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PERFORMANCE SPECIFICATION

LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, COMBAT/TACTICAL SERVICE

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This performance specification covers lubricating oils suitable for lubrication of reciprocating compression-ignition internal combustion engines and for power transmission fluid applications in combat/tactical service equipment (see 6.1). Grade SCPL has been added in this revision and is intended to be an all-season lubricant providing extended drain intervals and reduced fuel consumption (see 6.1).

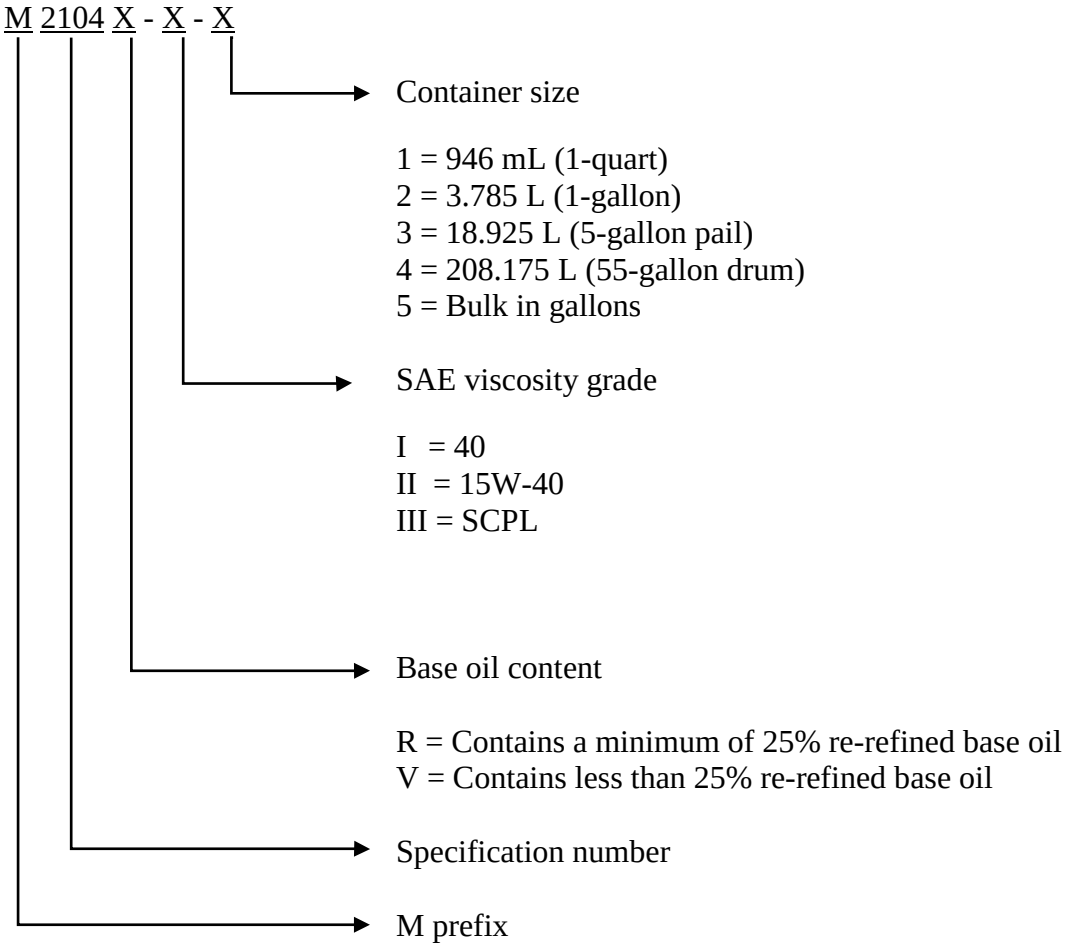
1.2 Classification. The lubricating oils are of the following viscosity grades:

SAE Viscosity Grade	Military Symbol	NATO Code
15W-40	OE/HDO-15/40	O-1236
40	OE/HDO-40	----
SCPL	OE/HDO-SCPL	---

Comments, suggestions, or questions on this document should be addressed to Tank-automotive and Armaments Command, 6501 E. 11 Mile Road, Warren, MI 48397-5000 or emailed to usarmy.detroit.rdecom.mail.tardec-standardization@mail.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla.mil.

AMSC N/A FSC 9150

1.3 Part or identifying number (PIN). PINs to be used in procurement of the lubricating oils acquired to this specification are created as follows: Example of reference part number: M2104 R-II-2



2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3 and 4 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3 and 4 of this specification, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

INTERNATIONAL STANDARDIZATION AGREEMENTS

AFLP-3747 - Guide Specifications (Minimum Quality Standards) for Aviation Turbine Fuels (F-24, F-27, F-34, F-35, F-37, F-40 and F-44)

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-PRF-25017 - Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble

(Copies of these documents are available online at http://quicksearch.dla.mil or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

ASTM INTERNATIONAL

ASTM D92 - Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
ASTM D97 - Standard Test Method for Pour Point of Petroleum Products
ASTM D130 - Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
ASTM D445 - Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)
ASTM D664 - Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration
ASTM D874 - Standard Test Method for Sulfated Ash from Lubricating Oils and Additives
ASTM D892 - Standard Test Method for Foaming Characteristics of Lubricating Oils
ASTM D1655 - Standard Specification for Aviation Turbine Fuels
ASTM D2270 - Standard Practice for Calculating Viscosity Index From Kinematic Viscosity at 40 and 100°C
ASTM D3244 - Standard Practice for Utilization of Test Data to Determine Conformance with Specifications
ASTM D4052 - Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
ASTM D4485 - Standard Specification for Performance of Active API Service Category Engine Oils
ASTM D4683 - Standard Test Method for Measuring Viscosity of New and Used Engine Oils at High Shear Rate and High Temperature by Tapered Bearing Simulator Viscometer at 150°C
ASTM D4684 - Standard Test Method for Determination of Yield Stress and Apparent Viscosity of Engine Oils at Low Temperature
ASTM D4739 - Standard Test Method for Base Number Determination by

Potentiometric Hydrochloric Acid Titration

ASTM D4741 - Standard Test Method for Measuring Viscosity at High Temperature and High Shear Rate by Tapered-Plug Viscometer

ASTM D5185 - Standard Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)

ASTM D5293 - Standard Test Method for Apparent Viscosity of Engine Oils and Base Stocks Between -5°C and -35°C Using Cold-Cranking Simulator

ASTM D5481 - Standard Test Method for Measuring Apparent Viscosity at High-Temperature and High-Shear Rate by Multicell Capillary Viscometer

ASTM D5800 - Standard Test Method for Evaporation Loss of Lubricating Oils by the Noack Method

ASTM D5949 - Standard Test Method for Pour Point of Petroleum Products (Automatic Pressure Pulsing Method)

ASTM D5950 - Standard Test Method for Pour Point of Petroleum Products (Automated Tilt Method)

ASTM D5966 - Standard Test Method for Evaluation of Engine Oils for Roller Follower Wear in Light-Duty Diesel Engine

ASTM D5967 - Standard Test Method for Evaluation of Diesel Engine Oils in T-8 Diesel Engine

ASTM D6278 - Standard Test Method for Shear Stability of Polymer Containing Fluids Using a European Diesel Injector Apparatus

ASTM D6417 - Standard Test Method for Estimation of Engine Oil Volatility by Capillary Gas Chromatography.

