Recommended Guideline

Global Performance Specification
for Diesel Engine Oil
(Global DHD-1)

SCOPE

This Specification has been jointly developed by Association des Constructucteurs Europeens D'Automobilies (ACEA), Engine Manufacturers Association (EMA) and Japan Automobile Manufacturers Association, Inc. (JAMA). It is a performance specification for engine oils to be used in high-speed, four stroke-cycle heavy-duty diesel engines designed to meet 1998 and newer exhaust emission standards worldwide. Oils meeting this specification are also compatible with certain older engines. Application of these oils is subject to the recommendation of individual engine manufacturers. Individual engine manufacturers have sole discretion as to oil recommendations for their engines. They may choose to recommend oil meeting this performance specification, or oil meeting this specification with additional performance requirements, or oil with other performance requirements.

Engine oils meeting the minimum performance requirements of Global DHD-1 are intended to provide a consistent oil performance worldwide and therefore may be recommended by engine manufacturers to maintain engine durability wherever their engine is being used. This Specification identifies engine oil for use under adverse applications that necessitate wear control, high-temperature stability and soot handling properties. In addition, Global DHD-1 is expected to provide engine oils with protection against non-ferrous corrosion, oxidative and insolubles thickening, aeration, and viscosity loss due to shear.

Recommendations of this performance specification in manufacturer's maintenance guides, owner's manuals, and related documents to describe the engine oils required for their products is voluntary. Oil marketers may voluntarily choose whether to market engine oils that meet this specification. ACEA, EMA and JAMA do not certify or license engine oils, are not responsible for individual oil marketer's claims of compliance with the Global DHD-1 specification, and make no representation or warranty concerning the appropriateness or performance of any oil alleged to meet this specification.

TERMINOLOGY

HEAVY DUTY

Engine oils formulated to this Specification are intended for use in diesel-fueled engines used in vehicles with a Gross Vehicle Weight Rating of 8600 pounds (3900 Kgs) or higher.

PERFORMANCE LIMITS

The performance limits for the Specification are summarized in Tables 2a and 2b. While ACEA, EMA, and JAMA believe that in order to meet the performance limits of Global DHD-1 engine oils should undergo a full test program, it is recognized that commercial practice often includes the use of base oil and viscosity modifier interchangeability and viscosity grade readacross guidelines. Therefore the use of interchangeability and readacross guidelines generally applied to the respective engine tests included is acceptable. ACEA, EMA and JAMA recommend that any producer or marketer claiming that an engine oil meets the Global DHD-1 specification have adequate performance data to support such claim and make such performance data reasonably available to interested parties upon request.

RECOMMENDED GUIDELINE
A document developed for the purpose of outlining the industry's position on certain technologies, regulatory practices, or the tests and limits necessary to measure performance of a product or technology. A Recommended Guideline represents the position of the members of an association adopted after formal review and comment from individuals and organizations outside of the association.

TEST AVERAGING ACCEPTANCE CRITERIA (TAAC)
Any data based approach for evaluation of the performance of an oil formulation where more than one test is run on an oil formulation, and the results are averaged. If three or more tests are conducted one test may be discarded from the average. All parameters must average to a passing result. TAAC only applies to those performance characteristics that are shown in Tables 2a and 2b with a single limit. Characteristics with more than one limit are based on the number of runs made and reflect the test's precision without further averaging.

SIGNIFICANCE AND USE OF THE RECOMMENDED PROPERTIES

For the benefit of end-users and other interested parties, the following section summarizes the critical properties of lubricating oils, and where appropriate, the reason for the selection of a particular quality level of that property.

Corrosiveness
Some oils may inadequately inhibit a chemical attack of metals other than iron, which are used in bushings, bearings and oil coolers of the engine. The Cummins High Temperature CBT evaluates corrosion of lead, copper and tin at the higher temperatures found in some engines.

Foaming / Aeration
Excessive oil aeration can cause low oil pressure; malfunction of hydraulic valve lifters; and in engines with hydraulic-electronic unit injectors, injection timing may be adversely affected, since air is compressible. Oil with an excessive amount of air does not lubricate engine parts properly, potentially leading to abnormal engine wear. The International 7.3L engine is used to measure this property.

