									D892
Seq I, ml, max.	150/0								
Seq II, ml, max.	75/0								
Seq III, ml, max.	150/0								

Note:

(1) These numbers are provisional; ASTM is trying to establish a technical consensus for possible revision.
Specifications also exist for HL, HV and HH type oils.

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ASTM D6158 Standard Requirements for Mineral Hydraulic Oils – Cont'd 2010

Test									ASTM Test Method
Air release									D3427
time (mins) at 50°C, max.	5	5	5	5	10	13	-	-	
time (mins) at 75°C, max.	-	-	-	-	-	-	Report	Report	
Oxidation stability time for acid number of 2mg KOH/g, h, min.	1000								D943
Sludge tendancy									D4310
Total insoluble sludge, mg, max.	200								
Copper oil/water/sludge, mg	Report								
Thermal stability									D2070
Copper appearance, visual	Report	Report	Report	5	5	5	Report	Report	
Steel appearance, visual	Report	Report	Report	1	1	1	Report	Report	
Sludge, mg/100ml	Report	Report	Report	25	25	25	Report	Report	
Wear protection									D7043
Weight loss vanes + ring, mg, max. at 65 6°C/100 hrs	-	-	Report	Report	Report	-	-	-	
Weight loss vanes + ring, mg, max. at 79 4°C/100 hrs	-	-	-	-	-	Report	Report	Report	

Note:
Also specifications for HL, HV and HH type oils.

DIN 51524 Part 1 (April 2006)

Rust and Oxidation Protected Hydraulic Oils

<table>
<tr><th>Grade</th><th>HL10</th><th>HL15</th><th>HL22</th><th>HL32</th><th>HL46</th><th>HL68</th><th>HL100</th><th>HL150</th><th>ASTM Test Method</th></tr>
<tr><td>ISO Viscosity Class (DIN 51519)</td><td>VG10</td><td>VG15</td><td>VG22</td><td>VG32</td><td>VG46</td><td>VG68</td><td>VG100</td><td>VG150</td><td></td></tr>
<tr><td>Kinematic Viscosity at 0°C/(-20°C), mm²/s, max.</td><td>90 (600)</td><td>150</td><td>300</td><td>420</td><td>780</td><td>1400</td><td>2560</td><td>4500</td><td>DIN 51562-1</td></tr>
<tr><td>Kinematic Viscosity at 100°C, mm²/s, min.</td><td>2.5</td><td>3.2</td><td>4.1</td><td>5.0</td><td>6.1</td><td>7.8</td><td>9.9</td><td>14</td><td>DIN 51562-1</td></tr>
<tr><td>Pour Point, °C, max.</td><td>-30</td><td>-27</td><td>-21</td><td>-18</td><td>-15</td><td>-12</td><td>-12</td><td>-12</td><td>DIN ISO 3016</td></tr>
<tr><td>Flash Point (COC), °C, min.</td><td>125</td><td>140</td><td>165</td><td>175</td><td>185</td><td>195</td><td>205</td><td>215</td><td>DIN EN ISO 2592</td></tr>
<tr><td>Contents of undissolved matter, mg/kg, max.</td><td colspan="8">50</td><td>ISO 4405</td></tr>
<tr><td>Water content, expressed as a proportion by mass, in %</td><td colspan="8">0.05</td><td>DIN EN ISO 12973</td></tr>
<tr><td>Steel Corrosion, max.</td><td colspan="8">Method A – Pass</td><td>DIN ISO 7120</td></tr>
<tr><td>Copper Corrosion, 3 hrs at 100°C, max.</td><td colspan="8">2</td><td>DIN EN ISO 2160</td></tr>
<tr><td>Air Release, 50°C, mins., max.</td><td colspan="4">5</td><td colspan="2">10</td><td>17</td><td>25</td><td>DIN 9120</td></tr>
<tr><td>Demulsibility, mins., max.</td><td colspan="3">20 (54°C)</td><td colspan="3">30 (54°C)</td><td colspan="2">30 (82°C)</td><td>DIN ISO 6614</td></tr>
<tr><td>Oxidation Stability, Acidity max. mg KOH/g at 1000 hrs</td><td colspan="8">2.0</td><td>DIN 51587</td></tr>
<tr><td>Behaviour towards the Relative SRE-NBR 1 sealant specified in DIN 53538 Part 1, after 7 days ±2h at 100 ±1°C</td><td colspan="8"></td><td rowspan="3">DIN ISO 1817</td></tr>
<tr><td>Change % in volume</td><td>0 to 18</td><td colspan="2">0 to 15</td><td colspan="2">0 to 12</td><td colspan="3">0 to 10</td></tr>
<tr><td>Change in Shore A hardness</td><td>0 to -10</td><td colspan="2">0 to -8</td><td colspan="2">0 to -7</td><td colspan="3">0 to -6</td></tr>
<tr><td>Foam Volume, ml, max.</td><td colspan="8"></td><td rowspan="4">ISO 6247 : 1998
Cor. 1 : 1999</td></tr>
<tr><td>Sequence I</td><td colspan="8">150/0</td></tr>
<tr><td>Sequence II</td><td colspan="8">75/0</td></tr>
<tr><td>Sequence III</td><td colspan="8">150/0</td></tr>
<tr><td>Density at 15°C , in g/ml</td><td colspan="8">To be specified by supplier</td><td>DIN 51757</td></tr>
<tr><td>Ash (oxide ash), expressed as a proportion by mass, in %</td><td colspan="8">To be specified by supplier</td><td>DIN 51575</td></tr>
<tr><td>Neutralization number (acid or alkaline), in mg KOH/g</td><td colspan="8">To be specified by supplier</td><td>DIN 51558-1</td></tr>
<tr><td>Cleanliness Class</td><td colspan="8">21 / 19 / 16</td><td>ISO 4406</td></tr>
<tr><td>Wet Filtration</td><td colspan="8"></td><td rowspan="3">EDIN ISO 13357-1</td></tr>
<tr><td>F1, %</td><td colspan="8">70</td></tr>
<tr><td>F2, %</td><td colspan="8">50</td></tr>
<tr><td>Dry Filtration</td><td colspan="8"></td><td rowspan="3">EDIN ISO 13357-2</td></tr>
<tr><td>F1, %</td><td colspan="8">80</td></tr>
<tr><td>F2, %</td><td colspan="8">60</td></tr>
</table>

DIN 51524 Part 2 (April 2006)

Anti-wear Hydraulic Oils

Grade	HLP10	HLP15	HLP22	HLP32	HLP46	HLP68	HLP100	HLP150	ASTM Test Method
ISO Viscosity Class	VG10	VE15	VG22	VG32	VG46	VG68	VG100	VG150	DIN 51502
Kinematic Viscosity at 0°C/(-20°C), mm²/s, max.	90 (600)	150	300	420	780	1400	2560	4500	DIN 51562-1
Kinematic Viscosity at 100°C, mm²/s, min.	2.5	3.2	4.1	5.0	6.1	7.8	9.9	14.0	DIN 51562-1
Pour Point, °C, max.	-30	-27	-21	-18	-15	-12	-12	-12	DIN ISO 3016
Flash Point (COC), °C	125	140	165	175	185	195	205	215	DIN ISO EN 2592
Cleanliness Class	21 / 19 / 16								ISO 4406 : 1999
Contents of undissolved matter expressed as a proportion by mass, mg/kg	50								DIN ISO 5884 ISO 4405 : 1991
Water content, expressed as a proportion by mass, in % m/m (DIN ENISO 12937)	0.05								DIN 12937
Steel Corrosion, max.	Method A – Pass								DIN ISO 7120
Copper Corrosion, 3 hrs at 100°C, max.	2								
Air Release, 50°C, mins., max.	5				10	13	21	32	DIN ISO 9120
Demulsibility, mins., max.	20 (54°C)		30 (54°C)				30 (82°C)		DIN ISO 6614
FZG A/8.3/90: Load Stage Fail, min.	-		10						DIN 51354-2
Vane Pump Wear, mg, max.									DIN ISO EN 20703
Ring	-		120				-		
Vanes	-		30				-		
Oxidation Stability, Acidity max. mg KOH/g at 1000 hrs	2.0								DIN 51587
Behaviour towards the Relative SRE-NBR 1 sealant specified in DIN 53538 Part 1, after 7 days ±2h at 100 ±1°C									
Change % in volume	0 to 18	0 to 15		0 to 12		0 to 10			DIN 51587
Change in Shore A hardness	0 to -10	0 to -8		0 to -7		0 to -6			DIN ISO 1817
Foam Volume, ml, max.									ISO 4247 : 1998
Sequence I	150/0								
Sequence II	75/0								
Sequence III	150/0								

DIN 51524 Part 2 (April 2006) – Cont'd

Anti-wear Hydraulic Oils

Grade		HLP10	HLP15	HLP22	HLP32	HLP46	HLP68	HLP100	HLP150	ASTM Test Method
Density at 15°C		To be specified by supplier								DIN 51757
Ash (oxide ash), expressed as a proportion by mass, in %		To be specified by supplier								DIN 51575
Neutralization number (acid or alkaline), in mg KOH/g		To be specified by supplier								DIN 515581
Filtration Test										ISO 13357-2
	F1, min. %	80								
	F2, min.%	60								
Filtration Test										ISO 13357-1
	F1, min. %	70								
	F2, min.%	50								

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DIN 51524 Part 3 (April 2006)

HVLP Hydraulic Oils

Grade	HVLP10	HVLP15	HVLP22	HVLP32	HVLP46	HVLP68	HVLP100	HVLP150	ASTM Test Method
ISO Viscosity Class	ISO VG 10	ISO VG 15	ISO VG 22	ISO VG 32	ISO VG 46	ISO VG 68	ISO VG 100	ISO VG 150	DIN 51519
Kinematic Viscosity at -20°C, mm²/s	To be specified by supplier					-	-	-	DIN 51562-1
Kinematic Viscosity at 0°C, mm²/s	To be specified by supplier								DIN 51562-1
Kinematic Viscosity at 40°C, mm²/s	≤ 11.0	≤ 16.5	≤ 24.2	≤ 35.2	≤ 50.6	≤ 74.8	≤ 110	≤ 165	DIN 51562-1
	≤ 9.0	≥ 13.5	≤ 19.8	≥ 28.8	≥ 41.4	≥ 61.2	≥ 90	≤ 135	
Kinematic Viscosity at 100°C, mm²/s	To be specified by supplier								DIN 51562-1
Viscosity index	≥ 140							≥ 120	DIN ISO 2905
Pour Point, °C	≤ -39	≤ -39	≤ -39	≤ -30	≤ -27	≤ -24	≤ -21	≤ -18	DIN ISO 3016
Flash Point, °C	≥ 125	≥ 125	≥ 175	≥ 175	≥ 180	≥ 180	≥ 190	≥ 200	DIN ISO EN 2592
Cleanliness Class	21 / 19 / 16								ISO 4406 : 1999
Contents of undissolved matter, expressed as a proportion by mass, mg/kg	≤ 50								DIN ISO 5884
Water content, expressed as a proportion by mass, in %	≤ 0.05								DIN ENISO 12937
Steel Corrosion, max.	Pass Method A								DIN/ISO 7120
Copper Corrosion, 3 hrs at 100°C max.	Maximum corrosion rating: 2								DIN ENISO 2160
Air Release, 50°C, mins., max.	5			13			21	32	DIN/ISO 9120
Demulsibility, 54°C, mins., max.	≤ 20 (54°C)			≤ 30 (54°C)			≤ 30 (82°C)		DIN 51599
Oxidation Stability, Acidity max. mg KOH/g at 1000 hrs	≤ 2.0								DIN 51587
Behaviour towards the SRE-NBR 1 sealant specified in DIN 53538 Part 1, after 7 days ±2h at 100 ±1°C									
Change % in volume	0 to 18	0 to 15		0 to 12		0 to 10			DIN 53538-1
Change in Shore A hardness	0 to -10	0 to -8		0 to -7		0 to -6			DIN ISO 1817
Foam Volume, ml, max.									ISO 6247 : 1998
Sequence I	≤ 150/0								
Sequence II	≤ 75/0								
Sequence III	≤ 150/0								

DIN 51524 Part 3 (April 2006) – Cont'd

<table>
<tr><th colspan="2">Grade</th><th>HVLP10</th><th>HVLP15</th><th>HVLP22</th><th>HVLP32</th><th>HVLP46</th><th>HVLP68</th><th>HVLP100</th><th>HVLP150</th><th>ASTM Test Method</th></tr>
<tr><td colspan="2">Behaviour in FZG gear rig test</td><td colspan="3">-</td><td colspan="5">≥ 10</td><td></td></tr>
<tr><td rowspan="2">Loss of mass, in mg after mechanical test by vane-pump</td><td>Ring</td><td colspan="3">-</td><td colspan="2">≤ 120</td><td colspan="3">-</td><td rowspan="2">DIN 51389-2</td></tr>
<tr><td>Vane</td><td colspan="3">-</td><td colspan="2">≤ 30</td><td colspan="3">-</td></tr>
<tr><td colspan="2">Relative Viscosity loss at 40°C and 100°C after 20 hrs, %</td><td colspan="8">To be specified by supplier</td><td>DIN 51350-6</td></tr>
<tr><td colspan="2">Density at 15°C, in g/ml</td><td colspan="8">To be specified by supplier</td><td>DIN 51757</td></tr>
<tr><td colspan="2">Ash content (oxide ash) or sulphate ash, as a percentage by mass</td><td colspan="8">To be specified by supplier</td><td>DIN 51575</td></tr>
<tr><td colspan="2">Neutralization number (acid or alkaline), in mg KOH/g</td><td colspan="8">To be specified by supplier</td><td>DIN 51558-1</td></tr>
<tr><td colspan="2">Filtration Test</td><td colspan="8"></td><td rowspan="3">ISO 13357-2</td></tr>
<tr><td></td><td>F1, min. %</td><td colspan="8">80</td></tr>
<tr><td></td><td>F2, min.%</td><td colspan="8">60</td></tr>
<tr><td colspan="2">Filtration Test</td><td colspan="8"></td><td rowspan="3">ISO 13357-1</td></tr>
<tr><td></td><td>F1, min. %</td><td colspan="8">70</td></tr>
<tr><td></td><td>F2, min.%</td><td colspan="8">50</td></tr>
</table>

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German Steel Industry Specifications SEB 181222

January 2007

Hydraulic Oil Type		HLP 22	HLP 32	HLP 46	HLP 68	HLP 100	ASTM Test Method
Kinematic Viscosity, mm^2/s.	at 0°C, max.	To be specified					DIN 51562-1
	at 40°C ± 10%	22	32	46	68	100	
	at 100°C, min.	4.1	5.0	6.2	8.0	10.2	
Viscosity Index		Report					DIN/ISO 2909
Pour Point, °C, max.		-24	-21		-18		DIN/ISO 3016
Flash Point, °C, min.		180	200		220		DIN EN ISO 2592
Oil Cleanliness		21 / 18 / 15					ISO 4406-99
Water Content, Vol, -%, max.		0.03					DIN/ISO 12937
Rust Prevention, max.		Method B No Corrosion					DIN/ISO 7120
Copper Corrosion (3 hrs at 125°C), max.		Rating 1					DIN EN ISO 2160
Oxidation Stability, Acidity max. mg KOH/g at 1000 hrs		2.0					DIN 51587
Behaviour towards the SRE-NBR 1 sealant specified in DIN 53538 part 1, after 7 days at 100°C							
Relative change in volume, % max.		0 to +8					DIN 53538-1 / ISO 1817
Shore A hardness, max.		0 to -6					DIN 53505
Contents of undisolved matter, ≤ mg/kg		50					SEB 181322
Air Release, mins., max.		5 (50°C)	10 (50°C)			15 (75°C)	DIN/ISO 9126
Foam volume, ml, max.	Sequence I	100/0					ISO 6247
	Sequence II	50/0					
	Sequence III	100/0					
Demulsibility at 54°C, time to 40ml oil, mins., max.		20			30		DIN/ISO 6614
Final state, max.-min.-max., ml		42-38-0					
Demusability at 60°C, time to 40ml oil, mins.		To be specified					DIN/ISO 6614
Final state, ml		To be specified					
FZG Gear Testing (A/8.3/90)							DIN/ISO 14635-1
Load Stage Fail, min.		10	12				
Work Related Weight Change, mg/ KWh		To be specified by supplier					
Vane Pump Wear, mg, max.	Ring	60					DIN EN ISO 20763
	Vanes	15					

Afton CHEMICAL

German Steel Industry Specifications SEB 181222 – Cont'd

December 1997

Hydraulic Oil Type		HLP 22	HLP 32	HLP 46	HLP 68	HLP 100	ASTM Test Method
Density at 15°C, kg/m³		To be specified					DIN 51757
Ash % mass		To be specified					DIN ENISO 6245
Neutralisation No., mg KOH/g		To be specified					DIN 51558
Filterability	Without water, ≥ %	60					ISO 13357-2
	With 0.2% water, ≥ %	60					ISO 13357-1

ISO 11158 Hydraulic Fluids

2009

Test	HL								HM								HV								ASTM Test Method
Viscosity grade (ISO 3448)	10	15	22	32	46	68	100	150	10	15	22	32	46	68	100	150	10	15	22	32	46	68	100	150	
Kinematic Viscosity																									
at -20°C, mm^2/s, max. (1)	600	-	-	-	-	-	-	-	600	-	-	-	-	-	-	-	Report								ISO 3104 / 3105
at 0°C, mm^2/s, max. (1)	90	150	300	420	780	1400	2560	4500	90	150	300	420	780	1400	2560	4500	Report								
at 40°C, mm^2/s, min/max. (1)	9.00 11.0	13.5 16.5	19.8 24.2	28.8 35.2	41.4 50.6	61.2 74.8	90.0 110	135 165	9.00 11.0	13.5 16.5	19.8 24.2	28.8 35.2	41.4 50.6	61.2 74.8	90.0 110	135 165	9.00 11.0	13.5 16.5	19.8 24.2	28.8 35.2	41.4 50.6	61.2 74.8	90.0 110	135 165	
at 100°C, mm^2/s, min. (1)	2.50	3.20	4.10	5.00	6.10	7.80	9.90	14.0	2.50	3.20	4.10	5.00	6.10	7.80	9.90	14.0	Report								
Viscosity Index	Report								Report								140							120	ISO 2909
Density at 15°C, kg/dm^3	Report								Report								Report								ISO 3675
Colour	Report								Report								Report								ISO 2049
Appearance at 25°C	Clear & Bright								Clear & Bright								Clear & Bright								Visual
Cleanliness	a								a								a								
Flash Point (COC), °C, min.	125	140	165	175	185	195	205	215	125	140	165	175	185	195	205	215	125	125	175	175	180	180	180	200	ISO 2592
Pour Point, °C, max	-30	-27	-21	-18	-15	-12	-12	-12	-30	-27	-21	-18	-15	-12	-12	-12	-39	-39	-39	-30	-27	-24	-21	-18	ISO 3016
Total Acid Number, mg KOH/g, max.	Report								Report								Report								ISO 6618
Water content, %m/m, max.	0.025								0.025								0.025								ISO 6296 / 12937 / 20764
Water separation (2)																									ISO 6614
time to 3ml emulsion at 54°C, mins., max.	30						-		30						-		30						-		
time to 3ml emulsion at 82°C, mins., max.	-						30		-						30		-						30		
Copper corrosion, 100°C, 3 hrs, class, max.	2								2								2								ISO 2160
Rust prevention, 24 hrs.																									ISO 7120
Procedure A	Pass								Pass								Pass								
Procedure B	Report			Pass					Report			Pass					Report			Pass					

Note:

(1) The requirements of the cleanliness of the hydraulic fluid is system-dependent. Cleanliness level expressed according to ISO 4406 may be established by agreement between the supplier and the end-user. It should be noted that the fluid is exposed to various influences during transport and storage; the cleanliness level required for the system should be guaranteed by careful filtering of the hydraulic fluid when filling.

(2) This method is not required for fluids with detergent properties.

ISO 11158 Hydraulic Fluids – Cont'd

2009

<table>
<tr><th>Test</th><th colspan="8">HL</th><th colspan="8">HM</th><th colspan="8">HV</th><th rowspan="2">ASTM Test Method</th></tr>
<tr><th>Viscosity grade (ISO 3448)</th><th>10</th><th>15</th><th>22</th><th>32</th><th>46</th><th>68</th><th>100</th><th>150</th><th>10</th><th>15</th><th>22</th><th>32</th><th>46</th><th>68</th><th>100</th><th>150</th><th>10</th><th>15</th><th>22</th><th>32</th><th>46</th><th>68</th><th>100</th><th>150</th></tr>
<tr><td>Foam Test</td><td colspan="8"></td><td colspan="8"></td><td colspan="8"></td><td rowspan="4">ISO 6247</td></tr>
<tr><td>Sequence I, ml, max.</td><td colspan="8">150/0</td><td colspan="8">150/0</td><td colspan="8">150/0</td></tr>
<tr><td>Sequence II, ml, max.</td><td colspan="8">80/0</td><td colspan="8">80/0</td><td colspan="8">80/0</td></tr>
<tr><td>Sequence III, ml, max.</td><td colspan="8">150/0</td><td colspan="8">150/0</td><td colspan="8">150/0</td></tr>
<tr><td>Air Release</td><td colspan="24"></td><td rowspan="3">ISO 9120</td></tr>
<tr><td>at 50°C, mins., max.</td><td colspan="4">5</td><td colspan="2">10</td><td colspan="2">-</td><td colspan="4">5</td><td>10</td><td>13</td><td colspan="2">-</td><td colspan="4">5</td><td>13</td><td>13</td><td colspan="2">-</td></tr>
<tr><td>at 75°C, mins., max.</td><td colspan="6">-</td><td colspan="2">Report</td><td colspan="6">-</td><td colspan="2">Report</td><td colspan="6">-</td><td colspan="2">Report</td></tr>
<tr><td>Elastomer compatibility, NBR 1, 100°C, 168 hrs. (3)</td><td colspan="24"></td><td rowspan="3">ISO 6072</td></tr>
<tr><td>relative increase in volume</td><td>0 to 18</td><td colspan="2">0 to 15</td><td colspan="2">0 to 12</td><td colspan="3">0 to 10</td><td>0 to 18</td><td colspan="2">0 to 15</td><td colspan="2">0 to 12</td><td colspan="3">0 to 10</td><td>0 - 18</td><td colspan="2">0 to 15</td><td colspan="2">0 to 12</td><td colspan="3">0 to 10</td></tr>
<tr><td>change in shore A hardness</td><td>0 to -10</td><td colspan="2">0 to -8</td><td colspan="2">0 to -7</td><td colspan="3">0 to -6</td><td>0 to -10</td><td colspan="2">0 to -8</td><td colspan="2">0 to -7</td><td colspan="3">0 to -6</td><td>0 to -10</td><td colspan="2">0 to -8</td><td colspan="2">0 to -7</td><td colspan="3">0 to -6</td></tr>
<tr><td>Oxidation Stability, 1000 hrs.</td><td colspan="24"></td><td rowspan="3">ISO 4263-1</td></tr>
<tr><td>increase acid number, mg KOH/g, max.</td><td colspan="8">2.0</td><td colspan="8">2.0</td><td colspan="8">2.0</td></tr>
<tr><td>Insoluble sludge, mg</td><td colspan="8">Report</td><td colspan="8">Report</td><td colspan="8">Report</td></tr>
<tr><td>Wear Protection, FZG A/8.3/90, fail stage</td><td colspan="8">-</td><td colspan="3">-</td><td colspan="5">10</td><td colspan="3">-</td><td colspan="5">10</td><td>ISO 14635-1</td></tr>
<tr><td>Vane pump,</td><td colspan="24"></td><td rowspan="3">ISO 20763, procedure A</td></tr>
<tr><td>weight loss cam ring, mg, max.</td><td colspan="8">-</td><td colspan="3">-</td><td colspan="3">120</td><td colspan="2">-</td><td colspan="3">-</td><td colspan="3">120</td><td colspan="2">-</td></tr>
<tr><td>weight loss vanes, mg, max.</td><td colspan="8">-</td><td colspan="3">-</td><td colspan="3">30</td><td colspan="2">-</td><td colspan="3">-</td><td colspan="3">30</td><td colspan="2">-</td></tr>
<tr><td>Filterability, dry</td><td colspan="24"></td><td rowspan="3">ISO 13357-2</td></tr>
<tr><td>Stage I, %, min.</td><td colspan="8">-</td><td colspan="8">80</td><td colspan="8">80</td></tr>
<tr><td>Stage II, %, min.</td><td colspan="8">-</td><td colspan="8">60</td><td colspan="8">60</td></tr>
<tr><td>Filterability, wet</td><td colspan="24"></td><td rowspan="3">ISO 13357-1</td></tr>
<tr><td>Stage I, %, min.</td><td colspan="8">-</td><td colspan="8">50</td><td colspan="8">50</td></tr>
<tr><td>Stage II, %, min.</td><td colspan="8">-</td><td colspan="8">50</td><td colspan="8">50</td></tr>
<tr><td>Shear Stability, tapered roller bearing, 20 hrs, 60°C</td><td colspan="24"></td><td rowspan="3">CEC L-45-A-99</td></tr>
<tr><td>loss in kinematic viscosity at 40°C, %</td><td colspan="8">-</td><td colspan="8">-</td><td colspan="8">Report</td></tr>
<tr><td>loss in kinematic viscosity at 100°C, %</td><td colspan="8">-</td><td colspan="8">-</td><td colspan="8">Report</td></tr>
</table>

Note:

(3) The definition of compatibility for types of elastomers other than NBR1 (e.g. FPM, EPDM, AU) may be agreed between the supplier and the end user.

