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METRIC

MIL-PRF-2104G
10 February 1997
SUPERSEDING
MIL-L-2104F
28 September 1992

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 engine oils suitable for lubrication of reciprocating internal combustion engines of both spark-ignition and compression-ignition types and for power transmission fluid applications in combat/tactical service equipment (see 6.1).

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

SAE Viscosity Grade	Military Symbol	NATO Code
10W	OE/HDO-10	O-237
30	OE/HDO-30	O-238
40	OE/HDO-40	---
15W-40	OE/HDO-15/40	O-1236

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: US Tank-automotive and Armaments Command, ATTN: AMSTA-TR-E/BLUE, Warren, MI 48397-5000, by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter.

AMSC N/A FSC 9150
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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 documents cited in sections 3 and 4 of this specification, whether or not they are listed.

2.2 Government.

2.2.1 Specifications and standards. The following specifications and standards form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

DEPARTMENT OF DEFENSE

MIL-L-21260	-	Lubricating Oil, Internal Combustion Engine, Preservative and Break-In.
MIL-L-46167	-	Lubricating Oil, Internal Combustion Engine, Arctic.

STANDARDS

FEDERAL

FED-STD-791	-	Lubricants, Liquid Fuels and Related Products; Methods of Testing.

(Unless otherwise indicated, copies of the above specifications, and standards are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.2.2 Other Government-documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

U.S. DEPARTMENT OF LABOR (DOL)

OSHA 29 CFR 1910.1200 - Hazard Communication; Interpretation Regarding Lubricating Oils.

(Copies of Guideline CPL 2-2.38 may be obtained from OSHA Publication Office, Room S-4203, 200 Constitution Avenue, NW, Washington, DC 20210.)

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USA MOBILITY TECHNOLOGY CENTER BELVOIR,

Guide for the Qualification of Engine and Gear Lubricants

(Copies of the guide may be obtained from USA Mobility Technology Center Belvoir, ATTN: AMSTA-RBF, 10115 Gridley Road, STE 128, Fort Belvoir, VA 22060-5843)

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 the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI Z1.4 - Sampling Procedures and Tables for Inspections by Attributes.

(Application for copies should be addressed to The American National Standards Institute, 11 West 42nd Street, New York, NY 10036.)

AMERICAN SOCIETY FOR QUALITY CONTROL (ASQC)

ASQC Z1.4 - Sampling Procedures and Tables for Inspections by Attributes.

(Application for copies should be addressed to American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53201-4606.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D 92 - Flash and Fire Points by Cleveland Open Cup. (DoD adopted)
ASTM D 94 - Saponification Number of Petroleum Products. (DoD adopted)
ASTM D 97 - Pour Point of Petroleum Oils. (DoD adopted)
ASTM D 129 - Sulfur in Petroleum Products (General Bomb Method). (DoD adopted)
ASTM D 130 - Detection of Copper Corrosion from Petroleum Products, by the Copper Strip Tarnish Test. (DoD adopted)
ASTM D 287 - API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method). (DoD adopted)
ASTM D 445 - Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity). (DoD adopted)
ASTM D 524 - Ramsbottom Carbon Residue of Petroleum Products. (DoD adopted)
ASTM D 664 - Neutralization Number by Potentiometric Titration. (DoD adopted)
ASTM D 808 - Chlorine in New and Used Petroleum Products (Bomb Method). (DoD adopted)
ASTM D 874 - Sulfated Ash from Lubricating Oils and Additives. (DoD adopted)
ASTM D 892 - Foaming Characteristics of Lubricating Oils. (DoD adopted)