Oxidation Control
The moving parts of an engine are designed to operate on a lubricating film. The thickness of this film determines the load carrying ability of the engine components. Therefore, to properly perform, the oil must maintain a consistent viscosity not only when new but also during service. Several factors impact an oil's ability to maintain a consistent viscosity. Soot and oxidation typically cause viscosity to increase while fuel

contamination and shear typically cause viscosity to decrease. Oxidation may be inhibited with the proper oil formulation. Oxidation control is measured with the ASTM Sequence IIIF test and the CEC L-85-T-99 PDSC method. The Sequence IIIF oxidation requirements may be satisfied with a Sequence IIIE test result at the passing API CH-4 level.

Piston Deposits and Bore Polish

Survey experience has shown buildup of ring belt deposits to cause improper ring operation that can lead to high oil consumption and cylinder scuffing. This condition generally determines the life to overhaul for most diesel engines and may have an effect on emission levels. Two engine tests have been identified to measure this performance requirement. The Mercedes Benz OM 441LA test is used for evaluating piston deposit control in engines equipped with aluminum pistons, while the Caterpillar 1R test is used for ferrous pistons. The 1R requirement may be satisfied with a Caterpillar 1P test result at the passing API CH-4 level.

Shear Stability

Engine oils that contain polymers typically undergo viscosity loss when subjected to high shear conditions. High shear regimes in an engine exist in piston ring and cylinder wall interface, valve train, and other areas of high relative parts velocity, high loading, and/or high temperature. Shear stability is measured by ASTM D3945, which accommodates the European CEC L-14-A-93 technique. Shearing which results in a permanent viscosity loss is evaluated in this test by passing fresh oil through a high shear fixture, followed by measuring kinematic viscosity (ASTM D445). An engine oil producing a test result below the prescribed limit may not maintain sufficient oil film thickness in heavily loaded areas of the engine. A “stay in grade” requirement is often viewed as an oil drain requirement.

Sludge Control / Filterability

Retarded injection timing increases the potential for partial combustion products to reach the cylinder wall and mix with crankcase oil. These resinous materials form sludge deposits and can plug oil filters if not adequately dispersed. The ability of an oil to control filter plugging is critical since plugged filters can allow unfiltered oil to circulate through the engine causing excessive wear of bearings. High filter delta pressure can also result in a delay in delivery of oil to critical bearings during cold starts. Under severe conditions sludge can accumulate restricting oil flow. Sludge accumulation is often used to judge oil quality at the user level. The Cummins M11 HST measures both sludge and filter plugging.

Soot Control

High levels of soot in the engine oil can cause sludge formation, wear and filter plugging. Soot accumulates in the engine oil of a diesel engine as a result of engine timing and combustion. Although the engine oil does not typically impact the formation of soot, a properly formulated engine oil can reduce the effects of soot on engine durability. The Mack T-8E engine test is used to measure this performance requirement.

Turbocharger Deposits
Engine lubricants may form deposits in the turbocharger that can lead to lower boost pressure. In modern engines, a central engine computer adjusts fuel rate based on monitored turbocharger boost pressure, among other parameters. In order to optimize the emission levels the fuel quantity will be reduced by decreasing boost pressure, which will prevent the engine from achieving its specified output. The ability of an oil to control turbocharger deposits is evaluated via the OM441LA engine test (CEC L-52-T-97).

Volatility
This characteristic evaluates the volatility of engine oils at 250 °C using a NOACK evaporative tester (ASTM 5800). Oils that exhibit high evaporative rate (high volatility) tend to have high oil consumption rates in engines. In some engine designs, high oil consumption may increase particulate emissions.

Wear, Ring/Liner
Piston ring and cylinder liner wear is directly related to engine service life. Under conditions of retarded fuel injection timing, used to meet reduced exhaust emission limits, fuel soot induced wear is likely. The capability of an engine oil to protect the piston rings and liner under these conditions is evaluated with the Mack T-9 test.