Afton CHEMICAL

MAG Cincinnati Machine Anti-wear Hydraulic Specifications 2000

Specifications	P-68 (HM-32)	P-69 (HM-68)	P-70 (HM-46)	ASTM Test Method
Viscosity Classification	ISO VG 32	ISO VG 68	ISO VG 46	
A.P.I. Gravity at 60°F	30 to 33	29 to 31	28 to 31.5	ASTM D287
Kinematic Viscosity at 40°C, mm^2/s	28.8 to 35.2	61.2 to 74.8	41.4 to 50.6	ASTM D445
Viscosity Index, min.	90	90	90	ASTM D2270
Colour, max.	2.0	3.0	3.0	ASTM D1500
Flash Point (COC), °F, min.	370	385	385	ASTM D92
Fire Point (COC), °F, min.	420	425	425	ASTM D92
Acid Number, mg KOH/g, max.	1.5	1.5	1.5	ASTM D974
Steel Corrosion, rating	Pass	Pass	Pass	ASTM D665A
Vickers pump wear test				ASTM D2882
Total Ring and Vane Wt. Loss, mg, max.	50	50	50	
CM Thermal Stability				CCM'A'
Change in Kinematic Viscosity, %, max.	5	5	5	
Acid Number change, %, max.	±50	±50	±50	
Sludge, mg/100ml, max.	25	25	25	
Steel Rod Visual, max.	1.5	1.5	1.5	
Steel Rod Deposits per 200ml, mg, max.	3.5	3.5	3.5	
Steel Rod weight loss per 200ml, mg, max.	1.0	1.0	1.0	
Copper Rod Visual, CM rating, max.	5	5	5	
Copper Rod deposits per 200ml, mg, max.	10.0	10.0	10.0	
Copper Rod weight loss per 200ml, mg, max.	10.0	10.0	10.0	

MAG Cincinnati Machine Hydraulic Specifications

2000

Specifications	P-38 (HL-32)	P-54 (HL-68)	P-55 (HL-46)	P-57 (HL-150)	ASTM Test Method
Viscosity Classification	ISO VG 32	ISO VG 68	ISO VG 46	ISO VG 150	
A.P.I. Gravity at 60°F	30 to 33	29 to 31	28 to 31.5	27 to 30	ASTM D287
Kinematic Viscosity at 40°C, mm^2/s	28.8 to 35.2	61.2 to 74.8	41.4 to 50.6	135 to 165	ASTM D445
Viscosity Index, min.	90	90	90	90	ASTM D2270
Colour, max.	2.0	3.0	3.0	5.0	ASTM D1500
Flash Point (COC), °F, min.	370	385	385	430	ASTM D92
Fire Point (COC), °F, min.	420	425	425	475	ASTM D92
Acid Number, mg KOH/g, max.	0.20	0.20	0.20	0.20	ASTM D974
Steel Corrosion, rating	Pass	Pass	Pass	Pass	ASTM D665A
CM Thermal Stability Test					CCM'A'
Change in Kinematic Viscosity, %, max.	5	5	5	5	
Acid Number increase, mgKOH/g, max.	0.15	0.15	0.15	0.15	
Sludge, mg/100ml, max.	25	25	25	25	
Steel Rod Visual	No Discolouration	No Discolouration	No Discolouration	No Discolouration	
Steel Rod Deposits per 200ml, mg, max.	3.5	3.5	3.5	3.5	
Steel Rod weight loss per 200ml, mg, max.	1.0	1.0	1.0	1.0	
Copper Rod Visual, CM rating, max.	5	5	5	5	
Copper Rod weight loss per 200ml, mg, max.	10.0	10.0	10.0	10.0	

Afton CHEMICAL

Parker Denison Hydraulic Requirements - TP30560

03 October 2007

Test	HF-0	HF-1	HF-2	HF-3	HF-4	HF-5	HF-6	ASTM Test Method
Viscosity cSt at 40°C	Report	Report	Report	65 to 140 cSt	Report	Report	Report	D445
Viscosity cSt at 100°C	Report	Report	Report	Report	Report	Report	Report	D445
Viscosity index, min	90	90	90	90	90	90	90	D2270
Gravity (specific)	840 to 900	840 to 900	840 to 900	900 to 970	1050 to 1090	950 to 1300	840 to 900	
Zinc, % wt.	Report	Report	Report				Report	
Pour Point, °C	≤ -20°C	≤ -20°C	≤ -20°C				≤ -20°C	D97
PH at 25°C					8.5 to 10.5			
Aniline Point	> 100°C (3)	> 100°C (3)	> 100°C (3)				> 100°C (3)	D611
Flash Point, °C	Report	Report	Report				Report	D92
Water %				37 to 45	40 to 45			
Acid Number	Report	Report	Report				Report	D664
Rust Test								
Distilled Water	No rust	No rust	No rust	No rust	No rust	No rust	No rust	D665A
Synthetic Sea Water	No rust	No rust	No rust	No rust	No rust	No rust	No rust	D665B
Foam								D892
Allowable Foam after 10mn	None	None	None			None	None	
Filterability								(1)
Filtration Time without water	(4)	(4)	(4)				(4) (6)	TP-02100
Filtration Time with 2% water	(4)	(4)	(4)				(4) (6)	(Denison)

Note:

(1) Denison Instructions: Consult Standard TP-02100.

(3) If < 100°C to do seal test DIN 51524.

(4) 600 seconds maximum. Do not exceed twice the filtration time without water.

(6) Increasing in Dry Phase: 100mb, in Wet Phase: 600mb.

Afton CHEMICAL

Parker Denison Hydraulic Requirements - TP30560 – Cont'd

05 March 2007

Test	HF-0	HF-1	HF-2	HF-3	HF-4	HF-5	HF-6	ASTM Test Method
Demulsibility	40/37/3 (30 minutes)	40/37/3 (30 minutes)	40/37/3 (30 minutes)				40/37/3 (30 minutes)	D1401
Sludge and Corrosion								D4310 (2)
Neutralisation Number after 1000 hrs max.	1 mgKOH	1 mgKOH	1 mgKOH				1 mgKOH	
Insoluble Sludge max.	100 mg	100 mg	100 mg				200 mg	
Total Copper max.	200 mg	200 mg	200 mg				200 mg	
Thermal Stability								CINCINNATI P70 (ISO 46)
After 168 hrs at 135°C								
Sludge max.	100mg/100ml	100mg/100ml	100mg/100ml				100mg/100ml	
Copper Wt. loss	10 mg	10 mg	10 mg				10 mg	
Copper rod rating	Report	Report	Report				Report	
Hydrolytic Stability								D2619
Copper specimen wt. loss max.	0.2 mg/cm²	0.2 mg/cm²	0.2 mg/cm²				0.2 mg/cm²	
Acidity of Water Layer max.	4.0 mgKOH	4.0 mgKOH	4.0 mgKOH/g				4.0 mgKOH/g	
FZG, Load stage before damage	9 Pass	9 Pass	9 Pass				9 Pass	DIN 51524 Teil 2
Deaeration (ISO 46)								NFT 60-149 @ 30 cSt constant
ISO 32 @ 41°C	< 7 mn	< 7 mn	< 7 mn	< 7 mn	< 7 mn	< 7 mn	< 7 mn	
ISO 46 @ 50°C	< 7 mn	< 7 mn	< 7 mn	< 7 mn	< 7 mn	< 7 mn	< 7 mn	
ISO 68 @ 59°C	< 7 mn	< 7 mn	< 7 mn	< 7 mn	< 7 mn	< 7 mn	< 7 mn	
Pump Wear max. (vanes + pins)	15 mg		15 mg				15 mg	T6H20C
Pump Wear max. for 9 pistons	300 mg	300 mg					300 mg	T6H20C
Shear Test (High VI only)	15 %	15 %	15 %				15%	KRL (20 hrs)
T6H20C	(5)	(5)	(5)				(5)	after 307 hrs
T6H20C	(5)	(5)	(5)				(5)	after 608 hrs

Note:
(2) Instructions available on request: Same as used in military specification MIL-H-24459 Appendixes A & B.
(5) Viscosity at 40°C (Start - End) > 40 cSt for ISO 46 (-8 cSt).

Afton CHEMICAL

General Motors Hydraulic Lubricant Standards

November 2004

Specifications	Anti-wear Hydraulic Oil				Zinc-Free Anti-wear Hydraulic Oil				ASTM Test Method
Product Code	**LH-02-1-04**	**LH-03-1-04**	**LH-04-1-04**	**LH-06-1-04**	**LH-02-1-04**	**LH-03-1-04**	**LH-04-1-04**	**LH-06-1-04**	
ISO Viscosity grade	22	32	46	68	22	32	46	68	D2422
Viscosity at 40°C, mm²/s	19.8-24.2	28.8-35.2	41.4-50.6	61.2-74.8	19.8-24.2	28.8-35.2	41.4-50.6	61.2-74.8	D445
Viscosity at 100°C mm²/s	4.1	5.0	6.1	7.8	4.1	5.0	6.1	7.8	D445
Viscosity at 0°C mm²/s	300	420	780	1400	300	420	780	1400	D 5133
Viscosity Index	95				95				D2270
A.P.I. Gravity	Report				Report				D287
Flash Point (COC), °C	175	190		195	175	190		195	D92
Pour Point, °C	-21	-18	-15	-12	-21	-18	-15	-12	D97
Foam									D892
Sequence I	50/0				50/0				
Sequence II	50/0				50/0				
Sequence III	50/0				50/0				
Water separability, 30 mins., max.	40/40/0				40/40/0				D1401
Air Release at 50°C (IP 313), mins.	5		10		5		10		D3427
Copper Corrosion, 3 hrs at 100°C	1b				1b				D130
Steel Corrosion, Method B	Pass				Pass				D665
Life TOST, hrs to TAN of 2.0 mg KOH/g	1500				1500				D943
Cleanliness, as received, max.	19/16/13				19/16/13				ISO 4406
Acid number, max.	1.0				1.0				D664
Zn in final product, ppm, max.	1000				10				D4628
Thermal stability									D2070
Acid number change, % max.	+/- 50				+/- 50				
Viscosity change, 40/100°C, % max.	5				5				
Sludge, mg/100ml max.	25				25				
Cu rod colour (Cin. Mil), max.	5				5				
Cu weight loss, mg max.	10				10				
Steel rod colour (Cin. Mil), max.	No discolouration				No discolouration				

General Motors Hydraulic Lubricant Standards – Cont'd

November 2004

Specifications	Anti-wear Hydraulic Oil				Zinc-Free Anti-wear Hydraulic Oil				ASTM
Product Code	**LH-02-1-04**	**LH-03-1-04**	**LH-04-1-04**	**LH-06-1-04**	**LH-02-1-04**	**LH-03-1-04**	**LH-04-1-04**	**LH-06-1-04**	**Test Method**
Compatibility with SRE-NBR 1 seals DIN 53538 (168 hrs, 100°C)									D471
Volume change %	0 to 15	0 to 12		0 to 10	0 to 15	0 to 12		0 to 10	
Shore A hardness change	0 to -8	0 to -7		0 to -6	0 to -8	0 to -7		0 to -6	
FZG A/8.3/90	10 Fail				10 Fail				DIN 5182
Filterability									TP-02100
Without water, sec., max.	600				600				
With 2% water, max.	Not to exceed double the time without water				Not to exceed double the time without water				
Hydrolytic stability									D2619
Cu weight loss, mg/cm² max.	0.2				0.2				
Acidity of water layer, mgKOH, max.	4				4				
Vickers 35VQ25 Pump Test									M-2952-S
Ring Wear, mg, max.	10				10				
Vane Wear, mg, max.	50				50				
Denison Pump Test									T6H20C
Ring and vane wear	HF-0 Approval				HF-0 Approval				
Piston wear									

JCMAS HK (JCHASP 041:2004) Hydraulic Fluid for Construction Machinery

June 2007

Requirements	Single Grade		Multi Grade		Test Method	
	VG32	VG46	VG32W	VG46W	ASTM	Others
ISO Viscosity grade	VG32	VG46	VG32	VG46	D2422	ISO3448
Physical and Chemical Properties						
Flash Point, °C	Report				D92	ISO2592
Kinematic Viscosity at 40°C, cSt	32±3.2	46±4.6	32±3.2	46±4.6	D445 D2270	ISO3104 ISO2909
Kinematic Viscosity at 100°C, cSt, min.	5.0	6.1	5.3	6.8		
Viscosity Index, min.	90	90	120	120		
Pour Point, °C, max.	-17.5	-15	-40	-30	D97	ISO3016
Low Temperature Viscosity (Brookfield), mPa.s	-	-	5000 max. at -25°C	5000 max. at -20°C	D2883	JPI5S26
Foaming Tendency / Stability					D892	ISO6247
at 24°C, ml, max.	50 / 0					
at 93.5°C, ml, max.	50 / 0					
at 24°C after 93.5°C, ml, max.	50 / 0					
Shear Stability, Viscosity Loss Ratio at 100°C, %, max.			10		D5821	JPI5S29
Oxidation Stability (TOST:95°C, 1000 hrs.)					D943	ISO4263
Acid Number Increase, mgKOH/g, max.	1.0					
Rust-Preventing, Characteristics (synthetic sea water, 24 hrs.)	No rust to be identified				D665	ISO7120
Elastomer Compatibility (NBR, 120°C, 240 hrs.)[1]					D2240 D471	ISO13226
Change in Hardness, Grade, min.	-25					
Change in Tensile, %, max.	-50					
Change in Elongation, %, max.	-50					
Change in Volume, %, max.	+30					
Elastomer Compatibility (AU, 120°C, 240 hrs.)[2]					D2240 D471	ISO13226
Change in Hardness, Grade	-5 to +5					
Change in Tensile, %, max.	-30					
Change in Elongation, %, max.	-30					
Change in Volume, %	-5 to +5					
Aniline Point, °C, min.	90				D611	ISO2977
Filterability, Komatsu Method, mins., max.	25 for 1st test and 30 for 2nd test				-	JCMAS P043
Copper Corrosion (100°C, 3 hrs), max.	1				D130	ISO2160

Note:

(1) NBR in this specification is a low nitrile type elastomer specified in ISO13226.

(2) AU in this specification is a urethane type elastomer specified in JCMAS P040.

JCMAS HK (JCHASP 041:2004) Hydraulic Fluid for Construction Machinery – Cont'd

2004

Requirements	Single Grade		Multi Grade		Test Method	
	VG32	VG46	VG32W	VG46W	ASTM	Others
Mechanical Test Requirements						
Load Carrying Capacity					D2783	JP15S32
Four-Ball weld load, 30g/1200rpm/75°C/ 1 hr, N, min.	1235					
Wear Preventive Properties						
Load Carrying capacity						JP15S40
Four-Ball scar diameter, mm, max.	0.6					
Load Carrying Capacity					D5182	DIN51354 Part 2
FZG A/8, 3/90, Stage, min.	8					
High pressure piston Pump Test[3]						
Komatsu HPV 35+35 Pump Test (34.3MPa/2100rpm/95°C/62.5L/500 hrs.)	Pass (evaluate change of flow rate and used oil and wear of pump parts)					JCMAS P044
OR Rexworth A2F10 Pump Test[3] (35MPa/1500rpm/80°C/13L/Cu Cat./500 hrs.)						JCMAS P045
Viscosity Increase Ratio, %, max.	10					D445
Acid Number Increase, mgKOH/g, max.	2.0					D974
Sludge, 0.8 μ Filter, mg/100ml, max.	10					JIS B 9931
Vane Pump Test[4]					D6973	
Vickers 35VQ25 Pump Test						
Ring Wear, mg, max.	75					-
Vane Wear, mg, max.	15					-
OR Vickers V104C Pump Test					D2882	
Wear (ring + vane), mg, max.	50					-
Friction Characteristics						JCMAS P047
Micron Clutch Test, min.	0.08					
OR SAE No.2 clutch Test (1000 cycles), μ_s, min.[5]	0.07					JCMAS P047

Note:

(3) High pressure piston pump performance are evaluated in komatsu HPV35 or Rexroth A2F10.

(4) Vane pump performance are evaluated in Vickers 35VQ25 or Vickers V104C.

(5) Friction characteristics performance are evaluated in micro clutch test or SAE No 2 Test.

SAE MS1004 Type H Hydraulic Oil Specifications

November 2006

Specifications	HL Rust and Oxidation							HM Anti-wear							HV Anti-wear and Viscosity Improver							ASTM Test Method
ISO Viscosity grade	10	15	22	32	46	68	100	10	15	22	32	46	68	100	10	15	22	32	46	68	100	D2422
Viscosity at 40°C, mm^2/s	ISO Grade +/- 10%							ISO Grade +/- 10%							ISO Grade +/- 10%							D445
Viscosity Index, min.	Report							95							140						120	D2270
Density @ 15°C, g/ml	To be specified by supplier							To be specified by supplier							To be specified by supplier							D287
Flash Point (COC), °C, min.	125		165	175	185	195	205	125		165	175	185	195	205	125		165	175	185	195	205	D92
Pour Point, °C, max.	-30	-25	-21	-18	-15	-12		-30	-25	-21	-18	-15	-12		-30	-25	-21	-18	-15	-12		D97
Foam																						D892
Seq I, max.	150/0							150/0							150/0							
Seq II, max.	150/0							150/0							150/0							
Seq III, max.	150/0							150/0							150/0							
Water separability @ 54°C, min., max.	30		40			60		30		40			60		30		40			60		D1401
Water separability @ 82°C, min., max.							60							60							60	D1401
Air Release (IP 313), mins., max.	5				10			5				10			5				10			D3427
Copper Corrosion, 3 hrs. at 100°C, max.	2							2							2							D130
Steel Corrosion, Method A or B	Pass							Pass							Pass							D665
1000 hrs. TOST, TAN mg KOH/g, max.	2							2							2							D943
Cleanliness, as received, max.	19/16/13							19/16/13							19/16/13							ISO 4406
Neutralization number, mgKOH/g, max.	To be specified by supplier							To be specified by supplier							To be specified by supplier							D664
Water content, % mass	Below limit of quantitive detectability							Below limit of quantitive detectability							Below limit of quantitive detectability							D95
Contents of undissolved matter, % mass	Below limit of quantitive detectability							Below limit of quantitive detectability							Below limit of quantitive detectability							D4055
Ash (oxide ash), % mass	To be specified by supplier							To be specified by supplier							To be specified by supplier							D482
Thermal stability																						D2070
Acid number change, %, max.	+/- 50							+/- 50							+/- 50							
Viscosity change, 40/100°C, %, max.	5							5							5							
Sludge, mg/100ml, max.	25							25							25							
Cu rod colour (Cin. Mil), max.	5							5							5							
Cu weight loss, mg, max.	10							10							1							
Steel rod colour (Cin. Mil), max.	No discolouration							No discolouration							No discolouration							

Afton CHEMICAL

SAE MS1004 Type H Hydraulic Oil Specifications – Cont'd

November 2006

Specifications	HL Rust and Oxidation				HM Anti-wear				HV Anti-wear and Viscosity Improver				ASTM Test Method
Compatibility with SRE-NBR 1 seals DIN 53538 (168 hrs, 100°C)(1)													D471
Volume change %	0 to 18	0 to 15	0 to 12	0 to 10	0 to 18	0 to 15	0 to 12	0 to 10	0 to 18	0 to 15	0 to 12	0 to 10	
Shore A hardness change	0 to -10	0 to -8	0 to -7	0 to -6	0 to -10	0 to -8	0 to -7	0 to -6	0 to -10	0 to -8	0 to -7	0 to -6	
FZG A/8.3/90[4]								11 fail				11 fail	
Hydrolytic stability													D2619
Cu weight loss, mg/cm^2 max.	0.2				0.2				0.2				
Acidity of water layer, mgKOH, max.	4				4				4				
Vickers 35VQ25 Pump Test													D2882
Ring Wear, mg, max.					120				120				
Ring Wear, mg, max.					30				30				
Denison Piston pump Test	No smearing, scoring, scratching, bronze transfer, corrosion				No smearing, scoring, scratching, bronze transfer, corrosion				No smearing, scoring, scratching, bronze transfer, corrosion				Denison P-46

Note:

(1) The definition of compatibility for types of elastomers other then NBR 1 (e.g. FPM, EPDM, AU) may be agreed between the supplier and the end-user.