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ASTM D 1091 - Phosphorus in Lubricating Oils and Additives. (DoD adopted)
ASTM D 1317 - Chlorine in New and Used Lubricants (Sodium Alcoholate Method).
ASTM D 1500 - ASTM Color of Petroleum Products (ASTM Color Scale). (DoD adopted)
ASTM D 1552 - Sulfur in Petroleum Products (High-Temperature Method). (DoD adopted)
ASTM D 2270 - Calculating Viscosity Index from Kinematic Viscosity at 40 and 100°C. (DoD adopted)
ASTM D 2622 - Sulfur in Petroleum Products (X-Ray Spectrographic Method). (DoD adopted)
ASTM D 2896 - Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration. (DoD adopted)
ASTM D 3228 - Total Nitrogen in Lubricating Oils and Fuel Oils by Modified Kjeldahl Method. (DoD adopted)
ASTM D 4047 - Phosphorus in Lubricating Oils and Additives by Quinoline Phosphomolybdate Method. (DoD adopted)
ASTM D 4057 - Manual Sampling of Petroleum and Petroleum Products. (DoD adopted)
ASTM D 4177 - Automatic Sampling of Petroleum and Petroleum Products. (DoD adopted)
ASTM D 4294 - Sulfur in Petroleum Products by Non-Dispersive X-Ray Fluorescence Spectrometry. (DoD adopted)
ASTM D 4485 - Standard Specification for Performance of Engine Oils.
ASTM D 4624 - Measuring Apparent Viscosity by Capillary Viscometer at High Temperature and High-Shear Rates. (DoD adopted)
ASTM D 4628 - Analysis of Barium, Calcium, Magnesium, and Zinc in Unused Lubricating Oils by Atomic Absorption Spectrometry. (DoD adopted)
ASTM D 4629 - Trace Nitrogen in Liquid Petroleum Hydrocarbons by Syringe/Inlet Oxidative Combustion and Chemiluminescence Detection. (DoD adopted)
ASTM D 4683 - Measuring Viscosity at High Temperature and High Shear Rate by Tapered Bearing Simulator. (DoD adopted)
ASTM D 4684 - Determination of Yield Stress and Apparent Viscosity of Engine Oils at Low Temperature. (DoD adopted)
ASTM D 4739 - Base Number Determination by Potentiometric Titration.
ASTM D 4741 - Measuring Viscosity at High Temperature and High Shear Rate by Tapered-Plug Viscometer. (DoD adopted)
ASTM D 4927 - Elemental Analysis of Lubricants and Additive Components - Barium, Calcium, Phosphorus, Sulfur, and Zinc by Wavelength-Dispersive X-Ray Fluorescence Spectroscopy. (DoD adopted)
ASTM D 4951 - Determination of Additive Elements in Lubricating Oils by Inductively Coupled Plasma Atomic Emission Spectrometry. (DoD adopted)
ASTM D 5119 - Evaluation of Automotive Engine Oils in the CRC L-38 Spark-Ignition Engine. (DoD adopted)
ASTM D 5185 - Determination of Additive Elements, Wear Metals and Contaminants in Used Lubricating Oils by Inductively-Coupled Plasma Atomic Emission Spectrometry. (DoD adopted)
ASTM D 5480 - Motor Oil Volatility by Gas Chromatography.
ASTM D 5533 - Evaluation of Automotive Engine Oils in the Sequence IIIE, Spark-ignition Engine.
ASTM D 5800 - Evaporation loss of Lubricating Oils by the Noack Method.

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ASTM D 5862 - Evaluation of Engine Oils in the Two-Stroke Cycle Turbo-Supercharged 6V92TA Diesel Engine.
ASTM D 5950 - Pour Point, Automatic
ASTM D 5966 - Roller Follower Wear Test
ASTM D 5967 - Evaluation of Diesel Engine Oils in the T-8 Diesel Engine
ASTM D 5968 - Corrosion of Diesel Engine Oils

ASTM Special Publication (STP) 315H

HEUI Engine Oil Aeration Test
Caterpillar 1N Test Procedures
Caterpillar 1M-PC Test Procedure

(Application for copies should be addressed to the ASTM test methods may be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.)

ALLISON TRANSMISSION DIVISION (ATD)/General Motors Corporation

C-4 Fluid Specification (TES-228).

(Application for copies should be addressed to the EG&G Stationary Testing, Attn: ATF/Specialty Lab (C-4), 5904 Bandera Road, San Antonio, TX 78283-1993.)

CATERPILLAR INC., ENGINE DIVISION (CAT.)

Caterpillar TO-4, Fluid Requirements, VC 70.

(Application for copies should be addressed to Caterpillar, Component Development, Technical Center - G, P.O. Box 1875, Peoria, Illinois 61656-1875)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

SAE J300 - Engine Oil Viscosity Classification.
SAE J183 - Engine Oil Performance and Engine Service Classification (Other than "Energy Conserving").

(Application for copies should be addressed to SAE, 400 Commonwealth Drive, Warrendale, PA 15096.)

2.4 Order of precedence. 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.

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3. REQUIREMENTS

3.1 Qualification. Engine lubricating oils furnished under this specification shall be products that are qualified by the qualifying activity (see 6.4) for listing on the applicable qualified products list at the time of contract award (see 4.11 and 6.4). Qualification will be granted by the qualifying activity (see 6.4) to any manufacturer (original or reblender) of lubricating oils provided a "Manufacturing Facility Survey" (MFS) has been accepted as described in the "Guide for Qualification of Engine and Gear Lubricants". Each manufacturing facility intended for the manufacture of products under this specification shall have a MFS. This is a one time requirement provided there is no change in facilities, blending method or equipment. Companies requesting rebrand approvals do not need an MFS to be qualified. The qualifying activity (see 6.4) may waive complete qualification testing or may require only partial qualification testing of SAE 40 grade oil if the contractor states in a written affidavit that the product has been formulated with base stocks, refining treatment, and additives the same as those used in the formulation of SAE 30 grade oil qualified under this specification.

3.1.1 Qualification period. Each viscosity grade of oil which satisfies all the requirements of this specification shall be qualified for a period not exceeding four years from the date of its original qualification. The qualification period for each SAE 40 grade oil qualified in accordance with 3.1 shall not exceed that of the SAE 30 grade used in the qualification procedure. When the qualification period has expired, or whenever there is a change in the base stock, in the refining treatment or in the additives used in the formulation, each product must be retested if the contractor wishes to maintain the formulation as a qualified product and be eligible to bid on government solicitations for this material.

3.1.2 Tolerances. The engine lubricating oil supplied under contract shall have the same base stocks and additives components, at the appropriate concentrations, as when qualified. The finished oil properties shall fall within permissible tolerances assigned by the qualifying activity to the properties listed in 3.5, of the product receiving qualification. The values resulting after the application of tolerances shall not exceed the maximum nor fall below the minimum limits specified herein (see table I and 3.4.1 through 3.4.11).