Wear, Valvetrain
Increased valve train loading, coupled with higher engine oil soot loading, as a result of engine design intended to meet reduced exhaust emission standards, has created a concern regarding excessive valve train wear. Wear of these components may change engine timing, impacting performance and exhaust emissions. Wear also shortens engine life. Valve train wear mechanisms may be either rolling or sliding depending on design. The General Motors Roller Follower Wear Test (RFWT ASTM D5966) is used to measure engine oil performance for its effect on axle shaft wear, indicating roller wear conditions. Sliding follower valve train wear protection is measured in two tests. The Mitsubishi 4D34T4 measures engine oil performance effects on cam lobe wear and the Cummins M11 HST evaluates oil performance impact on rocker pad wear.

DESCRIPTION OF ENGINE TESTS[1]

The following table (Table 1) provides a summary of the engine tests used for this Specification. The tests that describe the performance of engine oils which meet these recommendations have been identified by the particular engine manufacturer of each named test as being representative, either through actual field testing or engineering judgment, of the measured characteristic.

A brief description of each test follows. The complete engine test procedures described in this section are available from the Association des Constructucteurs Europeens D'Automobiles, the Engine Manufacturers Association and the Japan Automobile Manufacturers Association.

[1] The descriptions of ASTM Methods as compiled here by ACEA, EMA and JAMA include extracts from the Annual Book of ASTM Standards, copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959. The complete text of the original ASTM standards may be obtained directly from ASTM as follows: by phone: 610-832-9585, fax: 610-832-9555, e-mail: service@astm.org, or from the ASTM website: www.astm.org.

Table 1
Global DHD-1 Engine Test Summary

Test Identification	Engine Speed r/min	Test Length Hours	Fuel Flow	Power Output
Mitsubishi 4D34T4	3200	160	96.0 $\pm$ 1.0 mm^3/stroke cyl.	120 kW
MB OM 441 LA	1900 / 1330 / 1140	400	160 / 181 / 191 mg/stroke	240 / 205 / 185 KW
Caterpillar 1R	1800	504	240 g/min	68 kW
Cummins M11 HST	1600 / 1800	200	117 lb/h	335 / 360 hp
Mack T-8E	1800	300	139.5 $\pm$ 1% lb/h	353 hp
Mack T9	1800 / 1250	75 / 425	139.5 / 121.2 lb/h	360 / 425 hp
International 7.3L	3000	20	42 kg/h	153 kW
Roller Follower Wear Test - RFWT	1000	50	9.4 kg/h	32-36 kW
Sequence IIIF	3000	60	N/A	100 hp

MITSUBISHI 4D34T4

Protection performance of soot related valve train wear can be evaluated by this test. Decrease in cam-lobe diameter is used to determine the level of valve train wear. The test engine is the Mitsubishi 4D34T4 engine, a 3.9-liter, in-line, 4-cylinder, with charge-air inter-cooling. In order to obtain better discrimination among oils, a nodular cast iron camshaft, which is different from that of the production engine, is used. The engine conditions are set up to produce around 4.5% soot increase at the end of the test. This is achieved by operating at a steady state of 3200 rpm with 10% over fueled during the total test duration of 160 hours.

MERCEDES BENZ OM 441 LA

The OM 441 LA is an 11-litre, V6 Heavy Duty Diesel engine that produces 250 kW at 1900 rpm and meets ‘Euro 2’ exhaust emission standards. The test duration is 400 hours. It consists of alternative 50-hour phases of steady state and constant speed running. During the test the oil temperature rises to above 123 ^{o}C and coolant temperature is controlled at 106 ± 1^{o}C. Oil samples are taken every 50 hours during the test.

Primary test parameter: Bore Polish
Piston Cleanliness
Turbocharger Deposit (boost pressure loss)

CATERPILLAR 1R

The Caterpillar 1R test is similar to the Caterpillar 1P test used in API CH-4. The 1R utilizes a different piston and ring assembly than the 1P, but the test procedure is very similar. Both the 1R and 1P evaluate lubricant performance with regard to piston deposits, oil control, and scuffing resistance for ferrous pistons. The 1R test is run in a high-speed four-stroke cycle Caterpillar 1Y3700 single cylinder oil test engine (SCOTE). The 1Y3700 SCOTE represents the latest technology in diesel engine design, and it is equipped with the following features:

- Two piece articulated piston with steel crown and aluminum skirt
- Mid-supported low distortion cylinder liner
- Gear driven overhead cam
- High pressure electronically controlled fuel injection system
- High temperature oil system

Fuel sulfur for the 1R is set at 0.05% to represent diesel fuel used in North America after 1994 and in many other densely populated areas of the world. The 1R test is run for 504 hours with the engine operating steady state at full rated speed and load. At the end of the test, the piston deposits and oil consumption are evaluated and the pistons, piston rings, and cylinder liner are analyzed for any scuffing or seizure. The 1R test is designed to evaluate the performance of lubricants for current direct injection high-speed diesel engines operating on low sulfur diesel fuels.