ASTM D6594 - Standard Test Method for Evaluation of Corrosiveness of Diesel Engine Oil at 135°C

ASTM D6681 - Standard Test Method for Evaluation of Engine Oils in a High Speed, Single-Cylinder Diesel Engine—Caterpillar 1P Test Procedure

ASTM D6750 - Standard Test Method for Evaluation of Engine Oils in a High-Speed, Single-Cylinder Diesel Engine—1K Procedure (0.4% Fuel Sulfur) and 1N Procedure (0.04% Fuel Sulfur)

ASTM D6894 - Standard Test Method for Evaluation of Aeration Resistance of Engine Oils in Direct-Injected Turbocharged Automotive Diesel Engine

ASTM D6922 - Standard Test Method for Determination of Homogeneity and Miscibility in Automotive Engine Oils

ASTM D6923 - Standard Test Method for Evaluation of Engine Oils in a High Speed, Single-Cylinder Diesel Engine—Caterpillar 1R Test Procedure

ASTM D6984 - Standard Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIF, Spark-Ignition Engine

ASTM D7216 - Standard Test Method for Determining Automotive Engine Oil Compatibility with Typical Seal Elastomers

ASTM D7320 - Standard Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIG, Spark-Ignition Engine
ASTM D7422 - Standard Test Method for Evaluation of Diesel Engine Oils in T-12 Exhaust Gas Recirculation Diesel Engine
ASTM D7468 - Standard Test Method for Cummins ISM Test
ASTM E29 - Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
ASTM E168 - Standard Practices for General Techniques of Infrared Quantitative Analysis

(Copies of these documents are available from: http://www.astm.org).

ALLISON TRANSMISSION INC.

Severe Duty Extended Drain Interval Transmission Fluid Specification (TES-295)

(Copies of these documents are available from: http://www.swri.org).

CATERPILLAR INC.

TO-4 - Transmission and Drive Train Fluid Requirements
TO-4M - Multigrade Transmission and Drive Train Fluid Requirements

(Copies of these documents are available from: http://www.parts.cat.com/parts/machine-fluids).

SAE INTERNATIONAL

J300 - Engine Oil Viscosity Classification

(Copies of these documents are available from: http://www.sae.org).

2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Qualification. Lubricating oils furnished under this specification shall be products that are authorized by the qualifying activity for listing on the applicable qualified products list before contract award (see 4.2 and 6.3).

3.2 Materials. Lubricating oils shall be derived from petroleum fractions, synthetically prepared compounds or a combination of the two types of products. They may be virgin, re-refined stocks or a combination thereof. The stocks shall be compounded with such functional additives (e.g., detergents, dispersants, oxidation inhibitors, corrosion inhibitors, etc.) as are necessary to meet the specification requirements.

3.3 Recycled, recovered, environmentally preferable, or biobased materials. Recycled, recovered, environmentally preferable, or biobased materials should be used to the maximum extent possible, provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

3.4 Engine performance. Oils meeting the requirements of this specification shall lubricate, cool, and prevent corrosion of oil wetted components of diesel engines used in combat and tactical equipment. The oils shall limit wear, friction, and deposits of oil wetted engine parts.

3.4.1 Engine performance requirements. Grade 40 oils qualified under this specification shall comply with the conformance criteria as specified in section 3.4.1.1 through section 3.4.1.8 and align with the American Petroleum Institute (API) service category CH-4. The qualifying activity shall waive engine performance testing of grade 40 oils if they have been formulated using the same performance additive package, at the same treat rate, as those used in the formulation of a 15W-40 grade oil qualified under this specification. Grade 15W-40 and SCPL oils qualified under this specification shall comply with the acceptance criteria as specified in section 3.4.1.1 through section 3.4.1.9 and align with API service category CI-4.

3.4.1.1 Cylinder liner, piston, and bearing wear. All grades shall prevent cylinder liner, piston, and bearing wear under conditions of high soot in accordance with Table I. Oil grade 40 shall comply with the liner wear, ring weight loss, and lead content requirements only. Oil grades 15W-40 and SCPL shall comply with the merit rating requirement only. See section 4.3.1 for the verification test methods.

TABLE I. Cylinder liner, piston and bearing wear (T-12). 1/

Rated or measured parameter	Primary performance criteria		
	One-Test	Two-Test	Three-Test
Liner wear, µm[A], max[B]	30.0	30.8	31.1
Top ring weight loss, mg[C], max	120	132	137
Lead content at EOT, mg/kg[D], max	65	75	79
Merit rating, min[E]			
15W-40 and SCPL only	1000	1000	1000

A micrometer
B maximum
C milligram
D milligram per kilogram
E minimum
1/ See ASTM D4485 for alternate test method(s) and performance criteria.

3.4.1.2 Foaming/Aeration. All grades shall reduce the potential for loss of oil pressure or film and the associated malfunction or damage of oil operated and lubricated components in accordance with Table II *and* Table III. See section 4.3.2 for the verification test methods.

TABLE II. Properties of foaming.

Rated or measured parameter	Primary performance criteria
Sequence I, foaming/settling, mL[A], max	10/0
Sequence II, foaming/settling, mL, max	20/0
Sequence III, foaming/settling, mL, max	10/0

[A] milliliter

TABLE III. Properties of aeration.

Rated or measured parameter	Primary performance criteria
Aeration (EOAT)[A], volume, %, max	8.0 (MTAC)[B]

[A] Engine Oil Aeration Test

[B] 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. See ASTM D 4485, Annex A1 for additional information.

3.4.1.3 Piston deposit and scuffing control. All grades shall prevent the buildup of ring belt deposits on pistons, including those of the piston crown and lands, piston ring grooves, piston undercrown and piston skirts. Oil grade 40 shall comply with the requirements of Table IV *and* Table V. Oil grades 15W-40 and SCPL shall comply with the requirements of Table IV and, Table V *or* Table VI. See section 4.3.3 for the verification test methods.

TABLE IV. Piston deposit and scuffing control – aluminum piston (1K).

Rated or measured parameter	Primary performance criteria		
	One-Test	Two-Test	Three-Test
Weighted demerits (WDP), 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/MJ[A] (0-250 h[B]), max	0.139	0.139	0.139
Piston, ring, and liner scuffing	None	None	None

[A] grams per megajoule

[B] hour

TABLE V. Piston deposit and scuffing control – steel piston (1P).

Rated or measured parameter	Primary performance criteria		
	One-Test	Two-Test	Three-Test
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[A] (0 - 360 h), max	12.4	12.4	12.4
Final oil consumption, g/h (312 - 360 h), max	14.6	14.6	14.6
Piston, ring, and liner scuffing	None	None	None

[A] grams per hour

TABLE VI. Piston deposits, oil consumption and scuffing performance (1R).