3.1.3 Pour-point depressant. No changes shall be made in either the type or concentration of the pour-point depressant after qualification testing and approval unless:

a. The oil is retested for conformity to the pour-point, stable pour point, borderline pumping temperature and all viscosities (see table I).
b. The qualifying activity (see 6.4) is informed of the proposed change(s) and of the retesting.
c. The qualifying activity approves the proposed change(s) in writing.

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TABLE I. Finished oil requirements.

Property		SAE Grade 10W	SAE Grade 30	SAE Grade 40	SAE Grade 15W-40
Kinematic viscosity, cSt @ 100°C	min.	5.6	9.3	12.5	12.5
	max.	<7.4	<12.5	<16.3	<16.3
@ 40°C [1/]		X	X	X	X
Viscosity apparent, cP @°C[2/]	min.	3500@-25	----	----	3500@-20
	max.	3500@-20	----	----	3500@-15
High-temperature/high-shear viscosity, min.		2.9	X	X	3.7
Pumpability, 60,000 cP, max. @ temperature, °C		-30	----	----	-25
Viscosity index, min.		X	80	80	X
Pour point, °C, max.		-30	-18	-15	-23
Stable pour point, °C, max.[3/]		-30	----	----	-23
Flash point, °C, min.		205	220	225	215
Evaporative loss, %		18	----	----	15
Other properties [1/]					
Gravity		X	X	X	X
Carbon residue		X	X	X	X
Sulfur		X	X	X	X
Sulfated ash		X	X	X	X
Acid number		X	X	X	X
Base number		X	X	X	X
Phosphorus		X	X	X	X
Nitrogen		X	X	X	X
Metallic components		X	X	X	X

1/ Value shall be reported ("X" indicated report).

2/ Report the measured apparent viscosity for grades 10W and 15W-40 oils at the minimum and maximum temperatures.

3/ After being cooled down to its pour point, the oil shall regain its homogeneity on standing at a temperature not more than 6°C above the pour point. However, it should not exceed the indicated limits.

3.1.4 Material Safety Data Sheets. When applying for qualification, the manufacturer shall submit to the qualifying activity (see 6.4) a sample of the product tested (see 3.4.2.1) and include Material Safety Data Sheets prepared in accordance with FED-STD-313. When FED-STD-313 is at variance with the 29 CFR 1910.1200, the CFR shall take precedence, modify and supplement FED-STD-313.

3.2 Materials. The engine lubricating oils shall be derived from petroleum fractions, synthetically prepared compounds or a combination of the two types of products. They may be virgin, rerefined stocks or a combination thereof. The stocks shall be compounded with such functional additives (detergents, dispersants, oxidation inhibitors, corrosion inhibitors, etc.) as are necessary to meet the specified requirements. The contractor shall certify that no carcinogenic or

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potentially carcinogenic constituents are present as defined under the Hazard Communication Standard (29 CFR 1910.1200). Certification of this effect shall be made available to the contracting officer or the contracting officer's designated representative.

3.2.1 Recycled, recovered, or environmentally preferable materials. Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible provided that the material meet the herein specified requirements, and promotes economically advantageous life cycle costs.

3.3 Physical and chemical requirements.

3.3.1 Requirements for finished oil. The oils shall conform to the requirements specified in table I and 3.4.1 through 3.4.11.

3.3.2 Requirements for base stock. A 180 milliliters (mL) production sample of each base stock component used in formulating the finished oil, accompanied by the following property data, shall be submitted annually to the qualifying activity.

Viscosity cSt, @100 and 40° C	Elemental content, mass %
Viscosity Index	Nitrogen, mass %
Gravity, API @ 60°F	Chlorine, mass %
Pour Point, °C	Sulfur, mass %
Carbon Residue, mass %	Color
Acid Number	Boiling point distribution, °C
Sulfated Ash, mass %	@ 1%, 5%, 10%, 50%, & 90% points
Flash Point, °C	Saponification number

3.4 Performance requirements. The oils shall conform to the respective requirements specified in 3.4.1 through 3.4.11.

3.5 Foaming. All grades of oil shall demonstrate the following foaming characteristics when tested in accordance with 4.1.2, table II (ASTM D 892).

a. SEQ I. Initial test at 24 ±0.5°C. Not more than 10 mL of foam shall remain immediately following the end of the 5-minute blowing period. No foam shall remain at the end of the 10-minute settling period.

b. SEQ II. Intermediate test at 93.5 ±0.5°C. Not more than 20 mL of foam shall remain immediately following the end of the 5-minute blowing period. No foam shall remain at the end of the 10-minute settling period.

c. SEQ III. Final test at 24 ±0.5°C. Not more than 10 mL of foam shall remain immediately following the end of the 5-minute blowing period. No foam shall remain at the end of the 10-minute settling period.

d. SEQ IV. Test at 150 ±0.5°C. Not more than 50 mL of foam shall remain immediately following the end of the blowing period. No foam (0) shall remain at the end of the 1-minute settling period. Option A is not allowed (CG-4 requirement). If product fails this sequence than section 3.4.11 applies.