CUMMINS M11 HST

The Cummins M11 HST test is run in a six-cylinder engine that has a specially programmed electronic controller to generate soot in the crankcase oil. The test cycles represent conditions that generate soot and those that generate wear in the overhead valve train.

Test cycle:
50 Hours @ 1800 r/min Soot generating
50 Hours @ 1600 r/min Wear generating
50 Hours @ 1800 r/min Soot generating
50 Hours @ 1600 r/min Wear generating

The Cummins M11 HST is designed to evaluate an oil's abilities to prevent excessive filter pressure drop, excessive viscosity increase, sliding valve train wear, bearing corrosion and sludge deposits when it is subjected to high levels of soot.

MACK T-8E

The Mack T-8E test is run in an E7-350 six-cylinder engine with mechanical fuel injection. The fuel injection timing is adjusted to give a target level of soot build-up in the bulk lubricant. The Mack T-8E test is designed to evaluate an oil's ability to prevent excessive viscosity increase and filter plugging when it is contaminated with high levels of soot. The test length is 300 hr. (was 250 hr. for CG-4) to accumulate enough soot (4.8 % min.) for pass / fail limit. The limit includes relative viscosity (Visc. @ 4.8 soot / (0.5 ✶ (V new + V Din)) which removes the effect of oil shearing during test. The Mack T-8E shears oils to approx. 50% of the Din (D 3945) viscosity.

MACK T-9 (ASTM D 6483)

The Mack T-9 test is run in an E7-350hp V-MAC six cylinder Mack engine with electronic fuel injection control. The Mack T-9 was developed to evaluate ring and liner wear in a modem high-output diesel engine with two-piece ferrous/aluminum pistons. It also evaluates lead corrosion due to loss of total base number (TBN) in oil. It is a 2-stage test:

Phase 1 75 Hour @ 1800 r/min for soot generation.
Phase 2 425 Hour @ 1250 r/min for wear and corrosion

ENGINE OIL AERATION TEST (ASTM RR:D02: 1379)
The Engine Oil Aeration Test is a twenty (20) hour flush and run test, using International 7.3L DIT diesel engine. Engine oil from the oil sump is used to actuate the fuel injectors. The test evaluates the engine oil's resistance to aeration. Excessive oil aeration can adversely impact engine operation. In severe cases, it may prevent a cylinder from firing thus causing a rough engine operation. An oil sample is taken in a 100 ml graduated cylinder and aeration is calculated by taking the percent difference between the exact initial volume and final volume.

ROLLER FOLLOWER WEAR TEST (ASTM D-5966)
The Roller Follower Wear Test is a fifty (50) hour flush and run test, using GM 6.5L diesel engine, in which only the valve lifters are replaced between tests. This test is designed to evaluate an oil's ability to prevent wear of the axle shaft in roller follower hydraulic valve lifter assemblies equipped with needle bearings. This test has been correlated with stop-and-go delivery service.

ASTM SEQUENCE IIIF
ASTM Sequence IIIF test is designed to evaluate an oil's ability to resist thickening when subject to high-temperature service. This test replaces the Sequence IIIE Engine Test (ASTM D5533) used in API CH-4. The thickening measured in this test is not soot related.

DESCRIPTION OF BENCH TESTS[2]

While full scale fired engine tests are preferred for the evaluation of lubricant performance properties, it is not practical from a cost or availability perspective to measure certain properties. Therefore laboratory tests that simulate these performance areas are utilized. Such laboratory, or bench, tests offer evaluation of performance properties at a reduced cost and cycle time compared to engine tests. The following section provides a description of the bench tests utilized in this Specification.

CORROSION
The Standard Test Method for Evaluation of Corrosiveness of Diesel Engine Oil, ASTM D6594, is used to test diesel engine lubricants to determine their tendency to corrode alloys of lead and copper commonly used in cam followers and bearings.