Rated or measured parameter	Primary performance criteria		
	One-Test	Two-Test	Three-Test
Weighted Piston Demerits (WDP), max	382	396	402
Top groove carbon (TGC), demerits, max	52	57	59
Top land carbon (TLC), demerits, max	31	35	36
Initial oil consumption (IOC), average (0 - 252 h), g/h, max	13.1	13.1	13.1
Final oil consumption, average (432 - 504 h), g/h, max	IOC + 1.8	IOC + 1.8	IOC + 1.8
Piston, ring, and liner scuffing	None	None	None
Ring sticking	None	None	None

3.4.1.4 Roller follower wear. All grades shall prevent camshaft roller follower wear in accordance with Table VII. See section 4.3.4 for the verification test method.

TABLE VII. Roller follower wear test (RFWT).

Rated or measured parameter	Primary performance criteria		
	One-Test	Two-Test	Three-Test
Average pin wear, µm, max	7.6	8.4	9.1

3.4.1.5 Sludge control, filterability and sliding valve train wear. All grades shall prevent sliding valve train wear, filter plugging, and sludge deposits in accordance with Table VIII. See section 4.3.5 for the verification test methods.

TABLE VIII. Sludge control, filterability and sliding valve train wear (ISM). 1/

Rated or measured parameter	Primary performance criteria		
	One-Test	Two-Test	Three-Test
Crosshead wear, mg, max	7.5	7.8	7.9
Sludge rating, CRC merits, min[A]	8.1	8.0	8.0
Oil filter delta pressure at 150 h, kPa[B], max			
40 grade	79	95	103
15W-40 and SCPL	55	67	74

[A] minimum

[B] kilopascal

1/ See ASTM D4485 for alternate test method(s) and performance criteria.

3.4.1.6 Soot induced viscosity control. All grades shall prevent excessive viscosity increase caused by soot build up in the oil in accordance with Table IX. See section 4.3.6 for the verification test method.

TABLE IX. Soot induced viscosity increase (T-8E). 1/

Rated or measured parameter	Primary performance criteria		
	One-test	Two-test	Three-test
Relative viscosity at 4.8% soot by TGA[A], max			
40 grade	2.1	2.2	2.3
15W-40 and SCPL	1.8	1.9	2.0
Viscosity increase at 3.8% soot by TGA, mm^2/s[B], max			
40 grade	11.5	12.5	13.0

A Thermogravimetric Analysis

B square millimeter per second

1/ See ASTM D4485 for alternate test method(s) and performance criteria.

3.4.1.7 Oil thickening under high temperature conditions. All grades shall prevent excessive oil thickening under high temperature conditions in accordance with Table X *or* Table XI. See section 4.3.7 for the verification test methods.

TABLE X. Oil thickening under high temperature conditions (IIIG).

Rated or measured parameter	Primary performance criteria
Kinematic viscosity, % increase at 40°C, max	150 (MTAC)

TABLE XI. Oil thickening under high temperature conditions (IIIF).

Rated or measured parameter	Primary performance criteria
60 hour viscosity at 40°C, increase from 10 minute sample, %, max	
40 grade	295 (MTAC)
Kinematic viscosity at 40°C, % increase, max	
15W-40 and SCPL	275 (MTAC)

3.4.1.8 Oil corrosiveness at high temperatures. All grades shall inhibit the corrosion of oil wetted non-ferrous components in accordance with Table XII. See section 4.3.8 for the verification test method.

TABLE XII. Oil corrosiveness at high temperatures (HTCBT).

Rated or measured parameter	Primary performance criteria Used oil elemental concentration
Copper, mg/kg increase, max	20
Lead, mg/kg increase, max	120
Tin, mg/kg increase, max	report
Copper strip rating, max	3

3.4.1.9 Used oil pumpability. Oil grade SCPL shall minimize the effects of combustion blow-by products, soot accumulation, and other in-service contaminants on used oil pumpability in accordance with Table XIII. See section 4.3.9 for the verification test method.

TABLE XIII. Properties of used oil pumpability.

Requirement	Rated or measured parameter	Primary performance criteria
A	Viscosity after 75 h of Mack T-10A test, or viscosity after 100 h of Mack T-12A test, tested at -20°C, mPa·s [A], max	25 000
B 1/	Viscosity after 75 h of Mack T-10A test, or viscosity after 100 h of Mack T-12A test, tested at -20°C, mPa·s, max	25 000
	Yield stress, Pa [B]	< 35

[A] millipascal second

[B] pascal

1/ If yield stress is detected use requirement B

3.5 Physical and Chemical properties. All grades listed in this specification shall comply with the chemical and physical requirements listed in sections 3.5.1 to 3.5.10, and Table XIV.

3.5.1. Evaporation loss. All grades shall limit oil volatility at high temperatures in accordance with Table XIV. See section 4.3.10 for the verification test method.

3.5.2 Homogeneity and miscibility. All grades shall remain homogeneous and miscible with each other over ambient and operating temperatures typical for the application (see 1.1). No evidence of separation shall be detected when the candidate oil is diluted with standard reference oils and submitted to the prescribed cycle of temperature changes outlined in the test procedure designated in section 4.3.11.

3.5.3 Flash point. All grades shall limit the overall flammability hazard of its components in accordance with Table XIV. See section 4.3.12 for the verification test method.

TABLE XIV. Chemical and physical properties.

Property	Test Method	40	15W-40	SCPL
Kinematic viscosity, mm^2/s				
at 100°C	ASTM D445	12.5 to <16.3	12.5 to <16.3	8.0 to <9.3
at -40°C, max		----	----	15000
at -48°C, max		----	----	50000
Low temperature cranking viscosity, mPa·s,				
at -35°C, max	ASTM D5293	----	----	4300
at -20°C, max		----	7000	----
High-temperature/high-shear viscosity, mPa·s, at 150°C, min	ASTM D4683, D4741, or D5481	3.7	3.7	2.7
Low temperature pumping viscosity, mPa·s,				
at -40°C, max	ASTM D4684	----	----	13000
at -25°C, max		----	60000	----
Pour point, °C, max	ASTM D97, D5949, or D5950	-15	-25	-55
Flash point, °C, min	ASTM D92	225	215	210
Evaporative loss, %, at 250°C, max	ASTM D5800	----	15	14
Sulfated ash, mass %, max	ASTM D874	1.5	1.5	1.5

3.5.4 Kinematic viscosity. All oil grades shall meet the kinematic viscosity requirements in accordance with Table XIV. See section 4.3.13 for the verification test method.

3.5.5 Low temperature viscosity. All oil grades shall meet the low temperature cranking and pumping viscosity requirements in accordance with Table XIV. See section 4.3.14 for the verification test method.

3.5.6 High temperature and high shear viscosity. All oil grades shall meet the high temperature and high shear viscosity requirements in accordance with Table XIV. See section 4.3.15 for the verification test method.

3.5.7 Pour point. All oil grades shall meet the pour point requirements in accordance with Table XIV. See section 4.3.16 for the verification test method.

3.5.8 Sulfated ash. All oil grades shall meet the sulfated ash requirements in accordance with Table XIV. See section 4.3.17 for the verification test method.

3.5.9 Shear stability. Oil grades 15W-40 and SCPL shall resist permanent viscosity loss from high shear conditions in accordance with Table XV, particularly those containing polymeric viscosity modifiers. See section 4.3.18 for the verification test method.

TABLE XV. Shear stability performance.