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Table II. Test Methods

TEST	TEST METHODS		
	FED-STD-791	ASTM	SAE
Viscosity, kinematic		D 445	
Viscosity, apparent [1/]			J300
High temperature/high shear		D 4683, D 4624, D 4741	
Viscosity Index		D 2270	
Pour Point		D 97, D 5950	
Stable Pour Point	203		
Pumpability		D 4684	
Flash Point		D 92	
Evaporative Loss [2/]		D 5480, D 5800	
Gravity, API		D 287	
Carbon Residue		D 524	
Color		D 1500	
Acid Number		D 664	
Base Number		D 2896, D 4739	
Phosphorus		D 1091, D 4047, D 4927, D 4951, D 5185	
Chlorine [3/]		D 808, D 1317	
Sulfur [4/]		D 129, D 1552, D 2622,D 4294, D 4927, D 4951, D 5185	
Nitrogen		D 3228, D 4629	
Saponification Number		D 94	
Sulfated residue		D 874	
Boiling range distribution		D 2887	
Metallic components		D 4628, D 4927, D 4951, D 5185	
Foaming		D 892	
Engine Oil Aeration		HEUI	
Stability & compatibility			
Oxidation & wear characteristics	3470 [5/]	D 5533	
Dispersancy characteristics		D 5967	
Bearing Corrosion & shear stability		D 5119	
Ring-sticking, wear, & deposits			
Four-stroke cycle diesel engine-LS		Caterpillar 1N	
Four-stroke cycle diesel engine-HS		Caterpillar 1M-PC	
Two-stroke cycle diesel engine		D 5862	
Friction retention characteristics & wear:			
Slip time and wear		ATD C-4 [6/]	
Friction coefficient and wear		Caterpillar VC-70[7/]	
Seal compatibility		ATD C-4 [8/]	
Corrosion of diesel engine oils		D 5968	
Copper Corrosion		D 130	
Roller follower wear test		D 5966	

1/ Obtain the apparent viscosity using the method of test set forth by SAE J300, appendix A.
2/ ASTM D 5480 is the preferred method.
3/ ASTM D 808 is the preferred method.
4/ ASTM D 1552 is the preferred method. ASTM D 4294 is only for use with base stock.
5/ See 4.1.2.1 for clarifying instructions.

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6/ Use procedure described in item 8 and 9 of C-4 specification.
7/ Use test SEQs 1220 and FRRET (VC-70) described in the CAT. TO-4 specification.
8/ Use procedure in item 5 of C-4 specification.

3.4.2 Stability and compatibility.

3.4.2.1 Stability. The oils shall show no evidence of separation or color change when they are tested in accordance with 4.1.2, table II (FED-STD-791, method 3470). A one (1) L sample of the finished lubricant to be qualified and used for this test shall be provided to the qualifying activity (see 6.4) at the time of qualification.

3.4.2.1 Compatibility. The oils shall be compatible with oils previously qualified under non-performance specification MIL-L-2104, MIL-L-21260, and MIL-L-46167 and under performance specifications MIL-PRF-2104, MIL-PRF-21260, and MIL-PRF-46167. The oils shall show no evidence of separation when they are tested against selected reference oils in accordance with 4.1.2, table II (FED-STD-791, method 3470).

3.4.3 Oxidation and wear protection characteristics. The oils shall protect internal loaded engine components against excessive wear and oxidation. Satisfactory performance in this respect shall be demonstrated when the oils are tested according to multiple test criteria and rated in accordance with 4.1.2, table II (ASTM D 5533) and exhibit test results (single or average) meeting the following criteria:

	1 test	2 Test	3 Tests
Average rating @ 64 hrs.			
Viscosity increase, Hours to 375% avg. min.	67.5	65.1	64.0
Oil ring land deposits, avg. min	2.6	2.6	2.6
Piston skirt varnish, avg. min	8.7	8.7	8.7
Sludge, avg. min	9.0	9.0	9.0
Stuck rings, avg. max	None	None	None
Stuck lifter, avg. max	None	None	None
Scuffing and wear at 64 hrs.			
Cam or lifter scuffing	None	None	None
Cam plus lifter wear, :m			
Average (avg. max.)	64	64	64
Maximum (avg.)	145	145	145

3.4.4 Roller follower wear test(D 5966). The oils shall protect internal loaded diesel engine components against excessive wear caused by the presence of soot. Satisfactory performance in this respect shall be demonstrated when the oils are tested according to multiple test criteria and rated in accordance with 4.1.2, table II (D 5966) and exhibit averaged test results meeting the following criteria:

		1 Test	2 Test	3 Test
Pin Wear,	µm, avg. max.	11.4	12.4	12.7
	mils avg. max.	0.45	0.49	0.50

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3.4.5 Bearing corrosion and shear stability.

3.4.5.1 Bearing corrosion. The oils shall be non-corrosive to alloy bearings. Satisfactory performance in this respect shall be demonstrated when the oils are tested in accordance with 4.1.2, table II (ASTM D 5119) and exhibit test results meeting the following criteria:

		1 Test	2 Test	3 Test
Bearing weight loss,	milligrams (max.)	43.7	48.1	50.0

3.4.5.2 Shear stability. SAE 15W-40 grade oil shall demonstrate shear stability by exhibiting a viscosity at 100 °C of 13.0 cSt minimum, on any of the samples taken, when tested in accordance with 4.1.2.2.