Afton CHEMICAL

AGMA 9005-E02 Anti Scuff / Anti-wear E.P. Oils

December 2002

Test	ASTM Test Method	Requirements										
ISO Viscosity grade	D2422	32	46	68	100	150	220	320	460	680	1000-3200	> 3200
Viscosity at 40°C, mm^2/s	D445	28.8-35.2	41.4-50.6	61.2-74.8	90.0-110	135-165	198-242	288-352	414-506	612-748	900-2420	2880-3520
Viscosity at 100°C, mm^2/s	D445	Report										
Viscosity index, min.	D2270	90								85		Report
Bulk fluid dynamic viscosity at cold start-up, mPa/s, max.	D2983	150,000										
Flash Point, °C, min.	D92	180			200							
Resistance to aging at 121°C - max., % increase in kinematic viscosity at 100°C	D2893	6						8	10	15	Report	
Water content, ppm, max.	D6304	300										Report
Foam suppression	D892	5 Minutes Blow						10 Minutes Settle			5 Minutes Blow	10 Minutes Settle
Volume of foam (ml), max., after:												
Seq I at 24°C		50						0			75	10
Seq II at 93.5°C		50						0			75	10
Seq III at 24°C		50						0			75	10
Cleanliness	None visual	Must be free of visible suspended or settled contaminants at the time it is installed for use										
Water separation	D2711 (Procedure B)											
% H_2O in oil after 5 hr test, max.		2.0							2.0			Report
Cuff after centrifuging, ml, max.		1.0							4.0			Report
Total free H_2O collected during entire test starting with 90 ml H_2O, ml, min.		80.0							50.0			Report
Rust prevention, Part B	D665	Pass										
Copper corrosion prevention, 3 hrs @ 100°C, rating, max.	D130	1b										
Scuffing load capacity, FZG visual method, A/8.3/90, fail stage, min.	D5182	10		12				>12				

Afton CHEMICAL

AIST Requirements No. 224 Lead Free E.P. Gear Oil 2010

Test	Limits
A.P.I. Gravity, D287	25 min.
Viscosity Index, D567	95 min.
Precipitation Number, D91	Trace
Pour Point, D97	-9°C max. (based on viscosity)
Flash Point (COC), D92	
ISO Grade 150 and up	232.2°C min.
ISO Grade 68 and 100	203.4°C min.
3 hrs. Copper Strip Corrosion, D130	1b max.
Rust Test (A & B), D665	Pass
S-200 Oxidation - 312 hrs. at 121.1°C (250°F)	
Viscosity Increase at 98.9°C (210°F)	6% max.
Precipitation Number After Test	0.1 max.
Demulsibility, D2711	
Free Water	80.0 ml min.
Emulsion	1.0 ml max.
H_2O in Oil	2.0% max.
Four-Ball E.P. Test, D2783	
Load Wear Index	45 kg min.
Weld Point	250 kg min.
Four-Ball Wear Test, D2266	
20 kg. at 1800 rpm for 1 hr.	Scar Diameter 0.35 mm max.
Timken Load Arm Test, D2782	60 lbs min.
FZG - Four Square Gear Test	11th stage min.

DBGI Specifications for Mineral Based Lubricating Oils for use in Industrial Enclosed Gear Units.

Scope:

This specification covers the requirements for ten grades and three classifications of mineral based lubricating oils for use in DAVID BROWN enclosed gear units. The grades are numbered 0 to 9 and will be associated with a classification character.

M - straight mineral oils
A - anti-wear or mild EP additive oils
E - industrial extreme pressure additive oils

Description:

The lubricants shall be stable homogeneous blends of highly refined mineral oils and additives. They should not contain any grit, abrasives, sediments or other impurities. The lubricants should be branded products on general sale or intended to be so.

Classifications:

For mineral based lubricant the following general classifications will be used:

Type M These lubricants will usually contain additives to reduce corrosion, oxidation and foaming. They may contain other additives designed to improve their performance in service. They should not contain additives which will adversely affect the performance of sprag holdback (or similar) devices.

Type A These lubricants will usually contain anti-wear or mild extreme pressure additives which improve the load carrying properties of the base oil.

Type E These lubricants will contain additives which are designed to improve the load carrying properties of the base oil. They should not contain any lead or lead based additives.

The requirements for all three lubricant types are the same or similar in all respects except for carrying capacity.

David Brown Requirements for a Mineral Based Lubricant

Test	ASTM Test Method	Conditions	DBGI Lubricant Grade										
			Limit	0	1	2	3	4	5	6	7	8	9
Kinematic Viscosity mm^2/s	IP 71, ASTM D445	at 40°C	min.	24.5	36.0	52.8	77.6	114	167	245	360	528	776
		at 40°C	max.	36.0	52.8	77.6	114	167	245	360	528	776	1140
		at 100°C	min.	5.1	6.4	8.1	10.5	13.6	17.4	22.3	28.5	36.5	46.2
Viscosity Index	IP 226, ASTM D2270		min.	90	90	90	90	90	90	90	90	90	90
Pour Point (°C)	IP 15, ASTM D97		max.	-6	-6	-6	-6	-6	-3	-3	0	0	0
Load Carrying Capacity	IP 334, A/8.3/90 (Visual method)	FZG Load Stage at which damage occurs											
		Lubricant Type M	min.	5	5	6	6	6	6	7	7	7	7
		Lubricant Type A	min.	7	7	8	8	8	9	9	9	10	10
		Lubricant Type E	min.	11	11	12	12	12	12	12	> 12	> 12	> 12
Corrosion	IP 154, ASTM D130	Copper Strip Classification after 3 hrs. at 100°C	max.	1b	1b	1b	1b	1b	1b	1b	1b	1b	1b
Corrosion	IP 135, ASTM D665	Rust Prevention in the presence of water for 24 hrs.											
		Lubricant Type M	Pass	PROCEDURES A AND B									
		Lubricant Types A & E	Pass	PROCEDURE A									
			Report	DEGREE OF RUSTING - PROCEDURE B									
Oxidation Stability	ASTM D2893, (at 95°C)	% Change in Kinematic Viscosity at 100°C	max.	10	10	10	10	10	10	10	10	10	10

David Brown Requirements for a Mineral Based Lubricant – Cont'd

Test	ASTM Test Method	Conditions	DBGI Lubricant Grade										
			Limit	0	1	2	3	4	5	6	7	8	9
Foam Tendency/Stability	IP 146, ASTM D892	Volume of Foam (ml) Sequence I (24°C)											
		After 5 mins. blow	max.	75	75	75	75	75	75	75	75	75	75
		After 10 mins. rest	max.	10	10	10	10	10	10	10	10	10	10
		Sequence II (93°C)											
		After 5 mins. blow	max.	75	75	75	75	75	75	75	75	75	75
		After 10 mins. rest	max.	10	10	10	10	10	10	10	10	10	10
		Sequence III (24°C)											
		After 5 mins. blow	max.	75	75	75	75	75	75	75	75	75	75
		After 10 mins. rest	max.	10	10	10	10	10	10	10	10	10	10
Air Release	IP 313	Minutes at 50°C	max.	9	10	12	18	30	-	-	-	-	-
		Minutes at 90°C	max.	-	-	-	-	-	9	10	12	16	24
Demulsibility	ASTM D2711	Lubricant Types M & A											
		Water in Oil (%)	max.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
		Emulsion (ml)	max.	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
		Total Free Water (ml)	min.	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	ASTM D2711 Appendix 12	Lubricant Type E											
		Water in Oil (%)	max.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
		Emulsion in Oil (ml)	max.	2.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	4.0	4.0
		Total Free Water (ml) (Report average result)	min.	60.0	60.0	60.0	60.0	60.0	60.0	60.0	50.0	50.0	50.0

DIN 51517 Part 3 - Lubricating Oils CLP

August 2011

Lubricant Type	CLP 32	CLP 46	CLP 68	CLP 100	CLP 150	CLP 220	CLP 320	CLP 460	CLP 680	CLP 1000	CLP 1500	ASTM Test Method
ISO Viscosity grade	32	46	68	100	150	220	320	460	680	1000	1500	-
Viscosity at 40°C, mm²/s	28.8-35.2	41.4-50.6	61.2-74.8	90-110	135-165	198-242	288-352	414-506	612-748	900-1100	1350-1650	DIN EN ISO 3104
Viscosity Index	90								85			DIN/ISO 2909
Flash Point (COC), °C	180			200								DIN EN ISO 2592
Pour Point °C	-12				-9				-3			DIN/ISO 3016
Neutralisation Number, mg KOH/g	Report											DIN 51558-1
Density at 15°C, kg/m³	Report											DIN 51757
Water Content, %	<0.1 max											DIN 51777-2
Foam after 10 mins., Sequence I, II & III	100/10							150/60				ISO 6427
Water Separability @ 54°C, mins., max.	30	30	30	-	-	-	-	-	-	-	-	DIN ISO 6614
Water Separability @ 82°C, mins., max.	-	-	-	30	30	30	30	45	60	60	60	
Copper Corrosion, 3 hrs at 100°C	1 max.											DIN EN ISO 2160
Steel Corrosion, Method A	Pass											DIN/ISO 7120
Oxidation Stability, 95°C for 312 hrs												DIN EN ISO 4263-4
Increase in viscosity at 100°C, %	6 max.											
Precipitation number, %	0.1 max.											
FZG Scuffing Test, A/8.3/90	12 Fail min.											DIN ISO 14635-1
FAG FE-8 bearing wear test												DIN 51819-3
Roller wear, mg	30 max.											
Cage wear, mg	Report											
Compatibility with Seals SRE-NBR 28, 7 days @ 100°C												DIN ISO 1817
Relative change in volume, % max.	-0 to +10											
Change of Shore A hardness, % max.	-10 to +5											
Change of Tensile strength, % max.	30											
Change of Elongation, % max.	40											

Siemens Specification for Flender Gear Oils Revision 13

February 2011

Lubricant Type	Mineral	Synthetic	ASTM Test Method
DIN 51517 Part III	Pass*	Pass*	Various
FAG FE-8 roller bearing wear, D-7.5/80-80 ***			DIN 51819-3
Roller wear, mg	<30	<30	
Cage wear, mg	Report	<100	
Compatibility with internal coating Mäder P22-8050 ***	Pass	Pass	Mäder P22-8050
Compatibility with internal coating Mäder Nuvopur Aqua Primer 510.1.1400	Pass	Pass	Mäder Nuvopur 510.1.1400
Compatibility with liquid compound Loctite 128068 ***	Pass	Pass	Loctite material 128068
Compatibility with elastomer seals ***			DIN ISO 1817
Static Test, 72 NBR 902	1008 hrs at 100°C	1008 hrs at 100°C	
Hardness Shore A	± 5	± 5	
Volume swell, %	+ 5 / -2	+ 5 / -2	
Tensile Strength, %	-50 to + 20	-50 to + 20	
Elongation at Break, %	-60 to + 20	-60 to + 20	
Static Test, 75 FKM 585 ***	1008 hrs at 110°C	1008 hrs at 130°C	DIN ISO 1817
Hardness Shore A	± 5	± 5	
Volume swell, %	+ 5 / -2	+ 5 / -2	
Tensile Strength, %	-50 to + 20	-50 to + 20	
Elongation at Break, %	-60 to + 20	-60 to + 20	
Static Test, 75 FKM 260466 ***	1008 hrs at 110°C	1008 hrs at 130°C	DIN ISO 1817
Hardness Shore A	± 5	± 5	
Volume swell, %	+ 5 / -2	+ 5 / -2	
Tensile Strength, %	-50 to + 20	-50 to + 20	
Elongation at Break, %	-60 to + 20	-60 to + 20	
Dynamic Test, 72 NBR 902, 1008 hrs, 80°C 2 radial shaft seals ***	Pass	Pass	DIN ISO 3761
Dynamic Test, 75 FKM 585, 1008 hrs, 90°C 2 radial shaft seals ***	Pass	-	
Dynamic Test, 75 FKM 585, 1008 hrs, 110°C 3 radial shaft seals ***	-	Pass	
Dynamic seal Test 75 260466, 1008 hrs, 110°C 2 radial shaft seals ***	-	Pass	DIN ISO 3761
Flender Foam Test ***	1 min. after motor switched off		Flender report GG-V 425
Original Oil	15% max.	15% max.	
With 2% impurity of running in oil	15% max.	15% max.	
With 4% impurity of running in oil	15% max.	15% max.	
FZG Scuffing load Test, A/16.6/90 ***	>12	>12	DIN ISO 14635-1
FZG Scuffing load Test, A/8.3/90 ***	>12	>12	DIN ISO 14635-1
FZG Grey Staining Test at 90°C ***	≥10 & GF=High**	≥10 & GF=High**	FVA 54/7

Note:

* Flender has a basic requirement for oil to meet CLP quality in accordance with DIN 51517 Part III. Latest DIN specification is dated June 2009.

** ≥10 is based on a profile deviation measurement only. Flender have now updated the micropitting requirements as follows: In addition to profile deviation measurement, Flender now also specifically requires a GF class 'high' evaluated by a secondary evaluation method of the FVA 54/ 7 method looking at weight loss and micropitting area. Also Flender now requires a stabilization of weight loss values and micropitting levels in the endurance phase. The specification will be updated to reflect the change in requirements.

*** Must use specified laboratory as mandated by Siemens.

Afton CHEMICAL

ISO 12925-1:1996 Enclosed Gears of Category CKC 2002

Test	Specifications											ASTM Test Method
ISO Viscosity grade	VG 32	VG 46	VG 68	VG 100	VG 150	VG 220	VG 320	VG 460	VG 680	VG 1000	VG 1500	ISO 3448
Appearance	Bright & Clear	Bright & Clear	Bright & Clear	Bright & Clear	Bright & Clear	Bright	Bright	Bright	Bright	Bright	Bright	(1)
Viscosity index, min.	90	90	90	90	90	90	90	90	85	85	85	ISO 2909
Pour Point °C, max.	-12	-12	-12	-12	-9	-9	-9	-9	-3	-3	-3	ISO 3016
Flash Point °C, min.	180	180	180	200	200	200	200	200	200	200	200	ISO 2592
Foaming tendancy / stability, max. ml	100/10	100/10	100/10	100/10	100/10	100/10	100/10	100/10	100/10	100/10	100/10	ISO 6247
Copper corrosion, 3 hrs at 100°C, max.	1	1	1	1	1	1	1	1	1	1	1	ISO 2160
Demulsibility: Method: Appendix X2 modification (90 ml water at start):												ASTM D2711
Free water, min. ml	80	80	80	80	80	80	80	80	80	80	80	
Emulsion, max. ml	1	1	1	1	1	1	1	1	1	1	1	
Water-in-oil, max. ml	2	2	2	2	2	2	2	2	2	2	2	
Rust Test: Methods A and B	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	ISO 7120
Oxidation stability at 95°C												ASTM D2893
Viscosity increase at 100°C, max. %	6	6	6	6	6	6	6	6	6	6	6	
Precipitation number, max.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
Load-carrying property FZG A/8, 3/90 °C Fail stage, min.	12	12	12	12	12	12	12	12	12	12	12	DIN 51354-2

Note:

(1) There is presently no accepted test method. Visual observation is to be reported as indicated. The objective is to ensure that the lubricant does not appear turbid or contain suspended or settled impurities.

ISO 12925-1 Standard also covers other types of gear oils. Refer to official standard for further information.

cor.1:2002 (E) - issued 15 February 2002.

SEB 181226 Industrial Gear Specifications – Cont'd

September 2007

Specifications	CLP Type Oils							ASTM Test Method
ISO Viscosity grade	68	100	150	220	320	460	680	D2422
Viscosity at 40°C, mm²/s	64.6-71.4	95-105	142.5-157.5	209-231	304-336	437-483	646-714	51562-1
Viscosity Index, min.	90							ISO 2909
Density @ 15°C, g/ml	Report							51757
Flash Point (COC), °C, min.,	210							ISO 2592
Pour Point, °C, max.	-15		-12	-9		-6	-3	ISO 3016
Water separability @ 54°C, mins., max.	10							ISO 6614
Water separability @ 82°C, mins., max.			20		30		40	ISO 6614
Air Release (IP 313), mins., max.	15	20		25	40	55	75	ISO 9120
Foam								ISO 6247
Sequence I	50/0							
Sequence II	50/0							
Sequence III	50/0							
Copper Corrosion, 3 hrs. at 125°C, max.	1							ISO 2160
Steel Corrosion, Method A or B	Pass							51585
Aging behaviour, TAN after 1000 hrs. at 95°C, mg KOH/g max.	1.5							51587/51558-1
Neutralization number, mgKOH/g max.	Report							51558-1
Water content, % volume	Below limit of quantitive detectability							ISO 3733
Content of undissolved matter, max. mg/kg	50							SEB 181322
Compatibility with SRE-NBR 1 seals DIN 53538 (168 hrs, 100°C)								53521
Volume change %	0 to 8							53538-1
Shore A hardness change	0 to -6							53505
FZG A/8.3/90	12 Pass							51354-2
FAG FE-8 roller bearing wear, 80kN								51819-3
Roller wear, mg, max.	30							
Cage wear, mg	Report							
Conradson Carbon residue, % max.	Report							51551-1
Halogen content, %	0.01							51408-1
PCB content, mg/kg	Current detection limit							12766
PAK (PAH) content, mg/kg	10							GC-MS-Analysis

Air Compressor Lubricant Standard DIN 51506

September 1985

Oil Classifications	Compressed Air Temperature °C maximum	
	For compressors on moving equipment for brakes, signals and tippers	For compressors with storage tanks and pipe network systems
VDL	220	220
VC VCL	220	160[1]
VB VBL	140	140

Note:

(1) Some types of compressors up to 180°C with VCL or engine oils.

Air Compressor Lubricant Standard DIN 51506

September 1985

Lube Oil Group	VB and VBL									VC and VCL					ASTM Test Method
ISO Viscosity grade	22	32	46	68	100	150	220	320	460	32	46	68	100	150	
Kinematic Viscosity, min. at 40°C, mm^2/s, max.	19.8 to 24.2	28.8 to 35.2	41.4 to 50.6	61.2 to 74.8	90 to 110	135 to 165	198 to 242	288 to 352	414 to 506	28.8 to 35.2	41.4 to 50.6	61.2 to 74.8	90 to 110	135 to 165	DIN 51561
at 100°C, mm^2/s, min.	4.3	5.4	6.6	8.8	11	15	19	23	30	5.4	6.6	8.8	11	15	
Flash Point (COC), °C, min.	175		195		205	210	225		255	175	195		205	210	ISO 2592
Pour Point, °C, max.	-9					-3	0			-9				-3	ISO 3016
Ash, % m/m, max.	VB & VC: 0.02 oxide ash						VBL, VCL sulphated ash to be specified by supplier								DIN 51675
Water soluble acids	Neutral														DIN 51558
TAN, mg KOH/g max.	VB & VC: 0.15						VBL, VCL to be specified by supplier								DIN 51558 part 1
Water, % Mass	0.1 max.														ISO 3733
% Mass CRC max. after air aging	2.0					2.5				1.5				2.0	DIN 51352 part 1
% Mass CRC max. of 20% distillation residue	Not required									0.3				0.75	DIN 51535

Note:

Grades VB and VC are pure mineral oils. Grade VDL contains additives to increase aging resistance.

Grades VBL and VCL are HD type engine oils which are used as mineral oils.

Air Compressor Lubricant Standard DIN 51506

September 1985

Lube Oil Group	VDL					ASTM Test Method
ISO Viscosity grade	32	46	68	100	150	
Kinematic Viscosity						DIN 51561
at 40°C, mm^2/s	28.8 to 35.2	41.4 to 50.6	61.2 to 74.8	90 to 110	135 to 165	
at 100°C, mm^2/s, min.	5.4	6.6	8.8	11	15	
Flash Point (COC), °C, min.	175	195		205	210	ISO 2592
Pour Point, °C, max.	-9				-3	ISO 3016
Ash, % mass, max.	Sulphated ash to be specified by supplier					DIN 51575
Water soluble acids	Neutral					DIN 51558
TAN, mg KOH/g, max.	To be specified by supplier					DIN 51558 part 1
Water, % mass	0.1 max.					ISO 3733
% mass CRC max. after air aging	Not required					DIN 51352 part 1
% mass CRC max. after air/Fe_2O_3 aging	2.5		3.0			DIN 51352 part 2
% mass CRC max. of 20% distillation residue	0.3				0.6	DIN 51356
Kinematic Viscosity at 40°C max. of 20% distillation residue mm^2/s	Maximum of five times the value of the new oil					DIN 51535

General Motors Compressor Lubricant Standards

November 2004

Specifications Type	Compressor and turbine oils				Synthetic compressor / turbine oil - ester based				Synthetic compressor / turbine oil - non ester				ASTM Test Method
Product Code	LJ-03-1-04	LJ-04-1-04	LJ-06-1-04	LJ-10-1-04	LJ-03-2-04	LJ-04-2-04	LJ-06-2-04	LJ-10-2-04	LJ-03-3-04	LJ-04-3-04	LJ-06-3-04	LJ-10-3-04	
ISO Viscosity grade	32	46	68	100	32	46	68	100	32	46	68	100	-
Viscosity at 40°C, mm²/s	28.8-35.2	41.4-50.6	61.2-74.8	90-110	28.8-35.2	41.4-50.6	61.2-74.8	90-110	28.8-35.2	41.4-50.6	61.2-74.8	90-110	D445
Viscosity at 100°C, mm²/s	Report												D445
Viscosity Index	95				85				120				D2270
A.P.I. Gravity	Report												D287
Flash Point (COC), °C	190			195	200				210				D92
Pour Point, °C	-10				-20			-15	25			-20	D97
Auto ignition temperature, °C min.	N/A				350				350				D2155
Foam													D892
Sequence I	50/0												
Sequence II	50/0												
Sequence III	50/0												
Water Seperability, 30 mins., max.	40/40/0				40/37/0				40/40/0				D1401
Copper Corrosion, 3 hrs. at 100°C	1b				1b				1b				D130
Steel Corrosion, Method B	Pass												D665
Life TOST, hrs. to TAN of 2.0 mg KOH/g	2000				Report				2000				D943
Cleanliness, as received, max.	20/17/14												ISO 4406
Thermal stability													D2070
Acid Number change, %, max.	+/- 50 (or 0.15)												
Viscosity change, 40/100°C, % max.	5												
Sludge, mg/100ml, max.	25												
Cu rod colour (Cin. Mil), max.	5												
Cu weight loss, mg max.	10												
Steel Rod Colour (Cin. Mil), max.	No Discolouration												

General Motors Compressor Lubricant Standards – Cont'd

November 2004

Specifications Type	Compressor and turbine oils				Synthetic compressor / turbine oil - ester based				Synthetic compressor / turbine oil - non ester				ASTM
Product Code	LJ-03-1-04	LJ-04-1-04	LJ-06-1-04	LJ-10-1-04	LJ-03-2-04	LJ-04-2-04	LJ-06-2-04	LJ-10-2-04	LJ-03-3-04	LJ-04-3-04	LJ-06-3-04	LJ-10-3-04	Test Method
Four-Ball wear 40kg, mwsd, mm, max.	0.4												D4172
Aniline point	Report												D611
Compatibility with SRE-NBR 1 seals (168 hrs, 100°C)													D471 (DIN 53538)
Volume change %	-10 to 10												
Shore A hardness change	-7 to 10												
Conradson Carbon residue, % max.	0.05												D189