Rated or measured parameter	Primary performance criteria
Kinematic viscosity after shearing, mm^2/s, min	
15W-40	12.5
SCPL	8.0

3.6 Transmission frictional characteristics and wear. All oil grades shall maintain a stable coefficient of friction and shall minimize distress and wear in accordance with Table XVI during use in heavy-duty automatic and powershift transmissions and other cooled friction components such as steering, braking and disconnect clutches. See section 4.4 for the verification test methods.

TABLE XVI. Properties of frictional characteristics and wear.

Rated or measured parameter	Primary performance criteria
Allison Graphite and Paper Friction Test Mid-point dynamic friction Coefficient (see notes 1/ and section 4.4)	Measured mid-point dynamic friction coefficient 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 (see notes 1/, 2/, and section 4.4)	Slip time shall be less than or equal to the maximum acceptable slip time criteria
Caterpillar TO-4 or TO-4M, SEQ1220 Average dynamic coefficient, % Average static coefficient, % Disc wear, mm, max	 90.0 – 140.0 91.0 – 127.0 0.04

Rated or measured parameter	Primary performance criteria
Energy limit, m/s, min (see note 3/ and 4.4)	25
Caterpillar TO-4 or TO-4M, SEQFRRET Average dynamic coefficient, % @ 3000 cycles @ 8000 cycles @ 15 000 cycles @ 25 000 cycles (see note 3/ and 4.4)	 85.0 – 130.0 90.0 – 125.0 90.0 – 125.0 95.0 – 125.0

1/ 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

2/ Maximum acceptable slip time (tmax)

a. Allison Paper Friction Test: tmax = 1.108 – 6.012μ
b. Allison Graphite Friction Test: tmax = $1/[-221*(\mu-0.1421)^2 + 1.756]$
c. Where μ is the minimum acceptable coefficient at mid-point.

3/ TO-4M requirements are only for the 15W-40 and SCPL viscosity grade; grades 40 shall use TO-4 requirements

3.7 Elastomer seal compatibility. All oil grades shall minimize the deterioration, softening, and/or excessive hardening of elastomer seals in accordance with Table XVII. See section 4.5 for the verification test method.

TABLE XVII. Properties of elastomer seal compatibility.

Material designation	Volume change limits1/	Hardness change limits1/
V1 (Ethylene/Acrylic)	7 to 20	-15 to -2
V2 (Ethylene/Acrylic)	2 to 12	-7 to +3
V3 (Ethylene/Acrylic)	7 to 22	-14 to -2
P1 (Polyacrylate)	0.00 to 8	-10 to 0.00
P2 (Polyacrylate)	0.00 to 8	-11 to +3
P3 (Polyacrylate)	0.00 to 4	-8 to +4
F1 (Fluoroelastomer)	0.00 to 4	-5 to +4
F2 (Fluoroelastomer)	0.00 to 4	-2 to +5
N1 (Nitrile)	Report	Report

1/ When variation in elastomer performance from one batch to the next results in a reference being outside the limits stated in the table, the limit shall be replaced with “equal to or better than reference”.

3.8 Fuel consumption improvement. Oil grade SCPL shall provide a minimum fuel consumption improvement (FCI) relative to the reference oil of 2.0 %. See section 4.6 for the verification method.

3.9 High temperature durability. Oil grade SCPL shall resist oxidative and thermal break down and provide wear protection under conditions of high power output and high oil

temperatures in accordance with Table XVIII. See section 4.7 for the verification test method.

TABLE XVIII. High temperature durability used oil analysis at 168 hours.

Measured parameter	Performance criteria
Viscosity Increase, %, max	70
Total Base Number, mg KOH/g, min	4.0
Copper, mg/kg, max	60
Iron, mg/kg, max	430
Lead, mg/kg, max	150
Total Base Number/Total Acid Number, min	0.50

4. VERIFICATION

4.1 Classification of inspections. The inspection requirements specified herein are classified as follows:

a. Qualification inspections (see 4.2).

4.2 Qualification inspections. Qualification inspections shall consist of all verifications listed in table XIV and sections 4.3, 4.4, and 4.5. Table XIX cross-references requirements with appropriate qualification verification test methods.

TABLE XIX. Qualification requirements and verification.

	Requirements	Verification
Cylinder liner, piston, and bearing wear	3.4.1.1	4.3.1
Foaming/aeration	3.4.1.2	4.3.2
Piston deposits and scuffing control pistons	3.4.1.3	4.3.3
Roller follower wear	3.4.1.4	4.3.4
Sludge control, filterability and sliding valve train wear	3.4.1.5	4.3.5
Soot induced viscosity control	3.4.1.6	4.3.6
Oil thickening under high temperature conditions	3.4.1.7	4.3.7
Oil corrosiveness at high temperatures	3.4.1.8	4.3.8
Used oil pumpability	3.4.1.9	4.3.9
Evaporation loss	3.5.1	4.3.10
Homogeneity and miscibility	3.5.2	4.3.11
Flash point	3.5.3	4.3.12
Kinematic viscosity	3.5.4	4.3.13
Low temperature viscosity	3.5.5	4.3.14
High temperature and high shear viscosity	3.5.6	4.3.15
Pour point	3.5.7	4.3.16
Sulfated ash	3.5.8	4.3.17
Shear stability	3.5.9	4.3.18
Base oil viscosity	3.5.10	4.3.19
Transmission frictional characteristics and wear	3.6	4.4
Elastomer seal compatibility	3.7	4.5
Fuel consumption improvement	3.8	4.6
High temperature durability	3.9	4.7

4.3 Verification test procedures. Tests shall be conducted as specified in table XIX and sections 4.3.1 thru 4.3.18, 4.4, and 4.5. The testing specified in this section includes only the most recently developed category tests. Alternative test methods as specified in the most current revision of ASTM D4485 are allowed. For purposes of determining conformance with each requirement, an observed value or calculated value shall be rounded off to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding-off procedure given in ASTM E29. All values, unless otherwise stated or agreed upon by the qualifying activity are critical specifications as defined by ASTM D3244.

4.3.1. Cylinder liner, piston, and bearing wear. All grades shall demonstrate compliance with 3.4.1.1, Table I, when tested in accordance with ASTM D7422 (T-12). See ASTM D4485 for alternate test methods for grade 40, 15W-40 and SCPL. Grade 40 oils shall be tested in accordance with the requirements for category CH-4. Grade 15W-40 and SCPL shall be tested in accordance with the requirements for category CI-4.

4.3.2 Foaming/Aeration. All grades shall demonstrate compliance with 3.4.1.2, Table II and Table III, when tested in accordance with *each* of the follow standards:

a. Foaming (see Table II) - Test procedure ASTM D892 (Option A is not allowed)
b. Aeration (see Table III) - Test procedure ASTM D6894, Engine Oil Aeration Test (EOAT)

4.3.3 Piston deposit and scuffing control. All grades shall demonstrate compliance with 3.4.1.3 when tested in accordance the following standards as appropriate:

a. Table IV (Aluminum pistons) - Test procedure ASTM D6750 (1K)
b. Table V (Steel pistons) - Test procedure ASTM D6681 (1P)
c. Table VI - Test procedure ASTM D6923 (1R)

4.3.4 Roller follower wear. All grades shall demonstrate compliance with 3.4.1.4, Table VII, when tested in accordance with the ASTM D5966 (RFWT).