3.4.6 Ring-sticking, wear, and accumulation of deposits. The oils shall prevent the sticking of piston rings and port clogging, and shall minimize the wear of cylinders, rings and loaded engine components such as cam shaft lobes, cam followers, valve rocker arms, rocker arm shafts, and the oil pump and fuel injection pump drive gears.

3.4.6.1 Four-stroke cycle diesel engine - low sulfur fuel. Satisfactory performance shall be demonstrated when the oils are tested with low-sulfur fuel and rated in accordance with 4.1.2, table II (Caterpillar 1N) and exhibit test results meeting the following criteria: (Only one test is required. However, the test limits are adjusted according to the number of tests submitted and equivalency to original limits.)

	1 Test	2 Tests	3 Tests
Top groove filling, % avg. max.	20	23	25
WDN, demerits, avg. max.	286	311.7	323.0
Top land heavy carbon, %, avg. max.	3	4	5
Oil consumption, g/Kw-hr., avg. max.	0.5	0.5	0.5
Scuffing, piston-rings-liners, avg. max.	None	None	None
Stuck rings, avg. max.	None	None	None

3.4.6.2 Four-stroke cycle diesel engine - higher sulfur fuel. Satisfactory performance shall be demonstrated when the oils are tested with higher-sulfur fuel and rated in accordance with 4.1.2, table II (Caterpillar 1M-PC) and exhibit test results meeting the following criteria: (Only one test is required, however, when three or more tests are run, one test may be discarded and the average calculated from the remaining test results. This average result must meet the following criteria.):

Top groove filling, % max.	70
WTD, avg., max.	240
Ring Side Clearance Loss, mm, max.	0.013
Piston Ring Sticking	None
Piston, Ring, and Liner Scuffing	None

3.4.6.3 Two-stroke cycle diesel engine. Satisfactory performance shall be demonstrated when the oils are tested and rated in accordance with 4.1.2, table II (D 5862) and exhibit test results

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meeting the following criteria: (Only one test is required. However, if more than one test is run, the test limits are adjusted according to the number of tests run, maximum of three tests, and equivalency to original limits and in accordance with A6.2 thru A6.6 under ASTM D 4485.)

	1 Test	2 Tests	3 Tests
Piston, average % area			
Skirts tin removed	Report	Report	Report
Wrist pin slipper bushing copper exposed	Report	Report	Report
Average ring face distress, demerits (max.)			
Fire ring, avg.	0.33	0.34	0.36
Nos. 2 and 3 compression rings, avg.	0.28	0.29	0.30
Broken rings, avg.	None	None	None
Cylinder liner area			
Average liner distress, % area (avg. max.)	60.0	63.5	65.0
Port plugging, % area, (avg. max.)			
Average	2	2	2
Single cylinder	5	5	5

3.4.7 Friction retention characteristics and wear. The oils shall maintain a stable coefficient of friction and shall minimize distress and wear during use in power shift transmissions and other cooled friction components or hydraulic systems such as steering braking and disconnect clutches.

3.4.7.1 Slip time and torque. Satisfactory performance shall be demonstrated when the oils are tested and rated in accordance with 4.1.2, table II (ATD C-4) and exhibit test results meeting the following nominal criteria, as adjusted to accommodate slight changes in individual friction plate batches:

	Graphite	Paper	
	0-5500 cycles	0-10,000 cycles	10,000
Slip time at cycles, seconds (max.)	0.74	0.67	Report
Mid-point coefficient (min.)	0.097	0.080	Report

3.4.7.3 Friction coefficient and wear. Satisfactory performance shall be demonstrated when the oils are tested and rated in accordance with 4.1.2, table II (Caterpillar VC 70) and a test on each sequence exhibit results meeting the following nominal criteria as adjusted to accommodate slight changes in individual bronze plate batches and performance of the reference oil:

	Sequence 1220	Sequence FRRET
Average dynamic coefficient, %	90-140	---
@ 3000 cycles	---	85-130
@ 8000 cycles	---	90-125
@ 15000 cycles	---	90-125
@ 25000 cycles	---	95-125
Average static coefficient, %	91-127	---
Disc wear, mm (max.)	0.04	---
Energy limit, %	25	---

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3.4.8 Seal compatibility. The oils shall minimize deterioration of seal and friction materials.

3.4.8.1 Effect on seals. Satisfactory performance shall be demonstrated when the oils are tested and rated in accordance with 4.1.2, table II (ATD C-4) and exhibits test results meeting the following nominal criteria, as adjusted to accommodate slight changes in individual elastomer batches:

a. Buna N:	Volume changes, %	0 to +5
	Hardness changes, points	0 ± 5
b. Polyacrylate:	Volume changes, %	0 to +10
	Hardness change, points	0 to +5
c. Silicone:	Volume changes, %	0 to +5
	Hardness changes, points	0 to -10
d. Fluoroelastomer:	Volume changes, %	0 to +4
	Hardness change, points	-4 to +4
e. Ethyl Acrylic:	Volume changes, %	+12 to +28
	Hardness change, points	-6 to -18