Four metal coupons of copper, lead, tin and phosphor bronze are immersed in a measured amount of engine oil at 135 degrees C. Air is passed through the oil for the 168 hour test duration. The oil is then analyzed for copper, lead and tin content using

[2] The descriptions of ASTM Methods as compiled here by ACEA, EMA and JAMA include extracts from the Annual Book of ASTM Standards, copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959. The complete text of the original ASTM standards may be obtained directly from ASTM as follows: by phone: 610-832-9585, fax: 610-832-9555, e-mail: service@astm.org, or from the ASTM website: www.astm.org.

spectrometric analysis, ASTM D5185. Concentration of these metals must be below specified levels to meet the requirements of this Specification.

ELASTOMER COMPATIBILITY

The Evaluation of Oil-Elastomer Compatibility, CEC-L-39-T-97, is aimed at determining the degree of compatibility of lubricating oils and cured elastomers used in the automotive industry. Elastomer test pieces are immersed in the test oil for a given period of time and at a given temperature. The size, the volume, the hardness, and the stress-strain properties are determined before and after immersion. The compatibility of the oil and the elastomer is estimated by the change in these characteristics.

The materials and test temperatures are provided in the following table. Immersion duration is 168 hours (7 days), in fresh oil with no elastomer preaging.

Material Designation	**General Elastomer Type**	**Test Temperature**
RE 1	Fluoro-elastomer	150^oC
RE 2	Acrylic	150^oC
RE 3	Silicone	150^oC
RE 4	Nitrile	100^oC

FOAMING TENDENCY

The Standard Test Method for Foaming Characteristics of Lubricating Oils, ASTM D892 covers the determination of the foaming characteristics of lubricating oils at 24 degrees C and 93.5 degrees C. It provides a means of empirically rating the foaming tendency and stability of the foam.

The sample, maintained at a temperature of 24 degrees C is blown with air at a constant rate for 5 minutes, then allowed to settle for 10 minutes. The volume of foam is measured at the end of both periods (Sequence I). The foaming tendency is provided by the first measurement, the foam stability by the second. The test is repeated using a new portion of sample at 93.5 degrees C (Sequence II) however the settling time is reduced to 1 minute. For Sequence III the same sample is used from Sequence II, after the foam is collapsed and cooled to 24 degrees C, the oil is blown with dry air for 5 minutes, then settled for 10 minutes. The tendency and stability are again measured.

The Standard Test Method for High Temperature Foaming Characteristics of Lubricating Oils, ASTM D 6082, test method describes the procedure for determining the foaming characteristics of lubricating oils at 150 degrees C.

A measured quantity of sample is heated to 49 degrees C for 30 minutes and allowed to cool to room temperature. The sample is transferred to a 1000 mL graduated cylinder heated to 150 degrees C, and aerated at 200 mL/min with dry air for 5 minutes with a metal diffuser. The amount of foam generated before disconnecting the air is a measure of the foaming tendency, the amount of static foam after one minute of settling provides a measure of the foam stability.

OXIDATION - HOT SURFACE

Hot surface oxidation is determined by the CEC L-85-T-99 test. In this test, a small sample is heated under pressure using the Pressurized Differential Scanning Calorimetry (PDSC) technique. The pressure is kept at 100 psi while the temperature is ramped from 50 degree C to 210 degree C at a rate of 40 degree C/min. The heat flow to the sample is measured and compared to a reference and the Oxidation Induction Time (OIT) is hereby determined.

SHEAR STABILITY

The Standard Test Method for Shear Stability of Polymer-Containing Fluids Using a Diesel Injector Nozzle, ASTM D3945 or CEC L-14-A-93, measures the percent viscosity loss at 100 degrees C of polymer containing fluids when evaluated with a Bosch PE 2 A 90C300/3S2266 double plunger injection pump connected to an atomization chamber equipped with a Bosch DN 8 S2 pintle nozzle injector.

The engine oil is passed through the diesel injector nozzle at a shear rate that causes the less shear stable polymer molecules to degrade. The resultant degradation reduces the kinematic viscosity of the test oil. The specification requires that the oil remain within the designated SAE viscosity grade after 30 test cycles.