4.3.5 Sludge control, filterability and sliding valve train wear. All grades shall demonstrate compliance with 3.4.1.5 and Table VIII when tested in accordance with ASTM D7468 (ISM). See ASTM D4485 for alternate test methods for grade 40, 15W-40 and SCPL. Grade 40 oils shall be tested in accordance with the requirements for category CH-4. Grade 15W-40 and SCPL shall be tested in accordance with the requirements for category CI-4.

4.3.6 Soot induced viscosity increase. All grades shall demonstrate compliance with 3.4.1.6, Table IX, when tested in accordance with ASTM D5967 (T-8E). See ASTM D4485 for alternate test methods for grade 40, 15W-40 and SCPL. Grade 40 oils shall be tested in accordance with the requirements for category CH-4. Grade 15W-40 and SCPL shall be tested in accordance with the requirements for category CI-4.

4.3.7 Oil thickening and piston deposits under high-temperature conditions. All grades shall demonstrate compliance with 3.4.1.7, Table X or Table XI, when tested in accordance with one of the following standards:

a. Table X - Test procedure ASTM D7320 (Seq. IIIG)
b. Table XI - Test procedure ASTM D6984 (Seq. IIIF)

4.3.8 Oil corrosiveness at high temperatures. All grades shall demonstrate compliance with 3.4.1.8, Table XII, when tested in accordance with ASTM D6594. Use the rating system in ASTM D130 to rate the copper strip.

4.3.9 Used oil pumpability. Oil grades 15W-40 and SCPL shall demonstrate compliance with 3.4.1.9, Table XIII, when tested in accordance with ASTM D4684 (MRV-TP-1). If yield stress is detected use modified D4684 (external preheat).

4.3.10 Evaporation loss. All grades shall demonstrate compliance with 3.5.1, Table XIV, when tested in accordance with ASTM D5800. Alternatively, ASTM D6417 may be used but the requirements shall be adjusted downward by 3 % (e.g., 18 % by method D5800 shall be adjusted to 15 % for method D6417).

4.3.11 Homogeneity and miscibility. All grades shall demonstrate compliance with 3.5.2, when tested in accordance with ASTM D6922.

4.3.12 Flash point. All grades shall demonstrate compliance with 3.5.3, Table XIV, when tested in accordance with ASTM D92.

4.3.13 Kinematic viscosity. All grades shall demonstrate compliance with 3.5.4, Table XIV, when tested in accordance with ASTM D445.

4.3.14 Low temperature viscosity. All grades shall demonstrate compliance with 3.5.5, Table XIV, when tested in accordance with the following standards:

a. Low temperature cranking viscosity - ASTM D5293
b. Low temperature pumping viscosity - ASTM D4684

4.3.15 High temperature and high shear viscosity. All grades shall demonstrate compliance with 3.5.6, Table XIV, when tested in accordance with ASTM D4683, ASTM D4741, or ASTM D5481.

4.3.16 Pour point. All grades shall demonstrate compliance with 3.5.7, Table XIV, when tested in accordance with ASTM D97, ASTM D5949, or ASTM D5950.

4.3.17 Sulfated ash. All grades shall demonstrate compliance with 3.5.8, Table XIV, when tested in accordance with ASTM D874.

4.3.18 Shear stability. Oil grades 15W-40 and SCPL shall demonstrate compliance with 3.5.9, Table XV, when tested in accordance with ASTM D6278.

4.4 Transmission Frictional characteristics and wear. All oil grades shall demonstrate compliance with 3.6, Table XVI, when tested in accordance with the selected test procedures from Allison Transmission TES-295 Severe Duty Extended Drain Interval Transmission Fluid Specification and Caterpillar TO-4/TO-4M Transmission and Drive Train Fluid Requirements. Verification shall be demonstrated when tested in accordance with test procedure a, b, and c below.

a. Allison TES-295 Paper and Graphite High Energy Friction
b. Caterpillar TO-4 or TO-4M, SEQ1220
c. Caterpillar TO-4 or TO-4M, SEQFRRET

4.5 Elastomer seal compatibility. All oil grades shall demonstrate compliance with 3.7, Table XVII, when tested and rated in accordance with the seal compatibility requirements of Allison Transmission TES-295 Severe Duty Extended Drain Interval Transmission Fluid Specification.

4.6 Fuel consumption improvement. Oil grade SCPL shall demonstrate compliance with 3.8, when tested in accordance with the test procedure found in Appendix A.

4.7 High temperature durability. Oil grade SCPL shall demonstrate compliance with 3.9, when tested in accordance with the test procedure found in Appendix B.

5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When packaging of materiel is to be performed by DoD or in house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activity within the Military Service or Defense Agency, or within the military service's system commands. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The lubricating oils covered by this specification are military standard lubricants. The combination of engine and heavy-duty transmission requirements in this specification are not required of typical commercial diesel engine oils. They are intended for use in combat and tactical equipment including the crankcase lubrication of reciprocating compression-ignition engines, heavy-duty automatic and powershift transmissions, hydraulic systems, and non-hypoid gear units of engineer/construction and material handling equipment. Although lubricants meeting the requirements of this specification have been formulated to meet

a wide range of lubricating functions, it is brought to the attention of the equipment developer the requirement to ensure that equipment, whether military unique or commercially-off-the-shelf (COTS), are compatible with military standard lubricants (see AR 70-12 and MIL-HDBK-838 for additional guidance). Monograde lubricating oil (e.g. OE/HDO-40) covered by this specification meets, at a minimum, service category API CH-4. Multigrade lubricating oil (e.g., OE/HDO-15/40 and SCPL) covered by this specification meet, at a minimum, service category API CI-4. SCPL should not be used in high output 2-cycle heavy-duty diesel engines if ambient temperatures exceed 90°F. SCPL is intended to be a direct replacement for previous applications requiring a 10W and the arctic engine oil (i.e., MIL-PRF-46167, OEA-30). Although lubricants qualified to this specification have been tested in accordance with selected Allison Transmission Inc. and Caterpillar Inc. transmission lubricant requirements, without further testing and certification, they cannot be recognized as compliant with either company's lubricant specifications.

6.1.1 SCPL. SCPL (i.e., OE/HDO-SCPL) is a full synthetic, all season (i.e., arctic-to-desert) heavy duty diesel engine oil designed to reduce fuel consumption and extend oil drain intervals in many diesel powered vehicles and equipment. SCPL is intended to for use in combat and tactical equipment including the crankcase lubrication of reciprocating compression-ignition engines, heavy-duty automatic and powershift transmissions, hydraulic systems, and non-hypoid gear units of engineer/construction and material handling equipment. SCPL should NOT be used in high output 2-cycle heavy-duty diesel engines if ambient temperatures exceed 90°F. SCPL is intended to be a direct replacement for previous applications requiring a 10W and the arctic engine oil (i.e., MIL-PRF-46167, OEA-30). Table XX lists the National Stock Numbers (NSN) that have been established for SCPL.