3.4.9 Dispersancy characteristics (ASTM D 5967). Satisfactory performance shall be demonstrated when the oils are tested and rated in accordance with 4.1.2, table II (ASTM D 5967) and exhibits test results meeting the following criteria:

	1 test	2 test	3 test
Viscosity increase, cSt max.			
from min. corrected to 3.8% Soot by TGA	11.5	12.5	13.0
Oil Consumption, gm/Bhp·hr, max.	0.0005	0.0005	0.0005

3.4.10 Corrosion. Satisfactory performance shall be demonstrated when the oils are tested according to 3.4.10.1 and 3.4.10.2

3.4.10.1 Engine oil corrosion (ASTM D 5968) . Satisfactory performance shall be demonstrated when the oils are tested and rated in accordance with 4.1.2, table II (ASTM D 5968) and exhibits test results meeting the following criteria:

Cu ppm max. - 20, Pb, ppm, max. - 60

3.4.10.2 Copper Corrosion (ASTM D 130). Satisfactory performance shall be demonstrated when the oils are rated in accordance with 4.1.2, table II (Copper Corrosion, ASTM D 130). The copper coupons used in 3.4.9.1 shall be rated according to ASTM D 130 and the oil shall exhibit copper strip discoloration not exceeding ASTM No. 3 when compared to ASTM Copper Strip Corrosion Standard.

3.4.11 HEUI engine oil aeration test. Satisfactory performance shall be demonstrated when the oils are tested and rated in accordance with 4.1.2, table II (HEUI) and exhibit test results meeting the following criteria

HEUI A foam stability @ 20 hrs., % max. 10

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3.5 Other requirements and tolerances for quality conformance testing. The following physical and chemical properties shall be tested in accordance with the appropriate methods listed in 4.1.2 to insure that purchased products are of the same compositions as the respective qualification samples and to identify the products. No specific values or limits are assigned in qualification testing, except as otherwise specified in table I and 3.4.1 through 3.4.10.2, but test results shall be reported for all properties listed. The qualifying activity (see 6.4) shall establish specific values and tolerances for subsequent quality conformance testing of the finished lubricant for these properties (see 6.3 and 6.4):

Viscosity, apparent and kinematic
High-temperature/high-shear
Viscosity index
Pour point
Pumpability
Flash point
Gravity, °API @ 60 °F
Chlorine
Carbon residue
Foaming
Phosphorus
Sulfur
Sulfated ash
Metallic components
Nitrogen

4. VERIFICATION

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

a. Qualification inspections (see 4.1.1).
b. Conformance inspections (see 4.4.2).

4.1.1 Qualification inspections. Qualification inspections consist of tests for all of the requirements specified in section 3 and may be conducted in any plant or laboratory approved by the qualifying activity (see 6.4). Qualification inspections shall be performed on each viscosity grade except as specified in 4.1.1.1 through 4.1.1.8.

4.1.1.1 Stable pour-point. The stable pour-point test (FED-STD-791, method 203) shall be required only on SAE grades 10W and 15W-40 oils.

4.1.1.2 Shear stability. Shear stability shall be required for only SAE 15W-40 grade oil.

4.1.1.3 Modified formulations. SAE 40 grade oils based on the formulation of an SAE 30 grade oil qualified under this specification may be qualified in accordance with 3.1.

4.1.1.4 Oxidation and wear protection. The qualifying activity (see 6.4), may waive ASTM D 5533 testing of the candidate oil when acceptable supporting ASTM D 5533 wear evaluations for formulations similar in additive technology to the candidate lubricant are presented to substantiate the wear protection characteristics.

4.1.1.5 Ring-sticking, wear, and accumulation of deposits. The two-stroke cycle diesel engine test (D 5862) shall be required only for SAE grades 30, 40, and 15W-40 oils. Requirements for

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this test may be waived for oils formulated with a specific additive technology (detergent, dispersant, inhibitor system) provided satisfactory performance is demonstrated for the technology used in conjunction with various base stock-viscosity improver additive combinations. Satisfactory performance shall be demonstrated by conducting the following acceptable two-stroke cycle diesel engine tests:

a. One test each of three SAE 15W-40 grade oils formulated using the additive system, a viscosity index improver additive but with base stocks of different manufacture.
b. One test each of an SAE 15W-40 grade oil formulated using the additive system, a base stock employed in 4.1.1.5.a for each viscosity index improver additive to be used in conjunction with the additive system.

4.1.1.6 Friction retention characteristics and wear. Test for friction retention characteristics and wear shall be required only for SAE grades 10W, 30, and 15W-40 oils. The qualifying activity (see 6.4) may waive testing for those requirements when acceptable supporting friction retention characteristics and wear evaluations for formulations similar in additive technology to the candidate lubricant are presented to substantiate these performance requirements.

4.1.1.7 Four-stroke cycle diesel engine (1N) - low sulfur fuel. The 1N test shall be required only on 15W-40.

4.1.1.8 HEUI engine oil aeration. The HEUI test shall be required only when a satisfactory sequence IV foam test (SEQ IV D 892) is not available.

4.1.2 Qualification inspection methods. Perform tests in accordance with table II and with 4.1.2.1 through 4.1.2.2, as applicable.