SULFATED ASH

The Standard Test Method for Sulfated Ash from Lubricating Oils and Additives, D874, covers the determination of the sulfated ash from unused lubricating oils containing certain metals. In this test method an oil sample is ignited and burned until only ash and carbon remain. After cooling, the residue is treated with sulfuric acid and heated to 775 degrees C until oxidation of carbon is complete. The ash is then cooled, retreated with sulfuric acid, and heated at 775 degrees C to a constant weight. The resulting mass as a percentage of the initial oil sample mass provide the reported value for this specification.

HIGH TEMPERATURE / HIGH SHEAR RATE VISCOSITY

Three test methods are listed for measurement of this property, consistent with the SAE J300 viscosity classification. Each method evaluates engine oil viscosity by subjecting it to conditions of high shear rate (1×10^6 s^{-1}) and high temperature (150 degrees C).

ASTM D4683 and CEC L-36-A-90 utilizes a motor driven tapered rotor that is closely fitted in a matched stator. The rotor exhibits a reactive torque response when it encounters a viscous resistance from an oil filling the gap between the rotor and stator. The unit is calibrated with reference oils.

ASTM D4624 utilizes a capillary viscometer which responds to the apparent shear rate at the walls of the capillary as determined by the pressure drop and flow rate through the capillary under desired conditions. This unit is also calibrated using reference oil.

VOLATILITY

The Standard Test Method for Evaporation Loss of Lubricating Oils by the Noack Method, ASTM D5800-95 or CEC L-40-A-93 measures the mass of volatile vapors lost when an oil is heated in a test crucible to 250^oC with a constant flow of air drawn through it for 60 minutes. The loss in the mass of oil is determined and reported.

REFERENCED DOCMENTS

Interested parties should consult the most recent versions of the documents referenced below.

ASTM Standards:

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance to Specifications:

E 178 Practice for Dealing with Outlying Observations

D 892 Test Method for Foaming Characteristics of Lubricating Oils

D 975 Specification for Diesel Fuel Oils

D 3945 Test Method for Shear Stability of Polymer Containing Fluids using a Diesel Injector Nozzle

D 5533 Sequence IIIE Engine Test

D 5800 Test Method for Evaporation Loss of Lubricating Oils by the Noack Method

D 5966 Test Method for Roller Follower Wear Test

D 5967 Test Method for Evaluation of Soot Control

D 6594 Test Method for Evaluation of Corrosiveness of Diesel Engine Oil at 135^{o}C

D 6983 Test Method for Evaluation of Ring and Liner Wear

Other ASTM Publications:

RR D02-1379 Engine Oil Aeration Test

RR D02-1440 Cummins M11 HST Test Procedure

CEC Testing Standards:

CEC L-52-T-97 OM 441 LA test for Bore Polish and Piston Deposits

CEC L-85-T-99 Oxidative Induction Time for Oils using Pressure Differential Scanning Calorimetry

CEC L-39-T-96 Elastomer Compatibility Test

CEC L-36-A-90 HT/HS Viscosity by Ravenfield Viscometer

CEC L-14-A-93 Test Method for Shear Stability of Polymer Containing Fluids using a Diesel Injector Nozzle Shear

CEC L-40-A-93 Test Method for Evaporation Loss of Lubricating Oils by the Noack Method

JASO Testing Standard:

JASO M 354-1999 Test Method for Evaluation of Valvetrain Wear Performance

Society of Automotive Engineers J300 Engine Oil Viscosity Classification System

Other Publications:

Until published by ASTM, the following test procedures are available via Internet at www.engine-manufacturers.org.