Table XX. National Stock Numbers for SCPL

NSN	Unit of Issue
9150-01-648-5541	1-quart
9150-01-648-5549	5-gallon
9150-01-648-5553	55-gallon

As a general recommendation, when switching from OE/HDO-15/40, OE/HDO-40, OE/HDO-30, or OE/HDO-10 to SCPL, the oil drain interval may be doubled. For example, if you have a fleet of HMMWV currently using OE/HDO-15/40 in the engine with a recommended oil drain interval of 6000 miles or 1-year and you change the oil to SCPL, your new oil drain interval would be 12000 miles or 2-years. When continuously operating in dusty locations, consideration should be given to shortening drain intervals because of the risk of dust contamination. Questions regarding the appropriate oil drain intervals for military equipment can be sent to the POL Help mail box at usarmy.detroit.rdecom.mbx.tardec-pol-help.mail.mil.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of this specification.
b. PIN (oil type, quantity of oil, and type container) (see 1.3).
c. Packaging requirements (see 5.1).

6.3 Qualification. With respect to products requiring qualification, awards will be made only for products which are, at the time of award of contract, qualified for inclusion in Qualified Products List No. 2104 whether or not such products have actually been so listed by that date. The attention of the contractors is called to these requirements, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. Information pertaining to qualification of products may be obtained from:

U.S. Army RDECOM-TARDEC
6501 E. 11 Mile Road
ATTN: Fuels and Lubricants Technology Team
RDTA-SIE-ES-FPT-FLT (MS-110)
Warren, MI 48397-5000
Usarmy.detroit.rdecom.mbx.tardec-pol-help.mail.mil

An online listing of products qualified to this specification may be found in the Qualified Products Database (QPD) at https://assist.dla.mil.

6.4 Subject term (key word) listing.

Diesel oil
Tracked vehicles
Transmission fluid
Wheeled vehicles

6.5 International standardization agreement implementation. This specification implements STANAG 1135, “Interchangeability of fuels, lubricants and associated products used by the armed forces of the North Atlantic Treaty Nations”. When amendment, revision, or cancellation of this specification is proposed, the preparing activity must coordinate the action with the U.S. National Point of Contact for the international standardization agreement, as identified in the ASSIST database at https://assist.dla.mil.

6.6 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

6.7 Shelf-life. This specification covers an item where the assignment of a Federal shelf-life code is a consideration. Specific shelf-life requirements should be specified in the contract or purchase order, and should include, as a minimum, shelf-life code, shelf-life package markings in accordance with MIL-STD-129 or FED-STD-123, preparation of a materiel quality storage standard for type II (extendible) shelf-life items, and a minimum of 85 percent shelf-life remaining at time of receipt by the Government. These and other requirements, if necessary, are in DoD 4140.27-M, *Shelf-life Management Manual*. The shelf-life codes are in the Federal Logistics Information system Total Item Record. Additive information for shelf-life management may be obtained from DoD 4140.27-M, or the designated shelf-life Points of Contact (POC). The POC should be contacted in the following order: (1) the Inventory Control Points that manage the item and (2) the DoD Service and Agency administrators for the DoD Shelf-Life Program. Appropriate POCs for the DoD Shelf-Life Program can be contacted through the DoD Shelf-Life Management website: https://www.shelflife.hq.dla.mil/.

APPENDIX A

TEST METHODS FOR THE DETERMINATION OF FUEL CONSUMPTION IMPROVEMENT

A.1 SCOPE

A.1.1 Scope. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance. This appendix provides the test procedure for the measurement of the effects of engine oils on the fuel consumption of military tactical vehicles using compression ignition engines. The tests are conducted using a specified 6.5L diesel engine on a dynamometer test stand. It applies to engine oils to be qualified as Single Common Powertrain Lubricants (SCPL).

A.2 TEST METHOD

A.2.1 Test Engine. The test engine shall be a military version General Engine Products (GEP) 6.5L V-8 Turbo Diesel engine (rated at 190 hp at 3200 r/min and 385 ft·lbf at 1800 r/min using diesel fuel). The engine shall be installed on a test stand equipped with a suitable conventional absorption dynamometer, data acquisition system, fluids process control system, and all necessary accessories for recording the speed, load, and various other operating parameters outlined in Table II. Engine accessories that are installed in a vehicle but not needed in a dynamometer test shall be omitted (e.g., alternator, cooling fan, etc.). Engine oil coolers should be supplemented when necessary to maintain the specified oil temperatures. Engine fuel consumption shall be measured using a coriolis type flow meter.

At all times during fuel consumption testing, inlet fuel temperature shall be maintained at 35 ± 3°C (95 ± 5°F), water jacket out temperature shall be maintained at 87.8 ± 3°C (190 ± 5°F), and inlet air temperature maintained at 23.9 ± 3°C (75 ± 5°F).

A.2.2 Test Fuel. The fuel used for testing shall be Jet A (military designation F-24) meeting the requirements of ASTM D1655 with added corrosion inhibitor/lubricity improver (CI/LI) qualified to MIL-PRF-25017 at a concentration between the MEC and the MAC for each additive listed in QPL-25017, FSII meeting MIL-DTL-85470 at a concentration between 0.07 vol % and 0.10 vol %, and STADIS 450 SDA at a concentration such that the electrical conductivity is between 50 pS/m and 600 pS/m. It is described in NATO AFLP 3747. Additional lubricity improver may be added to the fuel to ensure sufficient lubricity. The concentration shall not exceed double the maximum allowable concentration per MIL-PRF-25017. Each fuel consumption evaluation (baseline and test segment) shall be conducted using the same batch of fuel.

A.2.3 Engine Run-In. If the engine is new, prior to conducting the fuel consumption test, the engine shall be run-in following the procedure outlined in table AI using the baseline oil. After the initial 40 minutes (stages 1 – 4), repeat stages 5 – 11 twenty-four (24) times for a total of 312 minutes. The total runtime for engine run-in shall be 352 minutes (approximately 6 hours). Any mechanical issues arising during run-in shall be fixed as necessary, with the run-in continuing where left off.

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Table AI. Engine run-in test parameters.

Stage	Time, min	Mode	Speed, r/min	Torque, Nm	Coolant Out, °C	Oil Gallery, °C
1	10	Steady State	1500	14	100	105
2	10	Steady State	1600	148	100	105
3	10	Steady State	2400	197	100	105
4	10	Steady State	3200	224	100	105
5	1	Cyclic	900	0	100	105
6	2	Cyclic	2600	50%	100	105
7	2	Cyclic	1800	1%	100	105
8	2	Cyclic	1200	25%	100	105
9	2	Cyclic	1800	50%	100	105
10	2	Cyclic	3200	5%	100	105
11	2	Cyclic	2200	50%	100	105

A.2.4. Procedure. Each fuel consumption evaluation shall consist of three segments: an initial baseline, the candidate evaluation, and a repeat baseline. Each of these segment shall consists of operating a 14-stage measurement cycle a total of eight (8) times, with the first 14-stage cycle data ignored to allow for oil stabilization/shear, and the remaining seven (7) 14-stage cycles used to generate statistical confidence in measurements on the 95% and 99% confidence interval. A double flush method shall be employed on the lubricant between any baseline and candidate segments to reduce oil carry over between them.