4.1.2.1 Stability and compatibility. Determine the stability and compatibility of the oils by the procedures for "Homogeneity and Miscibility" given in FED-STD-791, method 3470, as explained in 4.1.2.1.1 and 4.1.2.1.2. The procedures in 4.1.2.1.1 and 4.1.2.1.2 should be performed at the same time.

4.1.2.1.1 Stability. Determine the stability by subjecting an unmixed sample of oil to the prescribed cycle of temperature changes, then examine the sample for conformance to the requirements of 3.4.2.1. Record the test results on a copy of the "Homogeneity and Miscibility Test" form in the column marked "None".

4.1.2.1.2 Compatibility. Determine the compatibility of the oil with other oils previously qualified under MIL-L-2104, MIL-L-21260, MIL-L-46167, MIL-PRF-2104, MIL-PRF-21260, and MIL-L-46167 by subjecting separate mixtures of the oil with selected reference oils designated by the qualifying activity (see 6.4) to the prescribed cycle of temperature changes, then examine the mixtures for conformance to the requirements of 3.4.2.2. Record the test results on the same copy of the "Homogeneity and Miscibility test" form (see 4.1.2.1) in the appropriate columns marked "1-30", "2-30", etc. Reference oils for conducting compatibility tests are to be obtained from the SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

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4.1.2.2 Shear stability. Determine the shear stability of SAE 15W-40 grade oil by the following method:

a. Weigh 25 grams of used oil, obtained every 10 hours of testing in accordance with ASTM D 5119.
b. Filter the sample through a 0.5 micron filter pad.
d. Determine the kinematic viscosity at 100°C of the filtered sample using ASTM D 445. Check the resulting viscosity for conformance to the requirements of 3.4.5.2.

4.1.3 Conformance inspections. Inspections for conformance of individual lots (see 6.5) shall consist of tests for the following requirements using the test method listed in table II. The results obtained when using the test methods in table II must fall within the tolerances/specific values (see 3.1.2 and 6.3) assigned at time of qualification:

Viscosities	Foaming
High-temperature/high-shear	Phosphorus
Viscosity index	Sulfur
Pour point	Nitrogen
Pumpability	Acid Number
Flash point	Base Number
Gravity, °API	Sulfated ash
Carbon residue	Metallic components

4.2 Sampling.

4.2.1 Sampling for the examination of filled containers. Take a random sample of filled containers from each lot in accordance with ANSI Z1.4 or ASQC Z1.4.

4.2.2 Sampling for tests. Take samples from bulk or packaged lots (see 6.5) for tests in accordance with ASTM D 4057 or D 4177, as appropriate.

4.3 Inspection. Perform inspection in accordance with FED-STD-791, method 9601. In addition to the inspection, the manufacturer shall provide certification of non-carcinogenicity as specified in 3.2 (i.e., materials are not considered carcinogenic or potentially carcinogenic).

4.3.1 Examination of filled containers. Examine samples taken in accordance with 4.2.1 with regard to fill, closure, sealing, and leakage. Reject any container having one or more defects or under the required fill. If the number of defective or under filled containers exceeds the acceptance number for the appropriate sampling plan of ANSI Z1.4, reject the lot (see 6.5) represented by the sample.

5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When actual packaging of materiel is to be performed by DoD personnel, these personnel need to contact the responsible packaging activity to ascertain requisite

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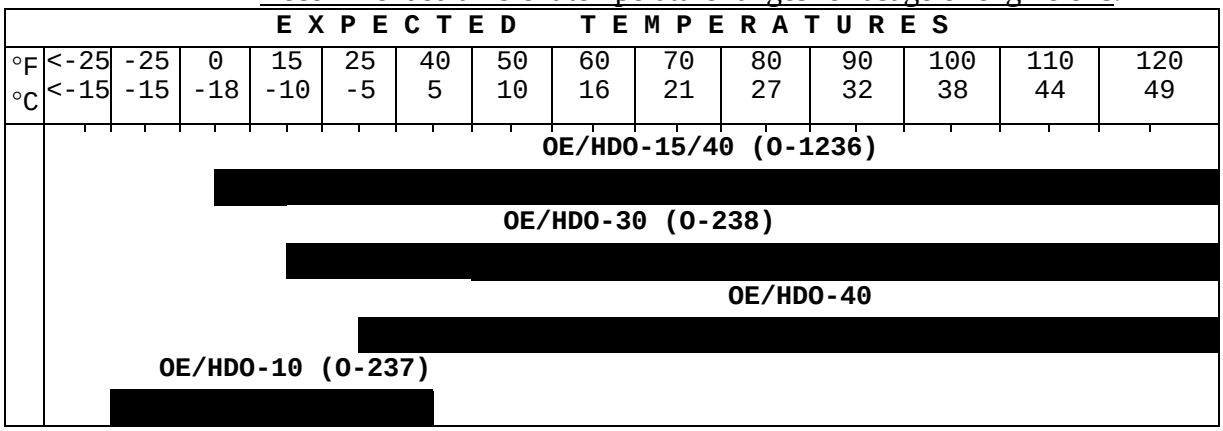
packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activity within the Military Department or Defense Agency, or within the Military Department's System Command. Packaging data retrieval is available from the managing Military Department's or Defense 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 SAE 10W grade oil is not to be used in high-output, two-cycle compression-ignition engines. The lubricating oils, except as mentioned above, covered by this specification are intended for the crankcase lubrication of reciprocating spark-ignition and compression-ignition engines used in all types of military combat/tactical ground equipment and for the crankcase lubrication of two-cycle, four-cycle, high-speed, high-output, supercharged compression-ignition engines used in all ground equipment. The oils are also intended for the same application in power transmissions, hydraulic systems, and non-hypoid gear units of engineer/construction equipment, materials handling equipment and combat/tactical ground equipment. The lubricating oils covered by this specification meet service classifications API CG-4, CF of SAE J183 and are intended for all conditions of operational service, as defined by appropriate lubrication orders, when temperatures are above -25 °C. Recommended ambient temperature ranges for specific grade oils are shown by table III.