Caterpillar SCOTE 1R Test Procedure

Sequence IIIF Test Procedure

Table 2a
Global Engine Oil Service Specification DHD-1

Characteristic	Test Method*	Test Name	Requirements	Limits
Engine Tests				
Aeration	ASTM RR D02-1379	International EOAT	Aeration, Vol. %, Max.	8.0
Bore Polish	CEC L-52-T-97	Mercedes Benz OM 441 LA	Bore Polish % Area, Max.	2.0
Corrosion	ASTM D 6483	Mack T-9	Used Oil Lead, ppm Max	15 (2)
			TAN Increase at EOT, max.	2.0
Filter Plugging	ASTM RR D02-1440	Cummins M11 HST	Oil Filter Diff. Press., kPa, Max.	79 / 93 / 100
Piston Cleanliness	ASTM D XXXX	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
	CEC L-52-T-97	Mercedes Benz OM 441 LA	Weighted Merits, Min.	25.0
			Oil Consumption, kg/test Max.	40
Oxidation	ASTM D XXXX	Seq IIIF, 60 Hrs. (1)	Kv 40C Viscosity Increase, % Max.	200
Turbocharger Deposits	CEC L-52-T-97	Mercedes Benz OM 441 LA	Boost Pressure Loss at 400 Hours, % Max.	4
Sludge Control	ASTM RR D02-1440	Cummins M11 HST	Eng. Sludge, CEC Merits, Min.	8.7 / 8.6 / 8.5
Soot Control	ASTM D-5967	Mack T-8E	Relative Viscosity @ 4.8% Soot	2.1 / 2.2 / 2.3
Wear, Valvetrain	JASO M354-1999	Mitsubishi 4D34T4 160 Hrs	Cam Lobe Wear, µm	
			Average	95.0
	ASTM D 5966-96	Roller Follower Wear Test	Pin Wear, µm maximum	7.6 / 8.4 / 9.1
	ASTM RR D02-1440	Cummins M11 HST	Rocker Pad Average Weight Loss, Normalized to 4.5% Soot, mg Max.	6.5 / 7.5 / 8.0
Wear, Ring / Liner	ASTM D 6483	Mack T-9	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

* Test methods noted ASTM XXXX are under development by ASTM. A numeric designation will be provided when it becomes available
(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

Table 2B
Global Engine Oil Service Specification DHD-1

Characteristic	Test Method	Test Name	Requirements			Limits	
Bench Tests							
Corrosion	ASTM D 6594	Corrosion Bench Test	Used Oil Element Content above Baseline, ppm, Max.			Copper 20, Lead 120, Tin 50	
Elastomer Compatibility *	CEC-L-39-T-96	Variation after 7 days fresh oil, No preaging		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/ +10	-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	ASTM D892 W/O Option A	Sequence I (24^{o}C)	Tendency / Stability, ml Max.			10 / nil	
		Sequence II (94^{o}C)	After 1 Min. Settling			50 / nil	
		Sequence III (24^{o}C)				10 / nil	
Foaming - High Temperature	ASTM D 6082	Sequence IV (150^{o}C)	Tendency / Stability, ml Max. After 1 Min. Settling			200 / 50	
Oxidation - Hot Surface	CEC-L-85-T-99	PDSC	Oxid. Induction Time, min., Min.			35	
Shear Stability	ASTM D 3945 CEC L-14-A-93	Bosch Injector Test	Viscosity after 30 Cycles, measured at 100 ^{o}C			Stay in Grade	
Sulfated Ash	ASTM D-874	Sulfated Ash	Mass %, Max.			2.0	
HT/HS Viscosity	ASTM D4624/D 4683 CEC-L-36-A-90	Tapered Bearing Simulator/Ravenfield	High Temperature / High Shear Rate Viscosity, cP, Min.			3.5	
Volatility	ASTM D 5800 CEC L-40-A-93	NOACK	% Mass Loss, Max			15	

* 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.

APPENDIX
Global DHD-1 Data Table

The following data tables are provided for recording the chemical, physical, and performance information for engine oil products marketed as meeting the Global DHD-1 specification. As stated in the Specification, ACEA, EMA and JAMA recommend that any producer or marketer claiming that an engine oil meets the Global DHD-1 specification have adequate performance data to support such claim and make such performance data reasonably available to interested parties upon request. Indicate any read across processes used and provide the relation between the tested and the marketed formulations.

It is recognized that such data is sensitive and will be maintained in strictest confidence by ACEA, EMA, and JAMA. However, the disposition of whether or not a product in general, meets this specification may be publicly stated.