To start each 14-stage cycle (baseline or candidate), operate the engine at 1500 rpm and approximately 35% load to bring the engine coolant and oil temperatures up to operating temperature as prescribed in Table AI. Following the completion of warm-up, ramp the engine to rated speed and load conditions (i.e., 3200 rpm and full throttle) and set inlet air restriction to 3.79 kPa (0.55 psi) and exhaust restrictions to 1.86 kPa (0.27 psi). After restrictions are set, ramp the engine to 1100 rpm and 81 Nm (59.7 ft·lbf) for 30 minutes to allow for temperature stabilization (all controller set points shall be targeting values for test stage 1). After the stabilization period has been completed, conduct the 14-stage measurement matrix as specified in Table II. At each step of the 14-stage measurement, allow the engine to stabilize for 15 minutes, and then collect 5 minutes of data for the determination of that stages average Brake Specific Fuel Consumption (BSFC) value. During this 5 minute interval record the fuel mass flow rate, engine output power, BSFC, and all test conditions as specified in table AII at a minimum of 30 second intervals. At the completion of the 14-stages, return to 1100 rpm and 81 Nm (59.7 ft·lbf) for 30 minutes, and then repeat the 14-stages until all 8 cycles are complete for the oil. Report all raw data collected during the 5-minute record intervals along with the following calculations:

- Calculates fuel consumed for each *stage*:

$$Average\ BSFC\left(\frac{kg}{kWh}\right) \times Nominal\ Power(kW) \times Weighting\ Factor = Fuel\ Consumed(kg)$$

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- Total 14-stage fuel consumption:

$$Total\ Fuel\ Consumed\ for\ all\ 14\ stages = \sum_{i=1}^{14} Fuel\ Consumed\ for\ stage\ i$$

- Calculated % fuel consumption improvement (FCI) for the test oil

$$\%FCI\ Test\ Oil = \frac{Avg.Total\ Fuel\ Consumed\ for\ Baselines - Avg.Total\ Fuel\ Consumed\ for\ Test\ Oil}{Avg.Total\ Fuel\ Consumed\ for\ Baselines}$$

(Note: The average (i.e. avg.) total fuel consumed for the baseline segments shall be calculated from both the starting and end baseline, for an average of all 14 total fuel consumed values. The average total fuel consumed for the test oil shall be calculated on the 7 14-stage runs only)

TABLE AII. Test conditions.

Condition	Stage													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Speed, rpm	1100	2100	1100	1100	1600	2100	2600	2100	3100	2600	3100	2600	2400	2800
Torque, Nm	81	81	135	243	135	189	135	243	135	189	189	243	410	340
Nominal Power, kW	9.3	17.8	15.6	28.0	22.6	41.6	36.8	53.5	43.9	51.5	61.4	66.2	103.1	99.7
Oil Temp Sump, °C	73.9±3	82.2±3			90.6±3		101.7±3				118.3±3			
Eng Water Out, °C	87.8 ±3													
Intake Air, °C	23.9±3													
Fuel Temp, °C	35±3													
Weighting Factor	0.02	0.04	0.03	0.04	0.04	0.06	0.07	0.07	0.09	0.09	0.11	0.1	0.13	0.14

A.2.5. Test Interruptions. If at any time a 14-stage measurement segment (baseline or candidate run) is interrupted due to engine or test cell issue, that 14-stage cycle must be re-completed from the start (stabilization step). All test interruptions shall be recorded and a listing of those interruptions provided to the qualifying activity.

A.2.6. Test Validity. The qualifying activity shall have the sole responsibility for the review and determination of the validity of fuel efficiency test. In order for a fuel efficiency test to be considered valid, the test procedures outlined in this appendix shall be followed. Any deviations from the test procedure can be cause for the test to be determined invalid, although the qualifying activity should be contacted for guidance. In addition to operating the test within the parameters specified herein, the initial baseline test and the final baseline test shall have means considered statistically equivalent at a 95% confidence level assuming normally distributed data and unknown but equal variance.

APPENDIX B

TEST METHOD FOR THE HIGH TEMPERATURE DURABILITY REQUIREMENT

B.1 SCOPE

B.1.1 Scope. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance. This appendix provides the test procedure for evaluating diesel engine oils for their high temperature thermal and oxidation stability and ability to control high temperature wear, whether it be related to adhesive or corrosive wear. The tests are conducted using a specified 6.5L diesel engine on a dynamometer test stand. It applies to engine oils to be qualified as Single Common Powertrain Lubricants (SCPL).

B.2 TEST METHOD

B.2.1. Test Engine. The test engine shall be a military version General Engine Products (GEP) 6.5L V-8 Turbo Diesel engine (rated at 190 hp at 3200 r/min and 385 ft·lbf at 1800 r/min using diesel fuel). Prior to testing the engine shall be disassembled, cleaned, and the following parts shall be measured for pre-test condition:

- Cylinder bore diameter
  - At top, middle, bottom – transverse & longitudinal direction
- Piston
  - Skirt diameter
  - Pin bore diameter
- Piston rings
  - Ring gap (all locations)
  - Oil control and 2nd ring side clearance
  - Top ring radial thickness (5 locations)
  - Second ring radial thickness (5 locations)
  - Ring mass (all locations)
- Piston pin
  - Pin diameter
  - Pin bore in connecting rod
- Bearing clearances
  - Main and connecting rod
- Crankshaft end play
- Main bearing mass
  - Upper and lower shell
- Connecting rod bearing mass
  - Upper and lower shell

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The injection nozzles shall be inspected and opening pressure, etc. recorded. Used parts in good condition and/or appropriately reconditioned condition are acceptable; however, new piston rings, main bearings, rod bearings, oil seals, and gaskets shall be used when reassembling the engine. Upon assembly, only new candidate lubricant shall be used to pre-lubricate all internal components.

B.2.2. Test Stand and Control. The engine shall be installed on a test stand equipped with a suitable conventional absorption dynamometer, data acquisition system, fluids process control system, and all necessary accessories for recording the speed, load, and various other operating parameters outlined in Table BI. Engine accessories that are installed in a vehicle but not needed in a dynamometer test shall be omitted (e.g., alternator, cooling fan, etc.). Engine oil coolers should be supplemented when necessary to maintain the specified oil temperatures.

Table BI. Controlled parameters and temperatures.

Parameter*	**Units**
Engine speed	r/min
Torque	Nm
Fuel flow	Kg/h
Nominal power	kW
Brake Specific Fuel Consumption(BSFC)	Kg/kWh
Temperatures*	
Coolant to engine	°C
Coolant from engine	°C
Oil sump	°C
Oil gallery	°C
Fuel in	°C
Ambient (wet and dry bulb)	°C
Cylinder 1 Exhaust	°C
Cylinder 2 Exhaust	°C
Cylinder 3 Exhaust	°C
Cylinder 4 Exhaust	°C
Cylinder 5 Exhaust	°C
Cylinder 6 Exhaust	°C
Cylinder 7 Exhaust	°C
Cylinder 8 Exhaust	°C
Pressures*	
Oil Gallery	N/m^2
Ambient	N/m^2
Boost	N/m^2
Fuel	N/m^2
Atmospheric	N/m^2
*Report average and standard deviation for all parameters, temperatures, and pressures	

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B.2.3. Test Fuel. The fuel used for testing shall be Jet A (military designation F-24) meeting the requirements of ASTM D1655 with added corrosion inhibitor/lubricity improver (CI/LI) qualified to MIL-PRF-25017 at a concentration between the MEC and the MAC for each additive listed in QPL-25017, FSII meeting MIL-DTL-85470 at a concentration between 0.07 vol % and 0.10 vol %, and STADIS 450 SDA at a concentration such that the electrical conductivity is between 50 pS/m and 600 pS/m. It is described in NATO AFLP 3747. Additional lubricity improver may be added to the fuel to ensure sufficient lubricity. The concentration shall not exceed double the maximum allowable concentration per MIL-PRF-25017. This fuel shall be used for the engine run-in, pre and post test power curves, and the 210 hour oil endurance test.