SAE MS I003-2 Compressor Oils

January 2004

Requirements	Ester based						Polyalphaolefin based						ASTM Test Method
Type of lubricating oil	DEA	DEB	DEC	DEG	DEH	DEJ	DPA	DPB	DPC	DPG	DPH	DPJ	
ISO Viscosity Classifications	VG 32-150						VG32-100						D2422
Kinematic Viscosity at 40°C, mm²/s	ISO Grade ± 10%						ISO Grade ± 10%						D445
Viscosity Index	-						130 min						D2270
Pour Point, °C	≤ -20						≤ -35						D97
Flash Point, °C	VG 32 ≥ 220						VG 32 ≥ 210						D92
	VG 46 ≥ 230						VG 46 ≥ 230						
	VG 68 ≥ 240						VG 68, 100 ≥ 250						
	VG 100 - 150 ≥ 250												
Demulsibility	-			40/37/3						40/40/0			D1401
Demulsibility													D2711
Water in oil after 5 hrs	Report			Report			Report			≤ 1%			
Emulsion after centrifuge	Report			Report			Report			≤ 2 ml			
Total free water	Report			Report			Report			≥ 60 ml			
Water content, ppm	≤ 100						≤ 100						D95 D1744
Corrosive effect on steel	Not exceeding degree of corrosion ISO 7120 - 0 - A						Not exceeding degree of corrosion ISO 7120 - 0 - A						D665A
Corrosive effect on copper 3 hrs at 100°C	Not exceeding degree of corrosion 1B: ISO 2160 - 100A3						Not exceeding degree of corrosion 1B: ISO 2160 - 100A3						D130
Foam Volume, in ml.													D892
Sequence I	≤ 50/0						≤ 50/0						
Sequence II	≤ 50/0						≤ 50/0						
Sequence III	≤ 50/0						≤ 50/0						
Oxidation stability TAN < 2 hrs	1000	1500	2000	1000	1500	2000	2000	3000	4000	2000	3000	4000	D943
Auto Ignition Temperature, °C	380 min												E-659

SAE MS I003-2 Compressor Oils – Cont'd

January 2004

<table>
<tr><th>Requirements</th><th colspan="6">Ester based</th><th colspan="6">Polyalphaolefin based</th><th rowspan="2">ASTM Test Method</th></tr>
<tr><th>Type of lubricating oil</th><th>DEA</th><th>DEB</th><th>DEC</th><th>DEG</th><th>DEH</th><th>DEJ</th><th>DPA</th><th>DPB</th><th>DPC</th><th>DPG</th><th>DPH</th><th>DPJ</th></tr>
<tr><td>Density at 15°C in g/ml</td><td colspan="6">To be specified by the supplier</td><td colspan="6">To be specified by the supplier</td><td>D4052
D1298</td></tr>
<tr><td>Four-Ball Wear Test (40kg load)
wear scar diameter, mm</td><td colspan="3">-</td><td colspan="3">≤ 0.4</td><td colspan="3">-</td><td colspan="3">≤ 0.4</td><td>D4172</td></tr>
<tr><td>Behaviour towards sealant.
Relative change in % volume</td><td colspan="6">-10 to +10</td><td colspan="6">-10 to +10</td><td>D471</td></tr>
<tr><td>Behaviour towards sealant.
Change in Shore hardness</td><td colspan="6">-7 to +10</td><td colspan="6">-7 to +10</td><td>D471</td></tr>
<tr><td>Level of Contamination by solid particles, max.</td><td colspan="6">20/18/14</td><td colspan="6">20/18/14</td><td></td></tr>
<tr><td>Thermal Stability</td><td colspan="12"></td><td rowspan="8">D2070</td></tr>
<tr><td>Comparative IR Scan</td><td colspan="6">Report</td><td colspan="6">Report</td></tr>
<tr><td>Acid Number Change</td><td colspan="6">0.15</td><td colspan="6">0.15</td></tr>
<tr><td>Viscosity Change</td><td colspan="6">≤ 5%</td><td colspan="6">≤ 5%</td></tr>
<tr><td>Sludge, mg / 100 ml</td><td colspan="6">≤ 25</td><td colspan="6">≤ 25</td></tr>
<tr><td>Copper rod colour</td><td colspan="6">≤ 5</td><td colspan="6">≤ 5</td></tr>
<tr><td>Copper weight loss, mg</td><td colspan="6">≤ 10</td><td colspan="6">≤ 10</td></tr>
<tr><td>Steel rod colour (Cinn, Mil.)</td><td colspan="6">1 max.</td><td colspan="6">1 max.</td></tr>
<tr><td rowspan="2">Neutralization number to be run on base oil only, mg KOH/g</td><td colspan="6">0.5 max.</td><td colspan="6"></td><td>D664</td></tr>
<tr><td colspan="6"></td><td colspan="6">1.0 max.</td><td>D974</td></tr>
</table>

DIN 51515 Part 1 and Part 2

February 2010

Specifications	DIN 51515-1				DIN 51515-2		ASTM Test Method
	L-TD - for normal service				L-TG - for high temperature service		
ISO Viscosity grade	32	46	68	100	32	46	-
Viscosity at 40°C, mm^2/s	28.8-35.2	41.4-50.6	61.2-74.8	90.0-110.0	28.8-35.2	41.4-50.6	ISO 3104
Viscosity Index, min.	90				90		ISO 2909
Density at 15°C g/ml	To be given by supplier				To be given by supplier		ISO 3675
Flash Point (COC), °C, min.	185	185	205	215	185	185	ISO 2592
Pour Point, °C, max.	-6				-6		ISO 3016
Neutralisation Value mg KOH/g	To be given by supplier				To be given by supplier		ISO 6618
Foam							ISO 6247
Sequence I	450/0						
Sequence II	50/0						
Sequence III	450/0						
Air Release (IP 313), mins., max.	5	5	6	No limit	5		DIN 9120
Steam Demulsibility, sec., max.	300				300		DIN 51589-1
Copper Corrosion							ISO 2160
3 hrs at 100°C	2 max.						
3 hrs at 125°C					2 max.		
Steel Corrosion, Method A	Pass				Pass		ISO 7120
Life TOST, hrs. to TAN of 2.0 mg KOH/g, min.	3000		2500	2000	3500		ISO 4263-1
RPVOT, mins., min.					750		ASTM D2722
RPVOT (modified), % of time in unmodified test, min.					85		ASTM D2722
Purity, min.	20/17/14				20/17/14		ISO 4406
Water content, mg/kg, max.	150				150		ISO 12937
Ash (oxide ash), % mass	To be given by supplier				To be given by supplier		ISO 6245

AIST Turbine Standard Requirements

Specifications	120 Turbine Oil				125 R & O Circulating Oil				ASTM Test Method
Viscosity	Suitable for turbine application				Suitable for application				
Viscosity Index, mins.	100				80				D88
A.P.I. Gravity, mins.	30				20				D287
Pour Point, °F, max.	20 (depending on location)				20 (lower dependent upon application)				D97
Flash Point (COC), °F, mins.	375				375				D92
Rust Prevention, Method A	Pass				Pass				D665
Oxidation Test	Not to exceed 2.0 neutralization number at 2000 hrs				Not to exceed 2.0 neutralization number after 1000 hrs				D943
RPVOT, mins., min.	120								D2272
Emulsion Characteristics @ 130°F	Minutes	ml Oil	ml Water	ml Emulsion	Minutes	ml Oil	ml Water	ml Emulsion	D1401
	≤ 20	40	37	3	≤40	40	37	3	
Vickers 104E Pump Test					Satisfactory for the application intended				D2271
Vane pump, wear loss, mg, max.	250								
Demulsibility									D2711
Free water, ml, max.					36				
Emulsion, ml, max.					1				
Water in oil, %, max.					2				

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British Standard Specifications BS 489: 1999 R&O Turbine Oils

Test	TO	TO	TO	TO	ASTM Test Method	
ISO Viscosity grade (BS 4231)	32	46	68	100	BS reference	Technically identical with
Kinematic Viscosity, at 40°C, mm^2/s					BS EN ISO 3104	IP71
min.	28.8	41.4	61.2	90		
max.	35.2	50.6	74.8	110		
Viscosity Index, min.	90				BS 2000: Part 226	IP 226/77
Flash Point (COC), °C, min.	185				BS EN 22592	IP 34
Pour Point, °C, max.	-6				BS 2000: Part 15	IP 15
Demulsification number, sec., max.	300	300	360	360	BS 2000: Part 19	IP 19
Copper Corrosion Classifications	1				BS EN ISO 2160 (3 hrs. at 100°C)	IP 154 (3 hrs. at 100°C)
Acid Number mgKOH/g, max.	0.45				BS 2000 : Part 177	IP 1 Method A
Rust-Preventing Characteristics	Pass				BS 2000 : Part 135 Procedure B (24 hr test), as amended by appendix A	IP 135 procedure B (24 hr test), as amended by appendix A
Foaming Characteristics: Foaming Tendency, ml					BS2000: Part 146	IP 146
Sequence I, max.	400	400	400	400		
Sequence II, max.	50	50	100	100		
Sequence III, max.	400	400	400	400		
Foam Stability after 10 mins., ml						
Sequence I, max.	Nil	Nil	20	30		
Sequence II, max.	Nil	Nil	10	10		
Sequence III, max.	Nil	Nil	20	30		
Air Release Value, minutes to 0.2% air content at 50°C, max.	5	6	7	10	BS 2000: Part 313	IP 313
Oxidation Characteristics: Total Oxidation Products					BS 2000: Part 280	IP 280
(TOP) % (m/m), max.	0.70	0.80	0.80	0.80		
Sludge % (m/m), max.	0.30	0.35	0.35	0.35		

SEB Turbine Specifications

Specifications	SEB 181229-1 Sep-07	SEB 181229-2 Sep-07	ASTM Test Method
Turbine type	TD Gas and Steam turbine oils for normal temperature range	TDP Gas and Steam EP turbine oils for normal temperature range	
ISO Viscosity grade	ISO 46	ISO 46	
Kinematic Viscosity, at 40°C, mm^2/s			BS EN ISO 3104
min.	41.4	41.4	
max.	50.6	50.6	
Viscosity Index, min.	90	90	ISO 2909
Density at 15°C kg/m^3	is to be indicated	is to be indicated	DIN 51757
Flash Point (COC), °C, min.	185	185	DIN EN ISO 2592
Pour Point, °C, max.	-12	-12	ISO 3016
Zinc content	Zinc free	Zinc free	
Neutralisation Value, mgKOH/g	is to be indicated	is to be indicated	DIN 51558-1
Foam			ISO 6247
Sequence I	450/0	450/0	
Sequence II	100/0	100/0	
Sequence III	450/0	450/0	
Air Release at 50°C, mins., max.	5	5	DIN 51381
Demulsibility with Water			DIN ISO 6614
Time to 40.37.3 at 54°C, mins., max.	30	30	
Time to 40.37.3 at 40°C, mins., max.	is to be indicated	is to be indicated	
Steam Demulsibility, sec., max.	300	300	DIN 51589-1
Copper Corrosion			DIN EN ISO 2160
3 hrs at 100°C, rating, max.	1	1	
24 hrs 150°C, rating	is to be indicated	is to be indicated	
Steel Corrosion, Method A	Pass	Pass	DIN EN ISO 2160
Life TOST			DIN 51587
TAN after 500 hrs, mgKOH/g, max.	1	1	
TAN after 1000 hrs, mgKOH/g, max.	2	2	
Ash (oxide ash), % mass	is to be indicated	is to be indicated	DIN EN ISO 6245
Water Content, %	None	None	DIN ISO 3733
Purity, max.	19/17/14	19/17/14	ISO 4406
FZG A/8.3/09, failure load stage		≥ 8	DIN 51354-2
IR Diagram	is to be provided	is to be provided	DIN 51451
Content of PCB, mg/kg	≤ current detection limit	≤ current detection limit	DIN 51527-1
Content of Total Halogens, % mass, max.	0.1	0.1	DIN 51577-2
Content of Lead, & mass	≤ current detection limit	≤ current detection limit	DIN 51827
Content of PAK (PAH), mg/kg, max.	10	10	GCMS Analysis

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GEK Turbine Specifications – Cont'd

Specifications	GEK 107395a	GEK 32568F	GEK 46506D	ASTM Test Method
	May-01	Feb-02	Dec-93	
Turbine type	Single shaft STAG, high temperature	Gas, High temperature	Steam	
ISO Viscosity grade	ISO 32	-	ISO 32	-
Viscosity at 40°C, mm^2/s	28.8-35.2	28.8 - 35.2	29.6-36.3	D445
Viscosity at 98.9°C mm^2/s			5.09-5.74	
Viscosity index, min.	98	95		D2270
Density at 15°C kg/m^3	0.83 to 0.88			D1298
Flash Point (COC), °C, min.	215	215	191	D92
Pour Point, °C, max.	-12	-12		D97
Colour, max.	2	2		D1500
Neutralisation Value mg KOH/g, max.	0.2	0.2	0.2	D664 / D974
Foam				D892
Seq I	50/0	50/0		
Seq II	50/0	50/0		
Seq III	50/0	50/0		
Air Release, mins., max.	5	5		D3427
Demulse Time to 40.37.3 at 54°C, mins., max.	30			D1401
Steam Demulsibility, sec.				IP19
Copper Corrosion, 3 hrs @ 100°C, max.	1B	1B		D130
Steel Corrosion, Method A			Pass	D665
Steel Corrosion, Method B	Pass	Pass		
Life TOST, hrs. to TAN of 2.0 mg KOH/g, min.	7000	3000	> 2000	D943

GEK Turbine Specifications – Cont'd

Specifications	GEK 107395a	GEK 32568F	GEK 46506D	ASTM Test Method
	May-01	Feb-02	Dec-93	
Turbine type	Single shaft STAG, high temperature	Gas, high temperature	Steam	
RPVOT, minutes, min. RPVOT (modified), % of time in unmodified test, min.	1000 85	500 85	>250	D2272 D2272
Carbon residue Ramsbottom, %, max.	0.10	0.10		D524 or equivalent
A.P.I. Gravity	29-39	29 - 33.5		D287
Water content, % wt., max.	0.02		0.01	ASTM E203
Evaporation Loss (149°C), % wt., max.	6			ASTM D972
AIGN, °C, min.	357			ASTM E659
Thermal stability, Change in Viscosity, % Total Precipitation	Report			CM Thermal Test A
Panel Coker Test, 320°F sump, 400°F panel	Report - Coking Value			FTM 791a-3462
Volatility / Oil thickening	Report			DIN 51356

Mitsubishi Heavy Industry Turbine Specifications

Specifications	High Temperature Turbines with Bearing Ambients above 250°C MS04-MA-CL002 (R-2) 24th October 2008		EP High Temperature Turbines with Bearing Ambients above 250°C MS04-MA-CL003 (R-2) 24th October 2008	High Temperature Turbines with Bearing Ambients above 250°C (Long Life Type) MS04-MA-CL005 (R-0) 24th October 2008		ASTM Test Method
ISO Viscosity grade	ISO 32	ISO 46	ISO 32	ISO 32	ISO 46	
Kinematic Viscosity						D445
at 40°C, mm²/s	28.8~35.2	41.4 - 50.6	28.8-35.2	28.8 to 35.2	41.4 - 50.6	
at 100°C, mm²/s, min.	5.0	6.5	min. 5.0	5.0	6.5	
Viscosity Index, min.	95		95	100		-
Colour, Rating, max.	L1.0		L1.0	L1.0		D1500
Pour Point, °C, max.	-12		-12	-12		D97
Density at 15°C, g/cm³	Report		Report	Report		D1289
Flash Point						
Cleveland Open Cup, °C, min.	200		200	215		D92
Pensky-Martens Closed Cup, °C	Report		Report	Report		D93
Acid Number, mg KOH/g, max.	0.2		0.2	0.2		D974
Rust-preventing characteristics Synthetic sea water, after 24 hrs at 60°C	Pass		Pass	Pass		D665B
Foaming						D892
Seq I, 24°C, ml, max.	50/0		50/0	50/0		
Seq II, 93.5°C, ml, max.	50/0		50/0	50/0		
Seq III, 24°C, ml, max.	50/0		50/0	50/0		

Mitsubishi Heavy Industry Turbine Specifications – Cont’d

Specifications	High Temperature Turbines with Bearing Ambients above 250°C MS04-MA-CL002 (R-1) 24th October 2008		EP High Temperature Turbines with Bearing Ambients above 250°C MS04-MA-CL003 (R-2) 24th October 2008	High Temperature Turbines with Bearing Ambients above 250°C MS04-MA-CL005 (R-0) 24th October 2008		ASTM Test Method
Oxidation Stability						
1st method Acid Number after 1000 hrs, mgKOH/g, max.	0.4		0.4			D4310
2nd method Time to Acid Number of 2.0, hr, min.	4000		4000	7000		D943
3rd method (Dry TOST at 120°C)						-
Sludge formation, mg/kg (1mm filter), max.	100 at 25% RPVOT		100 at 50% RPVOT	100 at 25% RPVOT		
Dry TOST life, hrs, min.	500 at 25% RPVOT		700 at 50% RPVOT	1000 at 25% RPVOT		
RPVOT at 150°C, min.	700		700	1200		D2272
Modified RPVOT, %	85% of time in unmodified test		85% of time in unmodified test	85% of time in unmodified test		
Mixture stability - 1 RPVOT at 150°C of New oil / Tested oil (Ratio: 50/50)(1), %	Report		-	Report		-
Mixture stability - 2 Dry TOST at 120°C of New oil / Tested Oil (Ratio: 50/50)(1) sludge formation mg/kg, max.	100 at 25% RPVOT		-	100 at 25% RPVOT		-
Air Release 0.2% air at 50°C, mins., max.	4	5	4	4	5	D3427
Water Separability at 54°C, time to 3ml emulsion, mins., max.	20	25	30	15	25	D1401
Corrosiveness to Copper, 3 hrs at 100°C, rating, max.	1		1	1		D130
Carbon Residue, mass %, max.	0.05		0.05	0.05		D4530
Total Sulphur, ppm, max.	300		1000	300		D2622
Zinc Content, ppm, max.	10		10	10		D5185
Evaporation Loss 760mmHg, 22hrs at 150°C, mass %, max.	10	8	10	7	5	D972

Note:
(1) Tested oil: The oil tested by dry TOST at 120°C until RPVOT value reaches 50% or less of new oil.

OEM Turbine Specifications 1

Specifications	ALSTOM HTGD 90 117 V0001 W 27th April 2009			Solar ES 9-224 W 1st February 2007		ASTM Test Method
ISO Viscosity grade	ISO 32	ISO 46	ISO 68	ISO 32	ISO 46	-
Viscosity at 40°C, mm^2/s	28.8-35.2	41.4-50.6	61.2-74.8	28.8-35.2	41.4-50.6	D445
Viscosity index	> 90					D2270
Density at 15°C kg/m^3, max.	880		900			D941 / D1298
Flash Point (COC), °C, min.	200		200	199		D92
Fire Point				227	232	
Auto ignition temperature, °C, min.				310		E659
Pour Point, °C, max.	-9		- 6			D97
Neutralisation Value mg KOH/g						D664 / D974
Without EP additive, max.	0.2					
With EP additive, max.	0.3					
Foam						D892
Sequence I	300/0			50/0		
Sequence II	50/0			50/0		
Sequence III	300/0			50/0		
Air Release at 50°C, min, max.		4	7	5	6	D3427
Demulse Time to 40.37.3 at 54°C, mins., max.	< 30			30 max. to 40-40-0		D1401
Steam Demulsibility, sec., max.	< 300					DIN 51589-1
Copper Corrosion, 3 hrs. at 100°C, max.	2			1b		D130
Steel Corrosion, Method B	Pass			Pass		D665
Life TOST, hrs. to TAN of 2.0 mgKOH/g				2000 min.		D943
Life TOST, hrs. to TAN of 1.0 mgKOH/g	2000 min.					D943
RPVOT, mins.	> 300			Report		D2272
Purity	Class --/18/15			16/14/12		ISO4406
Water content mg/kg, max.	< 200					D1533 / D1744

OEM Turbine Specifications 1 – Cont'd

Specifications	ALSTOM HTGD 90 117 V0001 W 27th April 2009	Solar ES 9-224 W 1st February 2007		ASTM Test Method
Filterability				ISO 13357-2
Level 1%	At least 93			
Level 2%	At least 85			
Zinc Content, ppm, max.	5	0.005% wt.		Optional
FZG A/8.3/90, failure load stage	≥ 8 (1)	≥ 6	≥ 7	D5182
Four-Ball wear, 40kg/1 hr/75°C/1200rpm, mwsd, mm, max.		0.90		
Electrical Resistivity, min. at 20°C, Ωm		Report		D4308 / D1169

Note:
(1) Additional requirements on turbine oils used in gear boxes.

OEM Turbine Specifications 2

Specifications	Siemens TLV 9013 04 May 2010 Turbine Oils with normal thermal stability		Siemens TLV 901305 May 2010 Turbine Oils with higher thermal stability		ASTM Test Method
ISO Viscosity grade	ISO 32	ISO 46	ISO 32	ISO 46	-
Viscosity at 40°C, mm^2/s	28.8-35.2	41.4-50.6	28.8-35.2	41.4-50.6	D445
Viscosity index	≥ 90		≥ 90		D2270
Density at 15°C kg/m^3, max.	Report		Report		D941 / D1298
Flash Point (COC), °C, min.	> 200		> 200		D92
Fire Point					
Auto ignition temperature, °C, min.					E659
Pour Point, °C, max	-6		-6		D97
Neutralisation Value mg KOH/g, max.	0.30		0.30		D974
Foam Sequence I	≤ 450/0		≤ 450/0		D892
Air Release at 50°C, mins., max.	4		4		D3427
Demulse Time to 40.37.3 at 54°C, mins., max.	30		30		D1401
Steam Demulsibility, sec., max.	300		300		DIN 51589-1
Copper Corrosion, 3 hrs at 100°C, max.	2		2		D130
Steel Corrosion, Method B	Pass		Pass		D665
Life TOST, hrs to TAN of 2.0 mg KOH/g, min.	3000		3000		D943
RPVOT, mins., min.			750		D2272
Purity	≤ 20/17/14		≤ 20/17/14		ISO4406
Water content mg/kg, max.	200		200		D1533 / D1744
FZG Test, A/8.3/90 failure load stage	≥ 8(1)		≥ 8(1)		D5182

Note:
(1) Additional requirements on turbine oils used in gear boxes.