Global Engine Oil Service Specification DHD-1
Formulation Information and Performance Test Results

Oil Product Name			
Current Date			
Marketing Oil Company			
Address			
Contact			
Telephone Number			
Email address			
Formulation Number			
Market Region for this Formulation			
	Test Method	**Specified Limit**	**Test Result**
Chemical and Physical Properties			
Viscosity, cSt @ 100 ^{o}C	ASTM D445	per J300	
Viscosity, cSt @ 40 ^{o}C	ASTM D445	Report	
Viscosity Index		Report	
Low Temp Crank Vis, cP @ XX ^{o}C	ASTM D5293 per J300	per J300	
Low Temp Pump Vis, cP @ XX ^{o}C	ASTM D4684 per J300	per J300	
Pour Point, °C	ASTM D97		
HT/HS, cP	ASTM D4624/D4683/CEC L-36-A-90 per J300	3.5 min.	
TBN, mg KOH/g	ASTM D4739	10 min.	
TAN, mg HCl/g	ASTM D664		
Sulfated Ash, % mass	ASTM D874	2.0 max.	

Oil Product Name	**Test Method**		**Specified Limit**	**Test Result**
Formulation Number				
Elemental	ASTM D5185		Report	
Barium, ppm				
Boron, ppm				
Calcium, ppm				
Magnesium, ppm				
Molybdenum, ppm				
Phosphorous, ppm				
Silicon, ppm				
Sodium, ppm				
Zinc, ppm				
Sulfur, % wt	ASTM D1552 or equiv		Report	
Nitrogen, % wt	ASTM D3228 or equiv		Report	
Viscosity after Shear, cSt	CEC L-14-A-93 (ASTM D3945)		Stay in Grade per J300	
Volatility, % wt	ASTM D5800 / CEC L-40-A-93		15 % max.	
Foaming Tendency	ASTM D 892		Tendency / Stability	
Sequence I			10 / nil	
Sequence II			50 / nil	
Sequence III			10 / nil	
High Temperature Foaming	ASTM D6082		200 / 50	
Corrosion Tendency	ASTM D6594 (HTCBT)			
Used Oil Copper, ppm			20 max.	
Used Oil Lead, ppm			120 max	
Used Oil Tin, ppm			50 max.	
Oil Elastomer Compatibility	CEC L-39-T-95		Pass or Fail -	
Material	Hardness	Tensile	Elongation	Volume Chg
RE1				
RE2				
RE3				
RE4				
	Test Method		**Specified Limit**	**Test Result**
Oxidation, Induction Time, min.	CEC L-85-T-99		35	
Aeration, Vol %	ASTM RR D02-1379		8	
Mack T9	ASTM D6483			
Formulation Number Tested				
Used Oil Lead, ppm			15	
TAN Increase at EOT			2.0	
Average Wear				
Normalized to 1.75% Soot				
Liner, µm			25.4 / 26.6 / 27.1	
Top Ring Wt. Loss, mg			120 / 136 / 144	

Oil Product Name Formulation Number	**Test Method**	**Specified Limit**	**Test Result**
Mack T8E	ASTM D5987		
Formulation Number Tested			
Relative Viscosity at 4.8% Soot		2.1 / 2.2 / 2.3	
MB OM 441 LA	CEC L-52-T-97		
Formulation Number Tested			
Bore Polish, % Area		2.0	
Piston Weighted Merits		25.0	
Oil Consumption, kg/test		40	
Boost Pressure Loss @ 400 h, %		4	
Mitsubishi 4D34T4, 160 hrs	JASO M354-1999		
Formulation Number Tested			
Average Cam Lobe Wear, µm		95.0	
Roller Follower Wear Test	ASTM D5966		
Formulation Number Tested			
Pin Wear, µm		7.6 / 8.4 / 9.1	
Sequence IIIF, 60 hours	ASTM DXXXX		
Formulation Number Tested			
Kv40 Viscosity Increase @ 60 hours		200	
Cummins M-11	ASTM D RR D02-1440		
Formulation Number Tested			
Rocker Pad Average Weight Loss, mg		6.5 / 7.5 / 8.0	
Oil Filter Differential Press., kPa		79 / 93 / 100	
Average Engine Sludge, CEC Merits		8.7 / 8.6 / 8.5	
Caterpillar 1R	ASTM DXXXX		
Formulation Number Tested			
Weighted Demerits (WDR)		397/ 416 / 440	
Total Groove Carbon, %		40 / 42 / 44	
Top Land Carbon, %		37 / 42 / 46	
Oil Consumption g/hr, Initial / Final		13.1/ 1.5 x int.	