B.2.4. Engine Run-In. Prior to conducting the durability test, the engine shall be run-in following the procedure outlined in table II using the candidate oil. After the initial 40 minutes (stages 1 – 4), repeat stages 5 – 11 twenty-four (24) times for a total of 312 minutes. The total runtime for engine run-in shall be 352 minutes (approximately 6 hours). Any mechanical issues arising during run-in shall be fixed as necessary, with the run-in continuing where left off.

Table BII. Engine run-in test parameters.

Stage	Time, min	Mode	Speed, r/min	Torque, Nm	Coolant Out, °C	Oil Gallery, °C
1	10	Steady State	1500	14	100	105
2	10	Steady State	1600	148	100	105
3	10	Steady State	2400	197	100	105
4	10	Steady State	3200	224	100	105
5	1	Cyclic	900	0	100	105
6	2	Cyclic	2600	50%	100	105
7	2	Cyclic	1800	1%	100	105
8	2	Cyclic	1200	25%	100	105
9	2	Cyclic	1800	50%	100	105
10	2	Cyclic	3200	5%	100	105
11	2	Cyclic	2200	50%	100	105

B.2.5. Pre-Test Engine Performance Check. Prior to endurance testing, perform an engine pre-test performance check to document start of test engine performance (use the same oil charge from the engine break-in). The performance check shall consist of running a full load power curve from 1000 r/min to max rated engine speed (3400 r/min) in 200 r/min increments. Prior to running the curve the engine shall be warmed up to full operating temperature, and intake and exhaust restrictions set at rated speed and load.

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B.2.6 Test Cycle. A fresh oil charge and new filter shall be installed on the engine prior to endurance testing. Weigh all oil entering the engine, and the dry filter weight prior to installation to support oil consumption calculations. The endurance test cycle used is outlined in table BIII, and is a modified version of the 210 hour Tactical Wheeled Vehicle cycle as outlined in CRC Report No. 406, Development of Military Fuel/Lubricant/Engine Compatibility Test. Modifications shall be made to the test temperatures to increase the severity of the oil being tested. Test termination shall occur at the completion of the scheduled 210 hours, or upon major oil degradation, whichever occurs first. Oil condemning limits for test termination can be found in table BIV. No oil changes are allowed over the test duration. Oil additions are allowed once daily at the completion of the engine soak period. All oil additions must be weighed and recorded during testing.

The test cycle consists of high temperature operation for two hours at rated speed and load, followed by low temperature one hour no-load idle speed. This alternating cycle is conducted 14 hours daily, followed by a 10 hour engine-off soak period. Daily 125 mL used oil samples are to be pulled at the completion of every 14 hours prior to shutting down the engine. All oil samples must be weighed and recorded during testing. Analysis shall be completed in accordance with table BIV.

The specified temperatures must be maintained within +/- 2.5°C throughout testing, with the exception of the first 10 minutes of every step to allow for stabilization. Engine output must be controlled to 347 Nm load at all time during the rated speed steps.

Table BIII. Endurance engine cycle.

Stage	Time, hrs	Speed, r/min	Torque, Nm	Coolant Out, °C	Oil Sump, °C
1	2	Rated	347	95.5	126.7
2	1	Idle	-	37.8	51.7
3	2	Rated	347	95.5	126.7
4	1	Idle	-	37.8	51.7
5	2	Rated	347	95.5	126.7
6	1	Idle	-	37.8	51.7
7	2	Rated	347	95.5	126.7
8	1	Idle	-	37.8	51.7
9	2	Rated	347	95.5	126.7
10	10	Shutdown	-	-	-

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Table BIV. Used oil analysis tests and condemning limits.

Every 14hrs		
Test Method	Parameter	Used Oil Condemning Limits
ASTM D4739	Total Base Number	3.0 min
ASTM D664	Total Acid Number	9.0 max
ASTM D445	Kinematic Viscosity @ 100°C	70% increase, max
ASTM D4052	Density	----
TGA Soot	Soot, %, max	----
ASTM E168 FTNG	Oxidation	----
ASTM E168 FTNG	Nitration	----
ASTM D5185	Wear Metals by ICP	(Iron, Lead, Copper) 500 mg/kg, max
Every 70hrs		
ASTM D445	Kinematic Viscosity @ 40°C	----
ASTM D2270	Viscosity Index	----

B.2.7. Post Test Power Curve. At the completion of endurance testing, perform an engine pre-test performance check to document end of test engine performance (use the same oil charge from the endurance test). The performance check shall consist of running a full load power curve from 1000 r/min to max rated engine speed (3400 r/min) in 200 r/min increments. Prior to running the curve the engine shall be warmed up to full operating temperature, and intake and exhaust restrictions set at rated speed and load.

B.2.8. Post Test Procedures. At the completion of testing the engine shall be disassembled and all oil wetted components inspected for condition. The following components shall be measured to document engine wear.

Post-Test Measurements:

- Cylinder bore diameter
  - At top, middle, bottom – transverse & longitudinal direction
- Piston
  - Skirt diameter
  - Pin bore diameter
- Piston rings
  - Ring gap (all locations)
  - Top ring radial thickness (5 locations)
  - Second ring radial thickness (5 locations)
  - Ring mass (all locations)
- Piston pin
  - Pin diameter
  - Pin bore in connecting rod
- Crankshaft end play
- Main bearing mass
  - Upper and lower shell

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- Connecting rod bearing mass
  - Upper and lower shell

The following parameters shall be rated per ASTM Deposit Ratings Manual 20:

- Piston ring sticking
- Piston percent scuffing area
- Piston carbon demerits
- Piston lacquer demerits
- Piston top groove fill percent
- Piston intermediate groove fill percent
- Piston top land heavy carbon
- Piston top land flaked carbon
- Valve tulip deposits (all locations)
- Cylinder bore (polish and scuffing)

All components where pre-test measurements and ratings were completed shall be retained, carefully stored to not disturb any ratings and deposits, and shipped to the qualifying activity.

Photographs shall be taken of the following components for submission with a final report:

- Piston (best and worst by deposit ratings)
  - Thrust and Anti-thrust (4 total pictures)
- Piston Rings (best and worst by weight loss)
- Piston Undercrown (best and worst, same as above)
- Cylinder Bore Best and Worst (best and worst by bore ratings)
- Intake and Exhaust Valve Pair (best and worst by ratings)
- Rod Bearings (all)
- Main Bearings (all)

Custodians:
Army - AT
Navy - SH
Air Force - 68

Preparing activity:
Army - AT

(Project 9150-2015-004)

Review activities:
Army - AR, MI, SM
Navy - AS, MC, SA, YD
Air Force - 03, 11
DLA - GS, PS
CIV - 6FEE

Industry associations:
ASTM, API, SAE

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at https://assist.dla.mil.