European Slideway Specifications

Specifications	AFNOR E 60-203 Lubricants, industrial oils and related products: lubricants for lubrication and control of machine tools and similar equipment, characteristics							ASTM Test Method
Issue Date	**February 1983**							
	L-G requirements					**L-HG requirements**		
ISO Viscosity grade, Kinematic Viscosity at 40°C, mm^2/s	32	68	100	150	220	32	68	NFT 60-100
Viscosity Index, min.	85					95		NFT 60-136
Neutralisation No., mg KOH/g	Report					Report		NFT 60-112
Density at 15°C, kg/m^3	Report					Report		NFT 60-101
Flash Point (COC) °C, min.	160	180				160	180	NFT 60-118
Pour Point, °C, max.	-9				-6	-9		ISO 3016
Aniline Point, °C, min.	95					95		NF M 07-021
Water Content, % mass, max.	0.05					0.05		NFT 60-113
Air Release @ 50°C, min.						Report		NFT 60-149
Foam, ml, max.								NFT 60-129
Sequence I	Report					100/10		
Sequence II	Report					100/10		
Sequence III	Report					100/10		
Water separation, time to 40/37/3, mins.						Report		NFT 60-125(7)
Copper Corrosion, 3 hrs @ 100°C, rating	< 3 (3 hrs @ 60 °C)					< 2		NFM 07-015
Steel Corrosion, Method A, rating	Pass					Pass		NFT 60-151
FZG A/8.3/90						Report		DIN 51354
Friction Test (method given by supplier)	Discuss with Supplier					Discuss with Supplier		
Compatibility with cutting fluid (method given by supplier)	Discuss with Supplier					Discuss with Supplier		
Compatibility with elastomers						Discuss with Supplier		NFE 48-610

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European Slideway Specifications – Cont'd

Specifications	ISO 19 378 (2003) Lubricants, industrial oils and related products: (Class L) - Machine Tool Lubricants - Categories and Specifications				ISO 11158 Lubricants, industrial oils and related products: (Class L) - Family H (Hydraulic Systems) - Specifications for categories HH, HL, HM, HV and HG		ASTM Test Method
Issue Date	**01/03/2003 First Edition**				**September 2009**		
	GA and GB requirements				**HG requirements**		
ISO Viscosity grade, Kinematic Viscosity at 40°C, mm^2/s	68	100	150	220	28.8 - 35.1	61.2 - 74.8	ISO 3104
Viscosity Index	Report	Report	Report	Report	Report		ISO 2909
Appearance	Clear & Bright	Clear & Bright	Bright	Bright	Clear & Bright		Visual
Neutralisation No., mg KOH/g	Report	Report	Report	Report	Report		ISO 6618
Colour					Report		ISO 2049
Density at 15°C, kg/m^3	Report	Report	Report	Report	Report		ISO 3675
Flash Point (COC), °C, min.	180	180	180	180	175	195	ISO 2592
Pour Point, °C, max.	-9	-9	-3	-3	-18	-12	ISO 3016
Cleanliness, rating					Discuss with Supplier		ISO 4406
Water Content, % mass, max.					0.025		ISO 2696
Oxidation Stability							ISO 4263-1
Increase in acid number after 1000 hrs, max.					2.0		
Insoluble sludge, mg, max.					Report		
Foam, ml, max							ISO 2647
Sequence I					150/10		
Sequence II					80/10		
Sequence III					150/10		
Copper Corrosion, 3 hrs @ 100°C, rating	2				2		ISO 2160
Steel Corrosion, Method A, rating	Pass				Pass (Method A & B)		ISO 7120
FZG A/8.3/90, failure load stage					10		ISO 14635-1
Wear protection, vane pump, max.							ISO 20763
Weight loss on cam rings, mg					120		
Weight loss on vanes, mgs					30		
Friction Test (method given by supplier)	Discuss with Supplier				Discuss with Supplier		
Compatibility with cutting fluid (method given by supplier)	Discuss with Supplier				Discuss with Supplier		
Compatibility with construction materials	Discuss with Supplier						
Elastomer combatibility, NBRI, 182 hrs @ 100°C							ISO 6072
Relative increase in volume					0 to 12	0 to 10	
Change in Shore A hardness					0 to -7	0 to -6	

US Slideway Specifications

Specifications	GM LS2 (04) GM Lubricants standard No. LW-03-1-04, LW-06-1-04, LW-22-1-04 Light, Medium and Heavy Way Oils			SAE MS 1007 Lubricants, industrial oils and related products, Type E Slideway Lubricants Specification		ASTM Test Method
	30-Nov-04	30-Nov-04	30-Nov-04	May 2001		
Test	LW-03-1-04, Light	LW-06-1-04, Medium	LW-22-1-04, Heavy			
ISO Viscosity grade	32	68	220	32 - 320	460 - 1000	
Kinematic Viscosity						ASTM D445
@ 100°C, cSt	Report	Report	Report			
@ 40°C, cSt	28.8 - 35.2	61.2 - 74.8	198 - 242	ISO VG +/- 10%	ISO VG +/- 10%	
Viscosity Index	Report	Report	Report			ASTM D2270
A.P.I. Gravity	Report	Report	Report			ASTM D287
Density @ 15°C, g/ml				Report	Report	ASTM D4052
Neutralisation No., mg KOH/g, max.				Report	Report	ASTM D664
Flash Point (COC), °C, min.	190	190	190	175	210	ASTM D92
Pour Point, °C, max.	-15	-10	-10	-10	-10	ASTM D97
Sediment	Nil	Nil	Nil			ASTM D473
Water content, ppm, max.	500	500	500	100	100	ASTM D6304
Precipitation Number, max.	0.05	0.05	0.05			ASTM D91
Cleanliness, as received, max.	20/18/14	20/18/14	20/18/14	20/18/14	20/18/14	ISO 4406
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max.	25/2	25/2	25/2			ASTM D5185
Residual Elements P, ppm max.	5	5	5			ASTM D5185
Water Separation, T to 40/37/3, mins., max.	30	30	30	60	60	ASTM D1401
Demulsibility						ASTM D2711
Water in Oil After 5 hrs., % max.	1	1	1	1	1	
Emulsion After Cntrfg., ml max.	2	2	2	2	2	
Total Free Water, ml min.	60	60	60	60	60	
Content of undissolved matter, % m/m, max.				Below detectability	Below detectability	DIN 51592

US Slideway Specifications – Cont'd

Specifications	GM LS2 (04) GM Lubricant Standard No. LW-03-1-04, LW-06-1-04, LW-22-1-04 Light, Medium and Heavy Way Oils			SAE MS 1007 Lubricants, industrial oils and related products, Type E Slideway Lubricants Specification		ASTM Test Method
	30-Nov-04	30-Nov-04	30-Nov-04	May 2001		
Test	LW-03-1-04, Light	LW-06-1-04, Medium	LW-22-1-04, Heavy			
Copper Corrosion, 3 hrs @ 100°C, max.	1b	1b	1b	2		ASTM D130
Steel Corrosion, rating						ASTM 665
Method A				Pass		
Method B	Pass	Pass	Pass			
Timken OK Load, kg, min.	16	16	16	16	27	ASTM D2782
CM Stick-Slip Frictional Test, ratio of static to kinetic friction, max.	0.8	0.8	0.8	0.85		ASTM D2877
Tackifier added	Report	Report	Report	Report		

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US Slideway Specifications – Cont'd

Specifications	MAG Cincinnati Machine P-53 Combination Hydraulic & Way Oil 2000	MAG Cincinnati Machine P-47 Heavy-Medium Way Oil 2000	MAG Cincinnati Machine P-50 Heavy-Medium Way Oil 2000	MIL-A-A-59113 Lubricating oil, machine tool slideways 30 December 1997 Type 1 - Medium	MIL-A-A-59113 Type 2 - Heavy	ASTM Test Method
Kinematic Viscosity						ASTM D445
@ 40°C, cSt	28.8 - 35.2	61.2 - 74.8	198 - 242	61.0 - 75.0	195.0 - 238.0	
A.P.I. Gravity	20 to 30	18 to 27	18 to 27			ASTM D287
Neutralisation No., mg KOH/g, max.	0.60	1.7	1.7			ASTM D974
Flash Point (COC), °F, min.	315	350	350	330	350	ASTM D92
Fire Point, °F, min.	355	360	410			ASTM D92
Pour Point, °F, max.				20	20	ASTM D97
CCMB (procedure 24 hrs @ 101°C)						CCMB
Neutralisation Number, max, inc.	0.2	0.5	0.5			
Sludge		None				
Steel Rod Rating, max.		1.5				
Copper Rod Rating, max.		5				
Steel Rod Deposit, mg, max.		3.5				
Copper Rod Deposit, mg, max.		6.0				
Steel metal removed, mg, max.		1.0				
Copper metal removed, mg, max.		5.0				
Copper Corrosion, 3 hrs @ 100°C, max.				1		ASTM D130
Steel Corrosion, rating						ASTM D665
Method A				Pass		
CM Stick-Slip Frictional Test, ratio of static to kinetic friction, max.	0.8	0.8	0.8	0.8		
Tackifier added				Report		

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Chinese National Slideway Specifications

Specifications	GB 11118.1-94 (L-HG Multifunction) Chinese national specification, hydraulic fluids, mineral oil and synthetic hydrocarbon type	SH/T 0361-98 (L-G Slideway) Chinese national specification slideway oil	ASTM Test Method	
Issue Date	**1994**	**1998**	**Chinese**	**ASTM**
ISO Viscosity grade	ISO 32, 68	ISO 32 - 320		
Kinematic Viscosity @ 40°C, cSt	ISO VG +/- 10%	ISO VG +/- 10%	GB/T 265	D445
Viscosity Index, min.	95	Report	GB/T 1995 GB/T 2541	D2270
Density at 20°C, kg/m³	-	Report	GB/T 1884 GB/T 1885	D1298
Neutralisation Number, mgKOH/g	Report	Report	GB/T 4945	D664
Appearance (transparency)	-	Clear	Visual	
Flash Point (COC), °C	≥ 160°C (ISO 32) ≥ 180°C (ISO 68)	≥ 150°C (ISO 32) ≥ 160°C (ISO 46) ≥ 180°C (ISO 68 + above)	GB/T 3536	D92
Pour Point, °C, max.	≤ -6°C	≤ -9°C (ISO 32-150) ≤ -3°C (ISO 220-320)	GB/T 3535	D97
Colour	Report	-	GB/T 6540	D1500
Water Content, % wt.	trace	trace	GB/T 260	D95
Mechanical Impurity, % wt.	None	None (ISO 32-150) 0.01 (ISO 220-320)	GB/T 511	Russian TOCT 6370
Seal Compatibility Index	Report	-	SH/T 0305	IP 278/72 (88)
Elastomer Compatibility	-	Report	GB/T 1690-92	ISO 1817-85
Copper Corrosion, rating, max	1 (@ 100°C, 3 hrs)	2 (@ 60°C, 3 hrs)	GB/T 5096	D130
Saponification number, mgKOH/g	Report	-	GB/T 8021	D94
Rust Test			GB/T 11143	D665A
Distilled water	No rust	No rust		
Foam, ml, max.			GB/T 12579	D892
Sequence I 24°C	≤ 150 / 10	-		
Sequence II 93.5°C	≤ 150 / 10	-		
Sequence III 24°C (after)	≤ 150 / 10	-		
Demulsibility @ 54°C, min.	Report	-	GB/T 7305	D1401
Oxidation Stability			GB/T 12581	D943
TAN after 1000 hrs, mgKOH/g, max.	2.0	-		
Insoluble sludge, mg	Report	-	SH/T 0565	D4310
RPVOT (or RBOT) @ 150°C, min.	Report	-	SH/T 0193	D2272
FZG (A/8.3/90), FLS	≥ 10	-	SH/T 0306	IP 334-80
Anti-wear Performance, Four-Ball wear scar, mm, max.	Report (392N, 1 hr)	0.5 (200N, 1 hr)	SH/T 0189	D4172
Stick-Slip (Difference of static and dynamic friction coefficient), max.	0.08	Report	Appendix A of SH/T 0361	
Metalworking Fluid Compatibility	-	Report	-	

Specification Handbook

Off Road

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STOU Specifications:

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TO-4 Specifications:

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STOU Specifications [1] - John Deere J27

Test	John Deere J27 (Jan 1992)
SAE Classification, J300D	10W-30, 15W-40
Engine Performance	
API	CD / CE
CCMC	D4 / D5
Kinematic Viscosity at 100°C, mm^2/s	Relevant SAE J300 Limits
Cold Cranking Viscosity (CCS), mPa·s, max.	
at -20°C (10W-30)	3500
at -15°C (10W-40)	3500
Pumpability Viscosity (MRV), mPa·s, max.	
at -20°C (10W-30)	30,000
at -15°C (10W-40)	30,000
Shear Stability, JDQ102, viscosity at 100°C, mm^2/s, min.	7.1
Pour Point, °C, max.	-33 (10W-30) -30 (15W-30)
Total Base Number, mgKOH/g, min.	8
Foaming, JDQ 33	
Sequence I, ml, max.	25/0
Sequence II, ml, max.	50/0
Sequence III, ml, max.	25/0
Foam break time, s, max.	30
Water Sensitivity, JDQ 19	
Solids, % volume, max.	0.1
Additive loss, % mass, max.	15
Rust protection, JDQ 22, hrs, min.	100
Oil Compatibility, JDQ 23	
Additive Separation	None
Foaming Characteristics	
Sequence I, ml, max.	25/0
Sequence II, ml, max.	50/0
Sequence III, ml, max.	25/0
Foam break time, s, max.	30
Oxidation Stability	
Evaporation loss, %, max.	5
Viscosity increase at 100 °C, %, max.	10
Sludge information	None
Additive separation	None
John Deere brake performance, JDQ 96	Pass
John Deere PTS Clutch performance, JDQ 94	Pass
John Deere spiral bevel & final drive performance, JDQ 95	Pass
Allison transmission performance, DDAD C-4[2]	Pass
ZF front axle performance, tests specified by ZF	Pass
Field test performance, >1yr or >1000 hrs	Pass

Note:

(1) STOU = Super Tractor Oil Universal, for use in engine, transmission, driveline and hydraulics.

(2) Allison C4 no longer list friction modified fluids.

STOU Specifications - Massey Ferguson CMS M1139/44/45

Test	Massey Ferguson CMS M1139 (April 1978)	Massey Ferguson CMS M1144 (June 1994)	Massey Ferguson M1145 (Sept 2004)
SAE Classification, J300D		5W-30, 10W-30, 10W-40, 15W-30, 15W-40, 20W-40	5W-30, 10W-30, 10W-40, 15W-30, 15W-40, 20W-40
Engine Performance			
API	CD	CD/ CE	
CCMS		D4/ D5	
Kinematic Viscosity, 100°C, mm^2/s	10.1 - 12.0	Relevant SAE classification	Relevant SAE classification
Kinematic Viscosity at 100°C after shearing, CEC L14A78 (250 Cycles), mm^2/s		9.0	See UTTO section for full Massey Ferguson (GIMA) CMS M1145 limits
Viscosity -18°C (Brookfield), mPa·s, max.	8000		
Pour Point, °C, NF T 60-105	-30°C	-10 °C below MRV limit defined by SAE J300d grade	
Flash point, COC, °C		-200°C	
Foaming, ASTM D892			
Sequence I, ml, max.	100/0	Report	
Sequence II, ml, max.	100/0	Report	
Sequence III, ml, max.	100/0	Report	
Foaming with 1% water added			
Sequence I, ml max.	100/0		
Sequence II, ml max.	100/0		
Sequence III, ml max.	100/0		
Water content, ppm, max		400	
Dry filterability, NF E 48-690, 5 micron filter, 1 bar (Afnor)		1.5 max	
Wet filterability, NF E 48-691, 5 micron filter, 1 bar (Afnor)		Report	
Copper strip corrosion, ASTM D130, 3 hrs at 150°C	1A		
Copper corrosion, 3 hrs at 100°C, NF M 07-015		1A	
Rust prevention, MF rust test	Pass		
Rust prevention, ASTM D665B		No rust	
Oxidation test, 100 hrs at 150°C			
Viscosity Increase at 100°C, %, max.	10		
Sludging	None		
Oxidation test, 100 hrs at 150°C, CEC L48T94			
KV100°C change, %		25 max	
Total Acid Number change, %		75 max	
Deposits		None	
Seal Test, ford RDR 008 nitrile, 168 hrs at 120°C			
Volume change, %	0 to +5		
Hardness change, (+ 21 days at 95°C), max.	10		
4-Ball wear			
Wear Scar Diameter, (1 hr at 65°C 1500rpm 40kg), mm, max.	0.4		
4-Ball wear			
Wear Scar Diameter, (1 hr at 40daN), mm max.		0.4	
4-Ball EP test, ASTM D2783			
Load Wear Index, kg, min.	55	45	
Vickers 104C vane pump test, NF E 48-617, ring and vane weight loss, mg, max.		80 mg	
IAE Gear rig, 2000rpm, 110°C, 1pt (0.57L)/s			
Scuff load, kg, min.	52		
Wet brake test	Pass		
IPTO Clutch test	Pass		
Transmission test	Pass		
Materials compatibility, various		Pass	
Friction test, proprietary test		Pass	

STOU Specifications - Ford M2C 159 B/C, FNH 82009201/2/3

Test	Ford M2C 159 B (July 1984)	Ford M2C 159 C (Sept 1991)	FNH 82009201/ 2/ 3 (Aug 1995)
SAE Classification, J300D	10W-30, 15W-30, 20W-40	10W-30, 15W-30, 20W-40	10W-30, 15W-30, 20W-40
Engine performance	API CD/ SE	API CE/ SF	API CF-4
Kinematic Viscosity at 100°C, mm^2/s	B1 = 10W-30 B2 = 15W-30 B3 = 20W-40	C1 = 10W-30 C2 = 15W-30 C3 = 20W-40	/1 = 10W-30 /2 = 15W-30 /3 = 20W-40
Kinematic Viscosity change at 100°C			
after shearing, IP 294/77 (30 passes), %, max.	-10%	-10%	-10%
after 100 hrs@ 150°C, max.	10%	10%	10%
Pumpability Viscosity (MRV), mPa·s	Relevant SAE classification		
Flash point, °C, min.	190	190	190
Foaming, ASTM D892			
Sequence I, ml, max.	20/0	20/0	20/0
Sequence II, ml, max.	50/0	50/0	50/0
Sequence III, ml, max.	20/0	20/0	20/0
Copper corrosion, ASTM D130			
Rating after 3 hrs at 150°C	1B	1B	1B
Copper weight loss after 48 hrs at 120°C, mg, max.		1	1
Rust prevention, ASTM D665A	No rust	No rust	No rust
Seal test, Ford ATRR-100 Buna N, 70 hrs at 125°C			
Volume change, %	0 - 10%	0 - 10%	1 - 10%
Hardness change, max.	± 10 points	± 10 points	± 10 points
180° bend test	No cracks	No cracks	No cracks
4-ball wear			
Wear scar diameter, (1 hr, 65°C, 1500rpm, 40kg), mm, max.	0.4	0.4	0.4
Water sensitivity			
Sediment volume, ml, max.	0.1	0.1	1.1
Water separation, max.	Trace	Trace	Trace
Wet brake noise/ capacity test(1)	Pass	Pass	Pass
PTO Clutch test(1)	Pass	Pass	Pass
Transmission test(1)	Pass	Pass	Pass
Hydraulic pump and relief valve protection(1)	Pass	Pass	Pass
Itching/ Shifting quality(1)			Pass
2000 hrs field test(1)			Pass
660 hrs Jenkins cycle test(1)			Pass
400 cycle stall test(1)			Pass
450 cycle high energy test(1)			Pass

Note:

(1) Ford/ FNH, at its option, may conduct the following tests on oils supplied to these specifications.

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UTTO[1] Specifications - John Deere J20C/D

Test	John Deere (Revised Nov 2000)	
	J20C	J20D [2]
Kinematic Viscosity at 100°C, mm^2/s, min.	9.1	7
Shear stability, JDQ102, viscosity at 100°C, mm^2/s, min.	7.1	5
Brookfield Viscosity, ASTM D2983, mPa·s		
at -20°C	5500	1500
at -35°C	70000	
at -40°C		20000
Flash point, °C, min.	200	150
Pour Point, °C, max.	-36	-45
Foaming, JDQ 33		
Sequence I, ml, max.	25/0	25/0
Sequence II, ml, max.	50/0	50/0
Sequence III, ml, max.	25/0	25/0
Foam break time, s, max.	30	60
Water sensitivity, JDQ 19		
Solids, % volume, max.	0.1	0.1
Additive loss, % mass, max.	15	15
Rust prevention, JDQ 22, hrs, min.	100	100
Oil Compatibility, JDQ 23 :		
Additive Separation	None	None
Foaming Characteristics		
Sequence I, ml, max.	25/0	25/1
Sequence II, ml, max.	50/0	50/1
Sequence III, ml, max.	25/0	25/1
Foam break time, s, max.	30	60
Oxidation Stability		
Evaporation loss, %, max.	5	10
Viscosity increase at 100 °C, %, max.	10	20
Sludge formation	None	None
Additive separation	None	None
Low temperature filtration, JDQ 24		Equal or better than JD reference
John Deere brake performance, JDQ 96	Pass	Pass
John Deere PTS Clutch performance, JDQ 94	Pass	Pass
John Deere Hydraulic pump performance, JDQ 84	Pass	Pass
John Deere spiral bevel & final drive performance, JDQ 95	Pass	Pass
Allison transmission performance, DDAD C-4[3]	Pass	Pass

Note:
(1) UTTO = Universal Tractor Transmission Oil, not for use in engine.
(2) J20D low viscosity UTTO for cold climates. Earlier UTTO specification versions on file.
(3) Allison C4 no longer list friction modified fluids.