TABLE III Recommended ambient temperature ranges for usage of engine oils.



Note:For power transmission, hydraulic system and non-hypoid gear box applications, lubricants may be used at all temperatures above the low temperature recommendation shown in table III.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of this specification.
b. Issue of DoDISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.2 and 2.3).
c. Certification of non-carcinogenicity (see 3.2).
d. Quantity of oil required, PIN, and type container

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6.3 Other requirements and tolerances for conformance inspections. Definite numerical values are not specified for certain of the physical and chemical properties listed in 3.5, and for which corresponding test methods are given in section 4. Values of some properties vary from one brand of oil to another for the same grade. These values are influenced by the source of the base stock, the identities and quantities of additives, etc. Definite numerical values are not always functionally important except, for some properties, within specified maximum and minimum limits. It is not possible (or necessary) to assign restrictive values in the specification before the testing of qualification samples. During qualification, test values will be determined which are characteristics of a particular product and which can serve thereafter to identify the product. Using the results of qualification testing, the qualifying activity (see 6.4) can set values, including permissible tolerances, for future quality conformance testing.

6.4 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 purchase orders for the products covered by this specification. Information pertaining to qualification of products may be obtained from the U. S. Army Mobility Technology Center Belvoir, ATTN: AMSTA-RBF, 10115 Gridley Road, Suite 128, Fort Belvoir, VA 22060-5843.

6.5 Definitions.

6.5.1 Bulk lot. An indefinite quantity of a homogeneous mixture of one grade of oil offered for acceptance in a single, isolated container; or manufactured in a single plant run (not exceeding 24 hours), through the same processing equipment, with no change in the ingredient materials.

6.5.2 Packaged lot. An indefinite number of 208.175L (55 gallon drum) or smaller unit containers of identical size and type, offered for acceptance, and filled with a homogeneous mixture of one grade of oil from a single, isolated container; or filled with a homogeneous mixture of one grade of oil, manufactured in a single plant run (not exceeding 24 hours), through the same processing equipment, with no change in the ingredient materials.

6.6 Part or identifying number (PIN).The PINs to be used for oil acquired to this performance specification shall consist of; a "M" prefix and specification number, a single digit "Dash Number" taken from table IV which indicates the container size, and the viscosity grade of the lubricant.

EXAMPLE

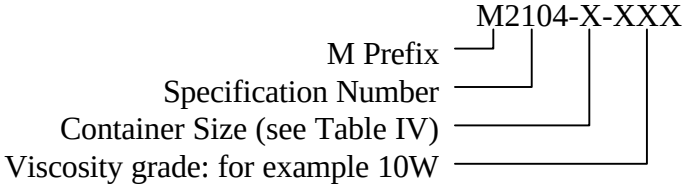

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TABLE IV. Dash number designations for use in PIN numbers.

Dash number	Container size
1	946 mL (1-quart)
2	3.785L (1-Gallon)
3	18.925L (5-Gallon pail)
4	208.175L (55-Gallon drum)

6.7 Subject term (key word) listing.

Engine oil
Heavy-duty diesel
Tracked vehicles
Tribology
Wheeled vehicles

6.8 International Standardization Agreement. Certain provisions of this specification are the subject of international standardization agreement STANAGs 2845 and 1135. When amendment, revision or cancellation of this specification is proposed which would affect or violate the international agreement concerned, the preparing activity will take appropriate reconciliation action through international standardization channels, including departmental standardization office, if required.

6.9 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.

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

Preparing activity:
Army - AT

(Project 9150-1159)

Review activities:
Army - AR, MI, SM
Navy - AS, MC, SA, YD1
Air Force - 11, 99
DLA - GS, PS

Industry Associations:
ASTM
SAE

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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER MIL-PRF-2104G(AT)	2. DOCUMENT DATE *(YYMMDD)* **970210**

3. DOCUMENT TITLE
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, COMBAT/TACTICAL SERVICE

4. NATURE OF CHANGE ***(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)***

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
c. ADDRESS *(Include Zip Code)*	d. TELEPHONE *(Include Area Code)* (1) Commercial (2) AUTOVON *(If applicable)*	7. DATE SUBMITTED *(YYMMDD)*

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a. NAME	b. TELEPHONE *(Include Area Code)* (1) Commercial (810) 574-8745 (2) AUTOVON 786-8745
c. ADDRESS *(Include Zip Code)* Commander U.S. Army Tank-automotive and Armaments Command ATTN: AMSTA-TR-E/BLUE Warren, MI 48397-5000	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403 Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340