UTTO Specifications - Massey Ferguson CMS M1135/41

Test	Massey Ferguson CMS M1135 (May 1969 - Europe)	Massey Ferguson CMS M1141 (June 1986)
Kinematic Viscosity at 100°C, mm^2/s	10.3-11.7	9.6 max
Shear stability, Viscosity at 100°C, ASTM 3945, mm^2/s, min.		7.3
Brookfield Viscosity, ASTM D2983, mPa·s		
at -18°C	10000	4000
at -34°C		70000
Pour point, °C, max.	-26	-37
Flash point, °C, min.		200
Viscosity Index, min.	95	130
Foaming, ASTM D892		
Sequence I, ml, max.	100/0	50/0
Sequence II, ml, max.	100/0	50/0
Sequence III, ml, max.	100/0	50/0
Copper strip corrosion, ASTM D130		
3 hrs at 121°C	1A	
1 hr at 150 °C		1B
Rust prevention		
MF rust test	Pass	
ASTM D1748, hrs, min.		100
Oxidation test, 100 hrs at 150°C		
Viscosity increase at 100°C, %, max.	10	15
Sludging	No Sludge	No Sludge
Seal compatibility, Pioneer MP 802 Nitrile seals, 168 hrs, 120°C		
Volume change, %	-2% to +5%	
Hardness change (after 21 days at 95°C), max.	10 IRHD	
Seal compatibility, Ford ATRR-100 Nitrile, 168 hrs, 120°C		
Volume change, %		0.5% to 10%
Hardness change (after 21 days at 95°C), max.		10 IRHD
4-ball wear test		
Wear scar diameter (1 hr, 65°C, 1500rpm, 40kg), mm, max.	0.4	0.4
4-ball EP test, ASTM D2783		
Load Wear Index, kg, min.		38
Weld point, kg, min.		200
IAE Gear rig, 2000rpm, 110 °C, 1pt (0.57L) /s		
Scuff load, kg, min.	61	
MF four square rig test	No scuffing	
Functional tests	Pass	Pass

UTTO Specifications - Massey Ferguson M1143/5

Test	Massey Ferguson M1143 (June 1994)	Massey Ferguson M1145 (Sept 2004)
Kinematic Viscosity at 100°C, mm^2/s	13.5 max	13.5 max
Shear stability, Viscosity at 100°C, mm^2/s, min.		
KO shear, CEC L14A78 (250 Cycles)	9	9
KRL shear, CEC L45A99, 20 hrs		6.8
Brookfield Viscosity, ASTM D2983, mPa·s		
at -18°C	4000	4000
at -34°C		
Pour point, °C, max.	-34	-33
Flash point, °C, min.	200	200
Water content, ppm	400	400
Foaming, ASTM D892		
Sequence I, ml, max.	50/0	50/0
Sequence II, ml, max.	50/0	50/0
Sequence III, ml, max.	50/0	50/0
Dry Filterability, NF E 48-690, 5micron filter, 1 bar (Afnor), max.	1.5	1.5
Wet Filterability, NF E 48-690, 5micron filter, 1 bar (Afnor)	Report	Report
Copper strip corrosion, ASTM D130, 3 hrs at 100°C	1A	1A
Rust prevention, ASTM D665B	No rust	No rust
Oxidation test, 192 hrs at 150°C, CEC L48T94		
Viscosity increase at 100°C, %, max.	25	25
Total Acid Number change, %, max.	75	75
Deposits	None	None
Seal compatibility, CEC L39T96		
RE1, Flouro elastomers, 168 hrs at 150°C		
Variation in hardness, DIDC, point	0 to +5	0 to +5
Variation in tensile strength, %	-50 to 0	-50 to 0
Variation in elongation rupture, %	-60 to 0	-60 to 0
Variation in volume, %	0 to +5	0 to +5
RE2, ACM elastomers, 168 hrs at 150°C		
Variation in hardness, DIDC, point	-5 to +5	-5 to +5
Variation in tensile strength, %	-15 to +10	-15 to +10
Variation in elongation rupture, %	-35 to +10	-35 to +10
Variation in volume, %	-5 to +5	-5 to +5
RE3, Silicone elastomers, 168 hrs at 150°C		
Variation in hardness, DIDC, point	-25 to 0	-25 to 0
Variation in tensile strength, %	-30 to +10	-30 to +10
Variation in elongation rupture, %	-20 to +10	-20 to +10
Variation in volume, %	0 to +30	0 to +30
RE4, NBR elastomers, 168 hrs at 150°C		
Variation in hardness, DIDC, point	-5 to +5	-5 to +5
Variation in tensile strength, %	-20 to 0	-20 to 0
Variation in elongation rupture, %	-50 to 0	-50 to 0
Variation in volume, %	-5 to +5	-5 to +5
4-ball wear, 1 hr, 65 °C, 1500rpm, 40kg		
Wear scar diameter, mm, max.	0.4	0.4
4-ball EP test, ASTM D2783		
Load Wear Index, kg, min.	45	47
Weld point, kg, min.		
FZG A/8.3/90, CEC L07A85, Load stage, min.	9	9
Vickers 104C pump test, mg, max.	80	
Vickers 35VQ25 pump test, mg, max.		
Cam wear, mg, max.		40
Vane wear, mg, max.		15
Friction Test, proprietary test	Pass	Pass
Materials compatibility, various	Pass	Pass

UTTO Specifications (1) - Ford M2C 86B/C and Ford M2C 134D

Test	Ford M2C 86 B (Oct 1980)	Ford M2C 86 C (Oct 1987)	Ford M2C 134 D(1) (Nov 1989)	FNHA-2-C-200.00 (Rev. B, July 1994)
Kinematic Viscosity, 100°C, mm^2/s, min.	10.5 - 11.6 (99°C)	9	9	8
Shear Stability, ASTM D3945, 30 cycles		-16%	-16%	$7mm^2/s$, min
Brookfield Viscosity, ASTM D2983, mPa·s				
at -18°C	9230	4000	4000	
at -40°C				17000
Pour Point, °C, max.	-27	-37	-37	-45
Flash Point, °C, min.	219	190	190	160
Viscosity Index, min.	105	-	-	210
Foaming, ASTM D892				
Sequence I, ml, max.	100/0	20/0	20/0	50/0
Sequence II, ml, max.	100/0	50/0	50/0	100/0
Sequence III, ml, max.	100/0	20/0	20/0	50/0
Copper corrosion, ASTM D130				
3 hrs at 99°C	1B			
3 hrs at 150°C		2B	2B	2B
Copper weight loss after 48 hrs at 120°C, mg, max.			1	1
Rust Protection				
Falex Pin corrosion (FLTM BJ 15-1)	No rust			
ASTM D665A		No rust	No rust	No rust
Oxidation Test, 100 hrs at 150°C				
Viscosity Increase at 100°C, % max.	5	10	10	10
Seal test, Ford ATRR-100 Buna N, 70 hrs at 125°C				
Volume change, %		0 to +10	0 to +10	0 to +10
Hardness change, max.		± 10 points	± 10 points	± 10 points
180° bend test		No cracks	No cracks	No cracks
4-Ball wear				
wear scar diameter, 1 hr, 65°C, 1500rpm, 40kg, mm, max.		0.4		
wear scar diameter, 1 hr, 85°C, 1500rpm, 40kg, mm, max.			0.4	0.4
Water Sensitivity				
Sediment volume, ml, max.		0.1	0.1	0.1
Water Separation, max.		Trace	Trace	Trace
Compatibility 50/50 mix	Pass	Pass	Pass	
Wet brake tests, Various	Pass	Pass	Pass	Pass
PTO clutch tests, Various	Pass	Pass	Pass	Pass
Transmission tests, Various	Pass	Pass	Pass	Pass
Hydraulic pump tests, Various	Pass	Pass	Pass	Pass
Driveline durability tests, Various	Pass	Pass	Pass	
Gear wear	Pass	Pass	Pass	
Dynamic co-efficient of friction				0.095 - 0.135
Static co-efficient of friction				0.085 - 0.110

Note:

(1) FNHA-2-C-201.00 = Ford M2C 134D specification. Superseded by Case MAT 3525.

UTTO Specifications - NH 410B/C, 420A

	NH 410B	NH 410C	NH 420A
Details	10W30 fluid to meet requirements of Ford M2C 134D	Fluid to meet the requirements of Case MAT 3505	20W30 fluid to meet the requirements of Ford M2C 86B
Requirements	See UTTO Ford M2C 134D (superseded)	See UTTO Case MAT 3505	See UTTO Ford M2C 86B
Relevant CNH genuine fluid	Ambra Multi-G	Mastertran Tractor fluid	Ambra Multi-F

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UTTO Specifications - J I Case MS 1205/6/10

Test	J I Case MS 1205 (Oct 1978)	J I Case MS 1206 (April 1982)	J I Case MS 1210 (April 1980)
Kinematic Viscosity at 100°C, mm^2/S, min.	11.1	8.8	6.65
Shear stability			
% Viscosity loss at 99°C, max.	10		10
After gear and driveline tests, mm^2/s, min.		7.5	
Brookfield Viscosity, ASTM D2983, mPa·s			
at -18°C	5600		1950
at -20°C		4000	
Cold Cranking Viscosity (CCS) at -18°C, mPa·s, max.			1800
API Gravity at 16°C	26-30	26-30	26-39
Pour point, °C, max.	-32	-34	-46
Flash point, °C, min.	193	190	182
Viscosity Index, min.	140	140	120
Foaming, ASTM D892			
Sequence I, ml, max.	25/0	25/0	25/0
Sequence II, ml, max.	50/0	50/0	50/0
Sequence III, ml, max.	25/0	25/0	25/0
Foaming, ASTM D892, Wet, 0.5% water			
Sequence I, ml, max.		25/0	
Sequence II, ml, max.		50/0	
Sequence III, ml, max.		25/0	
Copper corrosion, ASTM D130, 3 hrs 150°C	1B	1B	1B
Rust, humidity cabinet	Pass	Pass	Pass
Heat stability, 70 hrs at 125°C	Pass	Pass	Pass
Seal Compatibility	Pass	Pass	Pass
Water tolerance, various	Pass	Pass	Pass
Compatibility 50/50 mix	Pass	Pass	Pass
Hydraulic pump tests, various	Pass	Pass	Pass
Gear wear	Pass	Pass	Pass

UTTO Specifications - J I Case MS 1207/9, CNH MAT 3505

Test	J I Case MS 1207 (Nov 1986)	J I Case MS 1209 (Aug 1999) (1)	CNH MAT 3505 (Rev. Dec 2002) (2)
Kinematic Viscosity at 100°C, mm^2/S, min.	6.2	6.2	6.75
Brookfield Viscosity, ASTM D2983, mPa·s			
at -20°C	3500	4500	4900
at -30°C	15000	25000	30000
API Gravity at 16°C	Report	Report	28-32
Pour point, °C, max.	-37	-37	-36
Flash point, °C, min.	195	195	195
Viscosity Index, min.	95-115	95-115	95-115
Colour, ASTM	6 - 8 Aug	5.5-7.5	5.5-7.5
Trace sediment, % volume, max.	0.005	0.005	0.005
Sulfated ash, % mass	1.15-1.3		
Aniline point, °C	91-110	91-110	91-110
Water content, %, max.	0.1	0.1	0.1
Elemental analysis, % mass			
Barium	Report	Report	0.002 max.
Calcium	0.38 min.	0.29 min.	0.29 - 0.35
Chlorine	0.01 max.	0.01 max.	0.0075 max.
Magnesium	Report	Report	0.002 max.
Nitrogen	Report	Report	0.03 - 0.05
Phosphorus	0.3 min.	0.04 min.	0.04 - 0.06
Silicon	Report	Report	0.002 max.
Sodium	Report	Report	0.002 max.
Sulphur	Report	Report	0.75
Zinc	0.01 max.	0.01 max.	0.005 max.
Foaming, ASTM D892			
Sequence I, ml, max.	50/10	50/10	50/10
Sequence II, ml, max.	50/10	50/10	50/10
Sequence III, ml, max.	50/10	50/10	50/10
Foaming, ASTM D892, wet, 1% water			
Sequence I, ml, max.	50/0	50/0	50/10
Sequence II, ml, max.	50/0	50/0	50/10
Sequence III, ml, max.	50/0	50/0	50/10
Oxidation - corrosion, 190 hrs at 135°C	at 135°C	at 145°C	
Aluminium, loss or deposit, mg, max.	1	1	1
Copper, loss or deposit, mg, max.	8	8	5
Brass, loss or deposit, mg, max.	5	5	5
Steel, loss or deposit, mg, max.	1	1	1
Precipitation number after testing	0.01 max.	0.01 max.	0.01
Glassware rating	A or B	A or B	A or B
Water tolerance, 7 days with 1% water			
Precipitate volume, ml, max.	0.2	0.2	0.2
Centrifuged volume, ml, max.	0.1	0.1	0.1
Fluid clarity	Clear	Clear	Clear
Nephelometric Turbidity Units, NTU, max.	75	75	75
Four square gear performance, µ inch, max.	35		
Gear wear, mass loss, mg, max.	Lower than reference fluid L-3089A	Lower than reference fluid L-3939B	

Note:

(1) To qualify for requirements of Hy-Tran Ultra®.

(2) Supersedes J I Case MS 1209, both Zn free.

UTTO Specifications - J I Case MS 1207/9, CNH MAT 3505 - Cont'd

Test	J I Case MS 1207 (Nov 1986)	J I Case MS 1209 (Aug 1999) (1)	CNH MAT 3505 (Rev. Dec 2002) (2)
FZG low speed wear, D4998, mass loss, mg, max.			50
Gear wear, load stage pass, ASTM D5182, min.			7
Air release, minutes at 50°C, max.		13.5	13.5
Filterability, Case MT 807	Pass	Pass	Pass
Fluid Compatibility, 72 hrs at 125°C			
50:50 mix with reference	L-3623	L-3939B	L-3939B
Evaporation loss, % mass, max.	5	5	5
Viscosity change at 100°C, %, max.	10	10	10
Sludge formation or additive separation	None	None	None
50:50 mix with reference	L-3744	L-6384	L-6384
Evaporation loss, % mass, max.	5	5	5
Viscosity change at 100°C, %, max.	10	10	10
Sludge formation or additive separation	None	None	None
Corrosion resistance			
Galvanic corrosion, 10 dats at 50% humidity, FTMS 5322.1	Pass	Pass	Pass
Humidity corrosion, 100 hrs	Pass	Pass	Pass
Elastomer compatibility			
MS 560 reference elastomer, 70 hrs, 125°C			
Volume change, %	0 to +10		
Hardness change, points	-5 to +5		
C70 and C90 reference elastomers, 70 hrs, 125°C			
Volume change, %	0 to +5		
Hardness change, points	-5 to +5		
C70 and C90 reference elastomers, 14 days, 125°C			
Tensile strength change, %	0 to -40		
Ultimate elongation change, %	0 to -70		
P70 and P90 reference elastomer, 70 hrs, 125°C			
Volume change, %		0 to +10	0 to +10
Hardness change, points		-5 to +5	-5 to +5
Hydrolytic stability			
Fluid appearance after test		Haze permitted, no clumps or gel	Haze permitted, no clumps or gel
Copper specimen appearance, D130		1A or 1B	1A or 1B
Volume of separated matter, ml, max.		1	1
Fluid cleanliness	Level 2	Level 2	
Hydraulic pump test, Case ES A7626		Pass	Pass
Frictional performance		Pass	Pass
Brake noise (chatter)	Pass	Pass	Pass
Gear performance	Pass	Pass	Pass
Driveline durability	Pass		

Note:

(1) To qualify for requirements of Hy-Tran Ultra®.

(2) Supersedes J I Case MS 1209, both Zn free.

Afton CHEMICAL

UTTO Specifications - CNH MAT 3525/6

Test	CNH MAT 3525 (1) (Rev. D Sept 2001) (134-D fluid)	CNH MAT 3526 (Rev. B Sept 2001) (F200-A fluid)
Kinematic Viscosity, mm^2/s, ASTM D445		
at 100°C	9.1 - 9.8	8.5 - 9.0
at 40°C, typical	55	35
Shear Stability		
30 passes, min, %, ASTM D3945	-16	
Transmission/Hydraulic oil shear test, mm^2/s, min, CNH 86548393		7.9
Brookfield Viscosity, ASTM D2983, mPa·s, max.		
at - 18°C	4000	17000 @ -40°C
Viscosity Index, min.	130	185
Thermal stability, 100 hrs at 150°C, % viscosity change, max.	10, No sludge	10, No sludge
Pour point, °C, ASTM D97, max.	-37	-45
Flash point, °C, ASTM D92, min.	190	160
Foaming, ASTM D892		
Sequence I, ml, max.	20/0	50/0
Sequence II, ml, max.	50/0	50/0
Sequence III, ml, max.	20/0	50/0
Copper corrosion, ASTM D130, 3 hrs at 150°C, max.	2B	2B
Volatility, 48 hrs at 120°C, weight loss, %, max.	1	1
Rust protection, ASTM 665A	No rust	No rust
4-Ball wear, 1 hr, 85°C, 1500 rpm, 40 kg, ASTM D2266, mm, max.	0.4	0.4
Seal test, P70 and P90 reference elastomers, 70 hrs at 125°C		
Volume, %	-3 to +7	-3 to +7
Hardness change, max.	-5 to +5	-5 to +5
Water sensitivity, CNH test		
Sediment volume, ml, max.	0.1	0.1
Water separation, ml	Trace	Trace
Jenkins cycle test, 600 hrs	Pass	Pass
Tandem pump durability test	Pass	Pass
16 x 16 inching/shifting test	Pass	Pass
16 x 16 transmission, 400 cycle stall test	Pass	Pass
16 x 16 transmission, 450 cycle high energy test	Pass	Pass
Field test, 2000 hrs	Pass	Pass
Brake test	Pass	Pass
PTO clutch test	Pass	Pass
Dynamic co-efficient of friction	0.095 - 0.135	0.095 - 0.135
Static co-efficient of friction	0.085 - 0.110	0.085 - 0.110
Oil compatibility	Pass	Pass

Note:
(1) Supersedes Ford M2C 134D and FNHA-2-C-201.00.

UTTO Specification - Fiat AF87

Test	Fiat AF87 (Nov 1977)
Kinematic Viscosity, mm²/s, ASTM D445	
at 37.8°C	105 - 125
at 50°C	60 - 70
at 98.9°C	12.9 - 16.6
Apparent viscosity at -17°C, ASTM D2602, mPa·s	4500 - 9600
Pour point, °C, ASTM D97, max.	-25
Viscosity index, ASTM D1500, max.	125
Colour, ASTM D1500, max.	8
Appearance	Clear
Foaming, ASTM D892	
Sequence I, ml, max.	50/0
Sequence II, ml, max.	50/0
Sequence III, ml, max.	50/0
Oxidation at 150°C, FIAT 50520, hrs, min.	60
Gear wear using FZG rig, FIAT 50526/01	
Specific wear, mg	0.1
Load stage pass, min.	11
Co-efficient of friction on disc at 100°C, FIAT 50545	
Dynamic co-efficient on paper disc	0.08 - 0.15
Static co-efficient on paper disc, max.	0.085
Dynamic co-efficient on Cu-Sn sintered disc	0.06 - 0.13
Static co-efficient on Cu-SN sintered disc, max.	0.055
Seal compatibility, TO 125-70 elastomers, 70 hrs at 125°C, FIAT 50413	
Volume change, %	± 8
Hardness change, IRW, max.	± 8
Effect on bronze, 120°C for 100 hrs, FIAT 50516/1	Pass
Sulfated ash, % mass, ASTM D874	1.4 - 1.8
Sulphur, % mass, ASTM D126	0.8 - 1.0
Calcium, % mass, FIAT 50540	0.35 - 0.42
Zinc, % mass, FIAT 50540	0.145 - 0.175
Phosphorous, % mass, FIAT 50540	0.125 - 0.155
Impurities, including water, % mass, max, ASTM D96	0

Caterpillar TO - 4 Transmission and Drive Train Fluid Requirements

	Requirements		Test Method	
Viscometric Properties	SAE J300 Viscosity Grade	ASTM D2983 Maximum Temperature (°C) for Brookfield Viscosity of 150,000 mPa·s	ASTM D4684 Low Temp. Pumpability (MRV TP-1) 30,000 Centipoise Max, Temp. °C	ASTM D4683 (or Equiv) High Temp High Shear Viscosity at 150°C and $10^6 s^{-1}$ min. mPa·s
SAE J300 requirements plus additional low temp. and high temp. high shear requirements as shown opposite Caterpillar does not recommend oils that contain viscosity improvers in this application	0W	-55	-45	2.4
	5W	-40	-35	2.4
	10W	-35	-25	2.4
	20W	-30	-15	2.4
	30	-25	-15	2.9
	40	-20	-10	3.7
	50	-15	-5	4.5
	60	+5	+10	5.7
Wear Properties				
Gear wear	Average of three separate runs 100mg max. No single run with more than 150 mg weight.		ASTM D4998 (FZG Machine - 'A' gears, low speed, 100 rpm, 121°C, load stage 10, 20 hrs).	
Gear Scuffing	LSP (1) 8 min (SAE 10W and SAE 30 grades) ≥ LSP 10 min (SAE 40 and SAE 50 grades)		ASTM DS:82 FZG Visual 'A' gears, $8.3 ms^{-1}$, 90 °C	
Pumps	Total combined weight loss for vane and ring, < 90mg Pump parts, especially rings should not have evidence of unusual wear or stress in contact areas.		Vikers pump test procedure for mobile systems as defined in publication form M-2952-S.	
Friction Properties Link Model 1158 Oil/Friction Test Machine Dynamic Coefficient of Friction Static Coefficient of Friction Energy Capability Wear Properties - (7 friction disc-steel reaction plate combinations evaluated separately - 3 paper, 2 sintered bronze, 2 fluroelastomer friction discs.)	The results of each friction disc-reaction plate combination for the candidate oil must be within the allowable range of variation from the reference test oil.		Caterpillar VC 70 Standard Test Method.	

Note: (1) LSP = Load Stage Pass.

Caterpillar TO - 4 Transmission and Drive Train Fluid Requirements

	Requirements	Test Method
Physical Properties		
Rust Control	Less than 6 rust spots per linear inch on two out of three test specimens	Modified International Harvester BT-9 (175 hours under dynamic humidity conditions)
Copper Corrosion	1A max.	ASTM D130 (2 hrs at 100°C)
Fluid Compatibility	No sedimentation or precipitation	Mix 50 mls test oil with 50 mls reference oil; heat to 204°C, cool to ambient; centrifuge for 30 min at 6000G
Homogeneity	No sedimentation or precipitation	Test oil held at -32°C for 24hrs, warmed to ambient, centrifuged
Foam, tendency/stability, mls	Sequence I - 25/0 Sequence II - 50/0 Sequence III - 25/0	ASTM D892 Part 1: No water added Part 2: 0.1% water in oil
Flash Point	160°C min.	ASTM D92
Fire Point	175°C min.	ASTM D92
Elastomer Compatibility		
Fluoroelastomer	Av. Elongation of elastomer in aged test oil must not be greater than Av. Elongation with reference oil	ASTM D471 (240 hrs; 150°C)
	D Elongation with test oil must be less than or equal to D Elongation with reference oil + 10%	
Allison C-4 Elastomer Test	See Allison C-4 Specifications	See Allison C-4 Specifications
Oxidation Test		
Thermal Oxidation Stability (THOT)	See Allison C-4 Specifications	GM 6137 October 1990, Appendix E (ie DEXRON® IIE) (Fluoroelastomer input seal, production cooler, 35% silver)
Sludge/varnish on parts	Nil	
Total Acid Number Increase	4.0 max.	
Carbonyl Absorbance diff	0.75 max.	
Further inspection	Fluoroelastomer input seal should not fail. Copper bushings should not undergo mechanical failure due to corrosion attack. Cooler will not be graded.	
Viscosity after test		
Kinematic Viscosity, mm^2/s	Report	ASTM D445
Viscosity, mPa·s	Report	ASTM D2983[(1)]
Viscosity, mPa·s	Report	ASTM 4684[(1)]
Viscosity, mPa·s, 150°C, $10^6 s^{-1}$	Report	ASTM D683

Note:
(1) At the max. temperature specified in Section 4 of Cal T0-4 Specification for the appropriate viscosity grade.

Specification Handbook

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Engine Tests

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Mercedes Benz M111 Fuel Economy Test

CEC L-54-T-96

Equipment Used: 2.0L M111 E20 gasoline engine 4 cylinder.

Purpose: It uses flying flush oil system for changing oils without engine shutdown and enables to compare oils against a base line calibration oil. The test last 24 hours.

Test Conditions: The test procedure is based upon the ECE R15-04 and EUDC emissions test cycles. It uses flying flush oil systems to compare oils against a base line calibration oil.

Method of Rating: Fuel consumption through the test cycle is compared against that of a base line calibration oil.

Reduction in fuel consumption is expressed as a % fuel economy benefit.

Mercedes Benz M111 Sludge

CEC L-53-T-95

Equipment Used:

Mercedes Benz M111 E20, 4 cylinder 2.0L gasoline injection with 4 valves per cylinder.

Special engine required (bearings, piston rings, tappets, cams, timing chain, timing cover - cylinders differ in hardware set up).

Modified gear box by-passed by one piece main shaft arrangement or standard gear box is used.

Purpose:

To evaluate the performance of engine oils in comparison with a reference oil (RL 140) to control the formation of black sludge on engine internal surfaces. Also measured are piston deposits and cam wear.

Test Conditions:

No run in.

Phase 1:	48 hours of cyclic cold stage (includes 6 starts at -40°C ambient air temperature 25°C).
Phase 2:	1 hour power curve.
Phase 3:	75 hour alternating stage ($2^1/_2$ min. 3750 rpm. W.O.T.; $2^1/_2$ min. 3850 rpm. W.O.T.).
Phase 4:	100 hours full cyclic stage based on M102E procedure with 10 steps of varying speed, load and temperature.
Fuel:	RF-86-A-96.

Method of Rating:

Black sludge (CRC Manual No.12).
Cam wear.

Other:

Due to hardware shortages among others reasons, the M111 sludge is/will be unavailable soon. ACEA accepted M271 sludge test as an interim test to screen sludge for all ACEA categories Ax/Bx and Cx.

Piston cleanliness (DIN 51361 Part No. 2).

Mercedes Benz M271 Sludge

MB In-house Method

Equipment Used: 16 valve, 4 cylinder, 1.81 M271 E18 engine with port injection, intercooling and compressor supercharging.

Purpose: To evaluate an oil's ability to keep the engine free from sludge deposits.

Test Conditions: Following a 2.5 hour break-in, the engine is run for 250 hours with alternating hot and cold cycles. The maximum oil temperature is 145ºC.

Method of Rating: Sludge rating of rocker cover, cylinder head, front cover, oil pan.

Other: Allowed by ACEA as an interim test to demonstrate sludge performance of oils in ACEA categories Ax, Bx and Cx due to non-availability of M111 sludge test.

Mercedes Benz M271 Wear

MB In-house Method

Equipment Used: 16 valve, 4 cylinder, 1.81 M271 E18 engine with port injection, intercooling and compressor supercharging.

Purpose: To evaluate the ability of the oil to protect those components in the engine that are susceptible to wear.

Test Conditions: Following a 20.5 hour break-in, the engine is run for 250 hours with alternating test conditions. The maximum oil temperature is 145ºC.

Duration, hrs.	250
Max. Torque, Nm	240
Max. Power, kW	120
Coolant Outlet Temperature, °C	95
Max. Oil Temperature, °C	145

Method of Rating: Cam wear, piston ring wear, ring sticking, timing chain elongation, bore polishing, ring sticking, bearing wear.

Mercedes Benz OM 602 A

CEC L-51-A-98

Equipment Used: Mercedes Benz OM 602 A indirect injection, 5 cylinder in-line, turbocharged.

Purpose: To evaluate the performance of engine oils in respect of cam and cylinder wear under a combination of stop and go, medium speed and high speed operating conditions.

Test Conditions: Complex test cycle of 60 mins., which is repeated 200 times giving a test duration of 200 hours.

Currently 23 stages per cycle which includes 16 ramps.
Max. oil temperature: 142°C.
Min. oil temperature: 52°C.

Method of Rating: Cylinder and cam wear.

Oil viscosity increase.

Piston cleanliness.

Bore polish.

Engine sludge.

Other: Test no longer available.

Mercedes Benz OM 611 DE22 LA

Equipment Used:

OM 611 DE22 LA 4 cylinder turbocharged and intercooled, 16V common rail direct injection engine.

Purpose:

To evaluate the protection offered by the oil against engine wear, sludge and piston deposits.

Test Conditions:

Test length	300 hrs
Power, max.	105kW at 4200 rpm
Load, max.	315 Nm
Low sulphur fuel	(< 10ppm)

Method of Rating:

Valve train wear.

Bearing wear.

Cylinder wear.

Piston cleanliness.

Engine sludge.

Viscosity increase.

Other:

Test no longer available.

Mercedes Benz OM 646 LA

CEC L-099-08

Equipment Used:

4 cylinder Diesel, 2.2L, VTG turbocharger, I/C Direct Injection - 340Nm 110kW

Purpose:

OM 646 LA has been developed in replacement of OM 602 A and aims at evaluating the ability of an oil to control and prevent cam and tappet wear, cylinder wear, bore polishing (part ACEA oil sequences) and many others parameters such as piston cleanliness or engine sludge.

Test Conditions:

300 hrs alternating cycles using a fuel containing 5% RME and less than 10 ppm of sulphur. Oil samples taken every 50 hrs.

Method of Rating:

Valvetrain wear.

Cylinder wear.

Bore polishing.

Piston cleanliness.

Engine sludge.

Peugeot DV4 TD

CEC-L-093

Equipment Used: 1.4L, 4 cylinder DV4 TD engine with Bosch EDC 16 common rail injection system.

Purpose: To evaluate an engine oil's ability to control piston cleanliness and disperse soot in passenger car diesel engines.

Test Conditions: 120 hour test with 240 dual phase cycles.

	Phase 1	Phase 2
Duration, mins.	2	28
Speed, rpm	1100	400
Max. Torque, Nm	155	
Boost Air Pressure, mbar	710	
Boost Air Temperature, °C	120	
Oil Gallery Temperature	120	
Oil Charge, g	4200	

Method of Rating: Piston merit at end of test, increase in KV100 at 6% soot.

Afton CHEMICAL

Peugeot TU3M Valve Train Scuffing

CEC L-38-A-94

Equipment Used:

OHC Peugeot TU3M, 4 cylinder gasoline engine, 1360cc, fitted with batch approved cams and followers.

Purpose:

The method is used to evaluate the performance of engine oils in respect of valve train scuffing in a combination of hot and cold running conditions.

Test Conditions:

The test comprises two individual sequences run under different test conditions.

Total test duration: 100 hrs.

	Part A	Part B
Duration, hrs.	40	60
Engine Speed, rpm.	1500	3000
Engine Torque, Nm.	10	35
Oil Temp., °C	40	100
Coolant Out Temp., °C	45	90
Fuel Consumption, kg/hr.	1.5	4.0

Fuel: RF 83-A-91

Method of Rating:

The data is reported as ratings of the rocker pads according to the CEC M-02-A-78 test method and cam nose wear.

Afton
CHEMICAL

Peugeot TU5JP-L4

CEC-L-88-A-02

Equipment Used: In-line 4 cylinder gasoline TU5JP engine with multi-point fuel injection and catalyst system at L4 depollution level.

Purpose: To evaluate high temperature deposits, ring sticking and oil thickening control in a test that simulates high speed European highway driving.

Test Conditions: Total test length of 72 hours consisting of 6 x 12 hour, 2 stage cycles. Stage 1 is at wide open throttle, with an engine speed of 5600 rpm and oil temperature of 150°C and Stage 2 is at idle. No oil top-up.

	Stage 1	Stage 2
Duration, hrs.	11 hrs 50 mins	10 mins
Speed, rpm.	5600	Idle
Power, kW.	62	
Coolant Outlet Temperature, °C	110	
Exhaust Temperature, °C	860	
Oil Temperature, °C	150	
Fuel Specifications	RF 83-A-91	

Method of Rating: Ring sticking.

Piston varnish.

Absolute viscosity increase.

VW Intercooled T/C Diesel

CEC L-46-T-93

Equipment Used: VW 4 cylinder, 1.6L, turbocharged and intercooled diesel engine.

Purpose: Diesel detergency test for passenger car turbocharged diesel engines run under high load conditions.

Test Conditions:

Duration, hrs.	50
Speed, rpm.	4500
Power, kW (bhp)	55 (75)
Oil Temperature, °C	130
Water Temperature, °C	90
Fuel Sulphur, %	0.3

Method of Rating: Pistons rated for groove and land deposits and for ring sticking.

Other: Test no longer available.

VW TDi Diesel

CEC L-78-T-99

Equipment Used:

VW 4 cylinder, 1.9L, turbocharged, intercooled diesel engine with direct injection.

Purpose:

Diesel detergency test for passenger car diesel engines run under high load conditions.

Test Conditions:

Duration, hrs.	54
Speed, rpm.	4500
Power, kW (bhp)	82 (110)
Oil Temperature, °C	145
Water Temperature, °C	90
Fuel Sulphur, %	0.3

Test oil charge: 4.5L

No oil top-up.

Method of Rating:

Pistons rated for groove and land deposits and for ring sticking.

VW T4 (PV 1449)

Equipment Used:

4 cylinder VW PV 1449 engine with digifant injection and ignition control.

Purpose:

To evaluate the lubricant's ability to withstand oil oxidation and TBN depletion under extended service conditions.

Test Conditions:

A 2-phase test consisting of 48 x 4 hour, 3 stage cycles, followed by 56 hours steady state, with no oil top-up.

	Phase 1			Phase 2
	1	2	3	
Duration, hrs.	192			56
Duration, min.	120	72	48	
Load, Nm.	159	80	idle	80
Temperature	high	high	low	high

Method of Rating:

Piston rating.

Relative and absolute viscosity increase.

TBN depletion.

MAN D2876 LF04 (Meistersinger II)

Equipment Used: 6 cylinder MAN D2876 LF04 turbocharged Euro III engine with EGR, intercooler and reduced sump capacity.

Purpose: To evaluate the improvement in piston cleanliness, ring sticking and engine deposits of the test oil versus a reference oil.

Test Conditions: Total test duration: 400 hours.
Break-in followed by 4 x 100 hour, 2 stage cycles: 35 hours at max. power then 65 hours at max. torque.

	Stage 1	Stage 2
Duration, hrs.	35	65
Speed, rpm.	1900	1125
Power, kW.	338	
Torque, Nm.		2100
Oil Charge, L	30	

Method of Rating: Piston cleanliness.

Ring sticking.

Cylinder wear.

Engine deposits.

Sludge.

Valve train wear.

Soot related viscosity increase.

Mercedes Benz OM 364 LA

CEC L-42-T-99

Equipment Used: Mercedes Benz OM 364 LA, 4L turbocharged, intercooled diesel engine.

Purpose: To evaluate piston deposits, wear, sludge, varnish, oil consumption.

Test Conditions: The engine is run according to a cyclic procedure. Total duration 300 hours consisting of 3 x 100 hour phases of 20 x 2.5 hour cycles plus 50 hours steady state.

	Stage 1	Stage 2	Stage 3	Stage 4
Duration, hrs.	1.5	0.5	0.5	50
Speed, rpm.	2400	1500	1000	2400
Power, kW (bhp)	102 (137)	70 (94)	30 (40)	102 (137)
Coolant Outlet Temp., °C	105			
Intake Air Temp., °C	30			
Oil Temperature, °C	126			
Oil Charge, kg.	5.2			
Fuel Specifications	RF 90-A-92 (0.25 to 0.30% S)			

Method of Rating: Pistons rated for cleanliness.

Cylinder liners rated for bore polish and wear.

Cams and followers rated for wear.

Oil consumption reported.

Other: Test no longer supports current MB or ACEA specifications.

Afton CHEMICAL

Mercedes Benz OM 441 LA

CEC L-52-T-97

Equipment Used:

Mercedes Benz OM 441 LA EURO II V6, turbocharged and intercooled 250 kW engine with electronically controlled fuel pump.

Purpose:

To evaluate the performance of engine oils in respect of performance in low emission, high performance diesel engines.

Test Conditions:

Total test duration: 400 hours
50 hours cyclic (4 stages) followed each time by 50 hours constant speed/load.

	Stage 1	Stage 2	Stage 3	Stage 4	Constant Speed
Speed, rpm.	1900	1330	1140	2120	1900
Duration, hrs.	1.0	0.5	0.5	0.5	50
Power, kW (bhp)	250 (335)	210 (281)	185 (248)	2 (3)	250 (335)
Coolant Outlet Temp., °C	105				
Intake Air Temp., °C	25				
Oil Temperature, °C	> 123				
Oil Charge, kg.	16.1				
Fuel Specifications	RF 93-T-95 (0.05 % S)				

Method of Rating:

Piston cleanliness.

Bore polish.

Cylinder wear.

Oil consumption.

Sludge.

Inlet system deposits.

Turbocharger boost pressure drop.

Mercedes Benz OM 501 LA

Equipment Used: Euro V, V6 11.9L turbocharged engine with intercooler.

Purpose: To evaluate an oil's ability to prevent piston deposits and maintain engine cleanliness in a low emission, high performance engine.

Test Conditions: A 300 hour test with alternating and steady state cycles.

Duration, hrs.	300 hrs
Max. Power, kW	350
Max. Torque, Nm	2300
Exhaust Gas Temperature, °C	525
Coolant Outlet Temperature, °C	103
Oil Temperature, °C	125
Fuel	<10ppm S with 5% FAME

Method of Rating: Piston cleanliness, engine cleanliness, oil consumption.

MWM KD 12E (MWM-B)

CEC L-12-A-76, DIN 51361

Equipment Used: MWM KD 12E, single cylinder, naturally aspirated 850cc diesel engine. Compression ratio 22 to 1.

Purpose: To assess high performance diesel engine oils with respect to their influence on piston cleanliness.

Test Conditions:

Duration, hrs.	50
Speed, rpm.	2200
Power, kW (bhp)	10.7 (14.3)
Coolant Out Temp., °C	110
Oil Sump Temp., °C	110
Fuel Sulphur, % (1)	1

Method of Rating: The three ring grooves and the first and second lands are assessed for deposits.

Reporting of piston skirt and piston undercrown is optional.

The piston rings are also checked for ring sticking.

A final piston cleanliness rating is determined based on the five individual ring zone assessments.

Note: (1) To CEC RF-91-A-81 specifications.

Afton CHEMICAL

Volvo D12D

Volvo TC415

Equipment Used: A 6 cylinder, 12.1L, 460hp D12D Euro 3 engine.

Purpose: To evaluate an oil's ability to prevent piston deposits.

Test Conditions: 6 hour break-in followed by 400 hours consisting of a 12 step alternating cycle.

The fuel used is <10ppm sulphur

Max. power = 338kW

Max. torque = 2200Nm

Method of Rating: Piston cleanliness, ring riding, bore polish and oil consumption.

Ball Rust Test

ASTM D6557

Equipment Used: Custom-built bench rig, consisting of a temperature controlled shaker table and hydraulic lifter check valve balls.

Purpose: To evaluate a lubricant's ability to prevent corrosion of iron engine parts.

Test Conditions: The test simulates short trip service under typical winter conditions and correlates to the obsolete Sequence IID engine test. The oil is kept at a temperature of 40°C. The balls are submerged in the oil for 18 hours, during which time an air and acid mix is injected into the oil under controlled flow rates.

Method of Rating: The balls are rated either optically or by a computer or video system, for surface discolouration.

Sequence IIIF

ASTM D6984

Equipment Used: 1996-97 3800 Series II General Motors V-6 gasoline engine, with an overhead valve design and equipped with an external oil sump cooler.

Purpose: The test simulates high-speed service, under relatively high ambient conditions and evaluates the oil's performance with regards to oxidation induced oil thickening, piston deposits and valve train wear.

Test Conditions: The 80 hour long test is broken into 10 hour segments; at the end of each segment, an oil sample is taken and fresh oil is added.

Duration, hrs.	80 hrs
Speed, rpm.	3600
Power, kW.	~75
Torque, Nm	200
Coolant Outlet Temperature, °C	122
Oil Temperature, Filter Block °C	155
Air to Fuel Ratio	15.0:1

Method of Rating: Piston deposits, camshaft and lifter wear and increase in KV @ 40°C of the used oil.

Other: 60 hr rating applicable to API SJ and API CH-4

Sequence IIIG

Equipment Used: 1996-97 3800 Series II General Motors V-6 gasoline engine, with an overhead valve design and equipped with an external oil sump cooler.

Purpose: The test simulates high-speed service, under relatively high ambient conditions and evaluates the oil's performance with regards to oxidation induced oil thickening, piston deposits and valve train wear.

Test Conditions: The 100 hour long test is broken into 20 hour segments; at the end of each segment, an oil sample is taken and measured for KV @ 40, and fresh oil is added.

Duration, hrs.	100
Speed, rpm.	3600
Power, kW.	~94
Torque, Nm	250
Coolant Outlet Temperature, °C	115
Oil Temperature, Filter Block °C	150
Air to Fuel Ratio	15.0:1

Method of Rating: Piston deposits, camshaft and lifter wear, increase in KV @ 40°C of the used oil and low temperature used oil viscometrics.

Sequence IVA

Equipment Used: 1994 Nissan KA24E, in-line 4 cylinder engine with two inlet and one exhaust valve per cylinder.

Purpose: Designed to simulate excessive engine idling, this test measures the ability of an oil to control camshaft lobe wear in engines equipped with an overhead valve train and sliding cam followers.

Test Conditions: A 100 hour long test, consisting of 100 x 2 stage cycles.

	Stage 1	Stage 2
Duration, mins.	50	10
Speed, rpm.	800	1500
Torque, Nm.	25	25
Power, kW	2.1	3.9
Coolant Outlet Temperature, °C	50	55
Oil Temperature, °C	49	59

Method of Rating: Camshaft wear.

Sequence VG

ASTM D6593

Equipment Used: 1994 4.6L Ford V8 engine with two valves per cylinder.

Purpose: Evaluates an oil's ability to prevent sludge and varnish formation in a moderate temperature, high engine idling application.

Test Conditions: A 216 hour test, 3 stage test, consisting of 54 cycles, each lasting 4 hours.

	Stage 1	Stage 2	Stage 3
Duration, mins.	120	75	45
Speed, rpm.	1200	2900	700
Manifold pressure, kPa	66	69	Record
Oil Temperature, °C	68	100	45
Coolant Outlet Temperature, °C	57	85	45
Rocker Temperature, °C	29	85	29

Method of Rating: Engine sludge and varnish, piston skirt varnish and oil screen clogging.

Sequence VIB

ASTM D6837

Equipment Used: A 4.6L Ford V8 modular engine equipped with an external oil heating/cooling system.

Purpose: To evaluate the effect of a lubricant on the fuel consumption of a low friction engine.

Test Conditions: A baseline, 5W-30 oil is run first, and the fuel consumption is measured at 5 distinct speed/load/temperature conditions.

The test oil is then introduced, and is aged for 16 hours at Aging Phase 1 conditions, and then the fuel consumption of the test oil is measured under the same 5 speed/load/temperature conditions.

The test oil is then aged for a further 80 hours under Aging Phase 2 conditions, and then the fuel consumption at the 5 distinct conditions is measured again.

The baseline oil is then reintroduced and the fuel consumption at 5 distinct speed/load/temperature conditions is measured again.

Test length is approximately 134 hours.

	Aging Stages		Test Stages				
	Phase 1	Phase 2	1	2	3	4	5
Speed, rpm	1500	2250	1500	800	800	1500	1500
Power, kW	15.39	23.10	15.39	2.18	2.18	15.39	15.39
Oil temperature, °C	125	135	125	105	70	70	45
Coolant Temperature, °C	105	105	105	95	60	60	45

Method of Rating: FEI 1, relative fuel efficiency after 16 hours aging, and FEI 2 relative fuel efficiency after 96 hours aging, compared to the average fuel consumption of the baseline candidate oil run immediately before and after the candidate.

Sequence VIII

ASTM D6709

Equipment Used: Single cylinder, carburetted, CLR (Cooperative Lubricant Research) oil evaluation engine.

Purpose: Tests an oil's copper, tin, and lead bearing corrosion control capabilities and evaluates shear stability under high temperature operating conditions.

Test Conditions: Steady state test lasting 40 hours.

Duration, hrs.	40
Speed, rpm.	3150
Oil Temperature, °C	143

Method of Rating: Connecting rod bearing weight loss, used oil kinematic viscosity, 10 hour stripped viscosity for multigrade oils.

Sequence VID

ASTM D7589

Equipment Used: 3.6L GM Engine (LY7) installed on a dynamometer test stand.

Purpose: To evaluate the fuel economy benefit of a candidate oil in comparison with a baseline calibration oil. (SAE 20W-30)

Test Conditions: The test length is 155 hours. A baseline calibration oil is run first measuring the fuel consumption, then the candidate oil is run and finally the reference oil is run again. When changing the oil from the candidate to the reference one, a flush is required with a special flushing oil. The test is based on 6 stages each of which has constant speed/torque/temperature conditions.

Parameter	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Speed tr/min	2000	2000	1500	695	695	695
Load Cell, NM	105	105	105	20	20	40
Nominal Power, kW	22	22	16.5	1.5	1.5	2.9
Oil Gallery, °C	115	65	115	115	35	115
Coolant-In, °C	109	65	109	109	35	109

Method of Rating: Test results are expressed as a percent change in weighted fuel consumption relative to the baseline oil. FEI 1 is made after 16 hours of oil aging and FEI 2 evaluation is made after 100 hours of oil aging.

Roller-Follower Wear Test

ASTM D5966

Equipment Used: GM 6.5L diesel engine.

Purpose: Evaluation of valve train wear not related to soot.

Test Conditions:

Engine Speed, rpm.	1000
Power, kW (bhp)	30 (41) - 34 (46)
Coolant Out Temp., °C	120

Caterpillar 1K

ASTM D6750

Equipment Used:

Single cylinder supercharged diesel engine (1Y540) using one piece aluminium piston.

Purpose:

Diesel detergency test for high speed, severe supercharged conditions.

Test Conditions:

Duration, hrs.	252
Engine Speed, rpm.	2100
Power, kW (bhp)	67 (91)
Coolant Out Temp., °F	200
Inlet Air, °F/°C	260/127
Exhaust Gas, °F	1025
Inlet Air Pressure (in Hg)	71.1
Coolant Flow (galls. min).	17.3
Air Fuel Ratio	28.0
Fuel Injection Pressure (psi)	15,000
Fuel Sulphur, %	0.35 min.

Method of Rating:

Parameters assessed include piston deposits, oil consumption, piston ring projections and wear, liner polish and wear, and oil deterioration.

Caterpillar 1M-PC

ASTM D6618

Equipment Used: Single cylinder supercharged diesel engine (1Y73).

Purpose: Evaluation of ring sticking, ring and cylinder wear and piston deposits.

Test Conditions:

Duration, hrs.	120*
Engine Speed, rpm.	1800
Power kW, (bhp)	42
Coolant Out Temp., °C	88
Fuel Sulphur, %	0.4

* After 1 hour run-in

Method of Rating:

Piston and liner inspected.

Cylinder liner and piston ring wear determined.

Piston grooves and lands rated for carbon deposits.

Caterpillar 1N

ASTM D6750

Equipment Used:

Single cylinder supercharged diesel engine (1Y540) using one piece aluminium piston.

Purpose:

To determine acceptability of oils for Caterpillar engines, based on evaluation of oil consumption and piston deposits.

Test Conditions:

Duration, hrs.	252
Engine Speed, rpm.	2100
Power, kW (bhp).	67 (91)
Coolant Out Temp., °C	93
Fuel Injection Pressure (psi)	15,000
Fuel Sulphur, %	0.05

Method of Rating:

Piston deposits rated to include top groove fill (TGF) %, top land heavy carbon (TLHC) % and weighted deposits (WDK).

No stuck piston rings or piston, ring or liner distress are allowed.

Average oil consumption measured.

Caterpillar 1P

ASTM D6681

Equipment Used: Single cylinder, non-intercooled 1Y3700 engine.

Purpose: Evaluation of piston deposits and oil consumption when using two-piece pistons with forged steel crown and aluminium skirt.

Test Conditions:

Duration, hrs.	360
Power, kW (bhp).	55 (74)
Engine Speed, rpm.	1800
Inlet Air Temp., °C	60
Oil Temp., °C	130
Fuel Injection Pressure (psi)	28,000
Fuel Sulphur, %	0.03 – 0.05

Method of Rating: Total Weighted Piston Deposits (WDP), Top Groove and Top Land Carbon (TGC and TLC) and oil consumption rated.

Caterpillar C13

Equipment Used: A 2004 Caterpillar C13 ACERT, in-line 6 cylinder, 13L engine.

Purpose: Single stage test to determine an oils ability to minimize piston deposits and oil consumption.

Test Conditions:

Duration, hrs.	500
Speed, rpm	1800
Inlet Manifold Temperature, °C	40
Coolant Outlet Temperature, °C	88
Oil Gallery Temperature, °C	98
Fuel Sulphur, ppm	7-15

Method of Rating: Top groove carbon, top land carbon, 2nd ring carbon deposits and oil consumption.

Cummins M11 - HST (obsolete)

ASTM D6838

Equipment Used: 1994 Cummins M-11 330E engine which is electronically controlled and has been modified to provide over-fueling and retarded injection.

Purpose: To evaluate soot abrasive wear of the valve train, oil filter plugging and sludge formation on the rocker covers.

Test Conditions: 200 hour long test consisting of 2 x 100 hour cycles alternating 50 hour segments with retarded and standard timing. The engine runs 15% over-fuelled.

	Stage 1	Stage 2
Duration, hrs.	50	50
Speed, rpm.	1800	1600
Coolant Outlet Temperature, °C	88	
Oil Temperature, °C	115	
Timing	Retarded	Standard

Method of Rating: Crosshead wear at 4.5% soot.

Engine sludge.

Filter plugging.

Other: Test no longer available.

Cummins M11 EGR (obsolete)

D6975-03

Equipment Used: Cummins ISM 425 in-line 6 cylinder diesel engine which is turbocharged, aftercooled and has EGR.

Purpose: To evaluate the protection of an oil against soot related valve train wear, top ring wear, engine sludge and filter plugging in an high soot, EGR environment.

Test Conditions: 300 hour test length consisting of 3 x 100 hour 2 stage cycles, where Stage 1 generates soot and Stage 2 induces valve train wear.

	Stage 1	Stage 2
Duration, hrs.	50	50
Speed, rpm.	1800	1600
Torque, Nm.	1300	1930
Inlet Manifold Temperature, °C	80	65.5
Coolant Outlet Temperature, °C	65.5	
Oil Temperature, °C	115	
Oil Charge, L	30	

Method of Rating: Crosshead wear at 8.5% soot.

Top ring weight loss.

Engine sludge.

Filter plugging.

Other: Test no longer available.

Cummins ISB

Equipment Used: 2004 US EPA emission compliant, in-line, 6 cylinder Cummins 5.9L B series engine.

Purpose: To evaluate an oils ability to inhibit soot-induced valve train wear on a sliding tappet platform equipped with EGR.

Test Conditions: A 350 hour test consisting of 2 stages. Stage 1 is a 100 hour long soot generation phase, to reach 3.25% soot. Stage 2 is 250 hours of cyclical operation to induce valve train wear.

	Stage 1	Stage 2
Duration, hrs.	100	250
Speed, rpm	1600	800 - 2600 variable
Injection timing, °BTDC	15 nominal	variable
Inlet Manifold Temperature, °C	68	68
Coolant Outlet Temperature, °C	99	
Oil Sump Temperature, °C	110	
Oil Charge, kg	14.5	
Fuel sulphur, ppm	10	

Method of Rating: Average camshaft wear, average mass loss of tappet, crosshead and adjusting screw.

Cummins ISM

Equipment Used: In-line 6 cylinder 11L Cummins ISM with EGR.

Purpose: To evaluate an oil's ability to protect and engine against wear, filter plugging and sludge deposits in a high soot environment.

Test Conditions: A 200 hour test alternating between 2 x 50 hour stages where Stage 1 is a soot generation phase and Stage 2 is run under heavy load conditions.

	Stage 1	Stage 2
Duration, hrs.	50	50
Speed, rpm	1800	1600
Injection timing	Variable	Fixed
Inlet Manifold Temperature, °C	80	66.5
Coolant Outlet Temperature, °C	65.5	
Oil Gallery Temperature, °C	115	

Method of Rating: Crosshead weight loss, filter plugging, sludge rating.

Detroit Diesel 6V-92TA

ASTM D5862

Equipment Used:

Detroit Diesel 6V-92TA, 6 cylinder, two-stroke turbocharged diesel engine.

Purpose:

Evaluation of ability of lubricant to protect critical cylinder components under typical conditions of use.

Test Conditions:

Total test duration: 100 hrs consisting of 6 cycles. Half running at full load, the other half at full rated power.

	Load Mode	Power Mode
Speed, rpm.	1200	2300
Power, kW (bhp).	300 – 320	490 – 510
Oil Sump Temp., °C	112 – 119	123 – 131
Oil Consumption, g/hr., max.	340	340
Coolant Out Temp., °C	84	84

Method of Rating:

Rings, liners, slipper bushings and piston skirts rated for distress which relates to overall engine life.

Other:

Test no longer available.

MACK T-8/T-8E

ASTM D5967

Equipment Used:

Mack E7-350, 6 cylinder turbocharged, intercooled diesel engine.
12L, 350 BHP.

Purpose:

Evaluation of viscometric performance and soot loading of engine oils in turbocharged and intercooled diesel engines.

Test Conditions:

Duration, hrs.	250 at full load (T-8)
	300 at full load (T-8E)
Speed, rpm.	1800
Torque, lb/ft.	1010 – 1031
Oil Sump Temp., °C	102 – 107
Coolant Out Temp., °C	85
Fuel Sulphur, %	0.03 – 0.05

Method of Rating:

Viscosity increases from used oil analysis are measured.

Test method also stipulates max. oil consumption of 0.0005 lbs/BHP/hr.

Mack T-10 (obsolete)

ASTM D6987

Equipment Used: Mack E-Tech 460 diesel engine equipped with EGR.

Purpose: To evaluate an oil's performance with respect to piston, liner and bearing wear in an EGR environment.

Test Conditions: A 300 hour test consisting of two stages. Stage 1 is a 75 hour soot generation phase, and Stage 2 is 225 hours at peak torque.

	Stage 1	Stage 2
Duration, hrs.	75	225
Speed, rpm.	1800	1200
Power, kW.	~257	~324
Inlet Manifold Temperature, °C	70	66
Coolant Outlet Temperature, °C	66	85
Oil Temperature, °C	88	113

Method of Rating: Piston ring and liner wear.

Lead content in used oil.

Oil consumption.

Other: Test no longer available.

Mack T-11

ASTM D7156

Equipment Used: In-line, 6 cylinder Mack E-Tech V-Mac III diesel engine with EGR, turbocharging and intercooling.

Purpose: To evaluate the viscosity increase and soot loading performance of engine oils in an EGR environment.

Test Conditions: Single stage test lasting 252 hours, with variable timing to hit three different soot windows at 96 hr, 192 hr and 252 hr.

Duration, hrs.	252
Speed, rpm.	1800
Power, kW.	~257
Coolant Outlet Temperature, °C	66
Inlet Manifold Temperature, °C	70
Oil Temperature, °C	88

Method of Rating: % soot in oil leading to a 12 cSt increase in KV@100.

Mack T-12

Equipment Used: In-line 6 cylinder, 12L Mack E-TECH V-MAC III engine, turbocharged with heavy EGR.

Purpose: To determine an oils ability to minimize bearing corrosion, ring/liner wear and oil consumption.

Test Conditions: A 300 hour test consisting of two stages. Stage 1 is 100 hrs, 35% EGR, rated speed conditions to generate ~ 4.3% soot, then Stage 2 is 200 hrs, 15% EGR, peak torque conditions to generate wear and corrosion.

	Stage 1	Stage 2
Duration, hrs.	100	200
Speed, rpm	1800	1200
EGR, %	35	15
Inlet Manifold Temperature, °C	80	80
Coolant Outlet Temperature, °C	66	108
Oil Gallery Temperature, °C	88	116
Fuel	ULSD 7 -15 ppm sulphur	

Method of Rating: Increase in lead in oil, average liner wear, top ring weight loss.

Specification Handbook

Rig Tests

Contents

Rig Tests

European Tests:

Denison T6H20C Hydraulic Vane/Piston Pump Test

A-TP-30533

Scope: To evaluate the wear and filter blocking performance of hydraulic fluids in controlled conditions with and without water contamination.

Equipment: Denison T6H20C Vane/Piston Pump Rig which circulates fluid while cycling the pump output pressure and maintaining fluid flow.

Method: The same fluid is used for two 300-hr test phases, first with < 0.05% water then with 1% water.

Rating: Rating is carried out by Denison at their factory in Vierzon, France.

Specifications: Denison Specifications TP-30283.

Dynamic Seal Test

Scope: To assess sealing and wear capabilities of lubricants on oil seal materials.

Equipment: Test heads capable of applying different shaft speeds, temperatures and time duration to a fixed position test oil seal.

Methods: Test oil seal samples are held in plates that are in turn fixed to an oil chamber.

A shaft then fits through the test seal and the chamber is half filled with lubricant.

A cycle of conditions are then run.

Ratings: Visual wear and leakage during test is monitored. Other parameters are also rated including cracking, hardness and blistering.

Results: A pass or fail is derived from the rating.

FE8 Rolling Bearing Lubricant Test Rig

DIW 51819-3

Scope: The Rolling Bearing Lubricant Test Rig FE8 can be used to study the tribological system “Rolling Bearing”.

The test rig can be adapted to the most diverse operating and environmental conditions. This makes it extremely versatile, allowing field applications as well as lubricants, materials and roller bearings to be studied under their specific operating conditions.

Equipment: FE8 test rig with adaptors to run oil or grease lubricants and roller or ball bearings.

Method: A bearing is run to specific conditions for an allotted time either using a grease or oil lubricant.

Rating: A visual check for pitting of the bearing surfaces and post test weight loss, plus any increase in coefficient friction.

Flender Foam

Scope: To evaluate the behaviour of oils with regard to air absorption.

Method: The method consists of an enclosed gearbox with 1 litre of oil to be tested. The gear pair are used to mix the oil with the air and effect foam formation over a 5 minute period.

Rating: A visual rating on a numerical scale measuring the foam formation on top of the test oil.

Significance: The addition of suitable additives to reduce the effects of foaming thus reducing the possibilities of pitting and seizure.

Four-Ball Extreme Pressure Test

IP 239 & ASTM D2783

Scope: Covers two determinations of the load-carrying properties of lubricating fluids:

(a) Load-Wear Index (formerly Mean Hertz load), and
(b) Weld Point.

Equipment: A standardised machine design is used.

Method: The four-ball EP tester is operated with one steel ball rotating against three steel balls held stationary in the form of a cradle. The lubricant under test covers the lower three balls. The speed of rotation is 1780 rpm. A series of tests of 10 seconds duration are made at increasing load until welding occurs.

Load-Wear Index: An index of the ability of the lubricant to prevent wear at applied loads. The equation for load-wear index reflects the ability of a lubricant to carry a high load without welding and to allow only relatively small wear scars at loads below the weld point.

Weld Point: The lowest load in kilograms at which the rotating ball welds to the three stationary balls.

Specifications: The user should determine to his own satisfaction whether the results correlate with field performance or other bench test machines.

Four-Ball Wear Test

ASTM D4172

Scope: Covers a procedure for making a preliminary evaluation of anti-wear properties of fluid lubricants. Evaluation of greases using the same machine is detailed in Method D2266.

Equipment: A standardised machine design is used.

Method: Three 12.7 mm diameter steel balls are clamped together and covered with the lubricant under test. A fourth steel ball is pressed with a force of 147 or 392 N into the cavity formed by the three balls for the “three-point contact”. The temperature of the test lubricant is regulated at 75°C and the top ball is rotated at 1200 rpm for 60 minutes. Lubricants are compared by using the average size of the scar diameters worn on the lower three clamped balls.

Specifications: The user of this method should determine to his own satisfaction whether the results of this procedure correlate with field performance or other bench test machines.

FZG A10 Shock/Stage Test

FVA Research Project No. 243 CEC SG-T-084

Scope: To differentiate between lubricants with higher EP performance.

Equipment: (See FZG load carrying test).

Method: Special gears are run in a bath of candidate lubricant.

(Stage Test) The load on the tooth flanks is increased in stages from Stage 1 to load stage 10.

(Shock Test) The expected failure load is applied to an unused gear flank.

Ratings: The gears are inspected visually without removal at the end of each load stage.

The failure load stage is reached when the sum of the damaged area's width exceeds $100mm^2$.

Results: Report the failure load stage as the result.

FZG Load-Carrying Capacity Test

DIN 51354/CEC L-07-A-95

Scope: Assess the relative load-carrying capacities of oils when used to lubricate steel/steel spur gears.

Equipment: The FZG spur gear test rig consists of a closed power circuit with drive and test gears connected by two torsion shafts. One of the shafts has a positive clutch for application of the load.

Method: Special gear wheels are run in the lubricant under test at a constant speed for a fixed time. The initial oil temperature is controlled but allowed to rise freely during each stage of the test. Loading is raised in stages. The test is continued until the damage load stage is reached, but if no damage occurs at load stage 12 the test is terminated.

Ratings: The gears are inspected visually, without removal, at the end of each load stage.

The failure load stage is determined by the summation of deep scoring, seizure lines or seizure areas on any of the gear teeth.

Results: The load stage in which failure occurs is reported together with the test conditions; e.g. A/8.3/90, where A = gear type, 8.3 = pinion speed at pitch circle in m/sec, and 90 = initial temperature in oil sump in °C. These are the usual conditions, but they can be changed as required.

Specifications: Results are reported in terms of the highest pass stage for the CEC method or the first fail load stage, for the DIN Method.

Afton CHEMICAL

FZG Low Speed Test

Scope: Based on a test originally developed by Chevron, this new procedure has been adopted by ASTM D 4998-89 for the evaluation of final drive lubricants for use in agriculture tractors and similar off-road applications.

Method: Using the same test equipment and gear wheels as for the FZG load-carrying capacity test, this procedure requires a fixed load durability run to the following conditions.

Lubricant Temp., °C	121
Load Stage	10
Motor Speed, r/min.	100 ± 3
Duration, Revolutions	120,000

Results: The data is reported as total weight loss for both test gears, together with the total number of teeth exhibiting wear. The precision of the method has not been determined.

Note: CEC test method development working group has abandoned the method until further research studies are completed. This is due to poor discrimination.

FZG Pitting Test

FVA 2/IV

Scope:

For testing suitable gear oils in the viscosity range from ISOVG 32 to ISOVG 220 to discriminate pitting performance.

Equipment:

The FZG spur gear test rig consists of a closed power circuit with drive and test gears connected by 2 torsion shafts.

One of the shafts has a positive clutch for application of the load.

Method:

FVA Project No 2/IV - A set of test gears are run in approximately 1.5 litres of fluid with a constant tooth loading for up to 300 hours. A visual inspection is carried out every 24 hours.

Results:

The failure criteria is a pitting area on an individual tooth at least 4% of the active flank. This corresponds to approximately $5mm^2$.

FZG Micropitting Test

FVA 54/I - IV

Scope: Evaluates the ability of gear lubricants to resist micropitting.

Equipment: A FZG gear rig is specially adapted to supply spray lubrication at a given rate and temperature to both the slave and spur gear boxes.

Method: The two part procedure comprises a load stage test followed by an endurance test. During the load stage test, the ability of the gear lubricant tribological systems to resist micropitting is determined. The endurance test provides information on the progress of the damage after a higher number of load cycles.

Results: The gears are examined for weight loss, area of micropitting involute profile deviation.

SSP180 Synchromesh Test

CEC L-66-95

Scope: To determine the endurance life of synchromesh systems using different materials for manual gearboxes in automotive applications defined by wear and coefficient of friction.

Equipment: SSP 180 Synchromesh Test Rig, with measuring devices.

Method: After a short running in period a synchromesh is used to engage/disengage two individual revolving shafts.

The complete test comprises of 100000 cycles without clashing.

Results: The test is evaluated by clashing of the synchromesh, coefficient of friction and mechanical wear on the contact parts.

MB Planetary Gear Rig

Scope: To assess the relative EP/anti-wear and anti-pitting properties of gear oils under low speed - high torque non steady state conditions.

Equipment: The MB Planetary Gear rig is based upon a Mercedes Benz screening rig using vehicle hub reduction units.

Method: The test cycle below is repeated until a tooth breaks, excessive noise is heard, or the iron content of the oil sample, taken every second cycle, shows a significant increase.

DURATION (sec)	SPEED (rpm)	TORQUE (KNm)
154	420	-2.0
288	480	8.6
154	420	-2.0
88	420	9.4
154	420	-2.0
46	420	10.3
154	420	-2.0
24	420	11.1
58	420	-2.8
17	360	11.9
25	420	-3.7
4	360	12.8
6	420	-4.5
3	360	13.6
1	420	-5.4
5	300	14.4
154	420	-2.0
30	0	0
446	480	7.0
154	420	-2.0
414	480	7.8

Inlet oil temperature controlled at 100°C.

Rating Method: The two sun gears and ten planetary gears are inspected for amount of pitting and wear on the teeth.

Schmidt/Afton Tribo Tester Slideway Oil Test

Scope: The method evaluates oil in respect of static friction and stick slip behaviour when used in machine slideway applications.

Method: A slideway supporting a sliding block is lubricated with the test oil. The slideway is gradually inclined until the sliding block begins to move. The angle at which the block moves 20 mm is used to calculate the 'Schmidt Coefficient of Friction' which uses a calculation developed by the Hans Schmidt Tribology Laboratory for their original slideway test machine.

The method uses two combinations of test materials:

(a) Grey Cast Iron on Grey Cast Iron;

(b) SKC 3 plastic on Grey Cast Iron.

300 run-in cycles are carried out with the SKC 3 plastic test and 400 with the Grey Cast Iron test. After completing the run-in, 10 test cycles are carried out to determine the 'Schmidt Coefficient of Friction' of the oil.

Results: Graphical plots of all the run-in and test cycles are presented along with the calculated results of the 10 test cycles.

Shear Stability Test - Kurt Orban

CEC L-14-A-88

Scope: To correlate shear stability with the permanent viscosity drop expected in field service.

Equipment: Kurt Orban Injector rig.

Method: A sample of oil is subjected to 30 or 250 cycles of a two cylinder diesel injection pump and injector nozzle set to a pressure of 175 bar.

SKF Emcor (DIN 51802)

Scope: To evaluate rust and corrosion properties of a lubricant with the presence of water.

Equipment: Specially manufactered rig conisting of 8 test bearing housings connected on a common electric drive motor shaft.

Method: Bearings run in an oil/water mixture for 8 hrs. The rig then stands idle for a period of 16 hrs. This cycle is then repeated with a final running of 8 hrs before standing idle for 108 hrs. The bearings are then rated.

Rating: Bearings are visually rated on a scale of 1-5 depending on the amount of corrosion present.

Significance: Lubricant performance with the presence of water.

Afton CHEMICAL

The Brugger Test

Scope: The Brugger Test determines the load capacity of industrial, transmission and hydraulic lubricants. The test provides a useful technique for evaluating the wear protection of a lubricant under conditions of minimal lubrication.

Equipment: A Müller Weingarten Brugger Test Machine is used.

Method: A 25 mm diameter steel friction roller is rotated at 940 rpm (1.2 m/sec) against an 18 mm diameter fixed steel cylinder roller with a force of 400 N applied by a lever mechanism for 30 seconds. The surfaces are lubricated with a 5 ml sample poured over the assembly one minute before the start of the test.

Results: The result is reported in N/sqmm, calculated from the measurement of the wear scar.

Specifications: Typical pass criteria are:

Hydraulic Oil	≥ 30 N/sqmm
Transmission Oil	≥ 50 N/sqmm
Grease	≥ 30 N/sqmm

Significance: The user should determine to his own satisfaction whether the results correlate with field performance or other bench test machines.

Timken Extreme Pressure Test

ASTM D2782

Scope: Covers the determination of load-carrying capacity of lubricating fluids by means of the Timken Extreme-Pressure Tester.

Equipment: The test uses the Timken Wear and Lubricant Testing Machine, in which a pivoted test block is applied to the periphery of a rotating cylinder (cup) in such a way that the pressure of application can be controlled.

Method: The machine is operated with the steel cup rotating at 800 r/min. Two determinations are made: the minimum load that will rupture the lubricant film and cause scoring or seizure; and the maximum load (OK load) that will not rupture the lubricant film.

Testing is initiated at an applied load of 30 lbs and increased in increments of 10 lbs until scoring occurs. The load is then reduced by 5 lbs to determine the final score load and OK load values. Each load stage is run for a 10 minute duration and the lubricant temperature is brought to 38°C at the start of each stage.

Specifications: The method is widely used for specifications purposes and is used to differentiate between lubricants having low, medium or high extreme-pressure characteristics. The results may not correlate with results from service.

Volkswagen Shear Stability Test

CEC L45-A-99 Taper Roller Bearing Rig

Scope: Determination of the mechanical shear stability of lubricants containing polymer additives such as gearbox, shock-absorber, automatic transmission and engine oils.

Method: An adaptor, containing a standard single row taper roller bearing, is installed in a Four-Ball test machine. 40ml of test oil is introduced into a cup surrounding the bearing and the machine is run at 1500 r/min. with a 5 KN bearing axial load, for test durations of 4, 8 and 20 hours. The oil temperature is held at 60°C.

The percentage loss in kinematic viscosity of the oil after each test run is plotted against time.

Significance: The method is being standardised for specifications purposes and is a rapid means of assessing the shear stability of a wide range of lubricants.

Note: Limited service correlation of data from this test method is available.

It is anticipated that this test will be introduced into Volkswagen lubricant specifications as they become due for revision.

Conestoga Pump Test

ISO 20763 ASTM D7043

Scope: For determination of steel on steel anti-wear properties of hydraulic fluids by means of performance in a vane type hydraulic pump. It covers a range of hydraulic fluids, both anhydrous and aqueous, Intended for applications where high speed sliding contacts, such as those found in a vane pump are encountered.

Equipment: A Vickers type V-104-C 12 pump housing containing Conestoga internals is used to circulate a hydraulic fluid around a closed loop system.

Method: ISO 20763 The test consists of a vane pump circulating hydraulic ASTM D7043-4a oil with a relief valve pressure of 14 Mpa and at a temperature to achieve a viscosity of 13mm2/s for anhydrous fluids and 30mm^2/s for aqueous at the pump inlet port.

Rating: The vanes and cam ring from the test cartridge are weighed before and after test to determine weight loss.
A visual inspection is also carried out on the contact parts.

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