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MILITARY HANDBOOK

GUIDE FOR THE SELECTION OF LUBRICANTS, FUNCTIONAL FLUIDS, PRESERVATIVES AND SPECIALITY PRODUCTS FOR USE IN GROUND EQUIPMENT SYSTEMS

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MIL-HDBK-113C
Guide for Selection of Lubricants, Functional Fluids, Preventatives and Special Products For Use in Ground Equipment Systems.

1. This standardization handbook was developed by the Department of Defense in accordance with established procedure.

2. This publication was approved on 24 April 1989 for printing and inclusion in the military standardization handbook series.

3. This handbook provides design guides for selection of suitable lubricants, power transmission fluids and corrosion preventatives for use in ground equipment systems. This handbook is not intended to be referenced in purchase specifications except for informational purposes, nor shall it supersede any specification requirements. In case of conflict between this handbook and specifications or MIL-HDBK-200 the specifications and MIL-HDBK-200 shall take precedence.

4. Every effort has been made to reflect the latest information on lubricants, power transmission fluids, and corrosion preventatives for use in ground equipment systems.

5. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: US Army Belvoir Research, Development, and Engineering Center, ATTN: STRBE-TSE Fort Belvoir, VA 22060-5606 by using the self-addressed Standardization Document Imporvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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CHAPTER I

SCOPE

This Handbook establishes design guides for selection of suitable lubricants, power transmission fluids, and corrosion preventatives for use in ground equipment systems, which conform to approved specifications, as required by MIL-STD-838. It includes descriptive material relative to applications, limitations, and federal stock classification, where applicable, and material statements considered to be beneficial to field personnel. Various tables and figures list or show specific requirements and characteristics of a number of the more important lubricants and compounds. Chapters on "Product Shelf Life and Retest Frequencies" and "Product Limitations and Criteria for Low Temperature Applications" have been included to assure a proper quality surveillance and to assess a satisfactory operation under low temperature applications. Appendices contain viscosity and performance measurement and classification instructions and preparation procedures for solid film lubricant specifications.

CHAPTER II

GENERAL APPLICATIONS, LIMITATIONS, AND FEDERAL STOCK CLASSIFICATION

2.1 LUBRICATING ENGINE AND GEAR OILS

(a) A list of important properties with typical values are given in Table I.

2.1.1 MIL-L-2104, Lubricating Oil, Internal Combustion Engine,Tactical Service.

(a) Intended use: The engine oils covered by this specification are intended for the crankcase lubrication of reciprocating spark-ignition (gasoline) and compression-ignition (diesel) engines used in all types of military tactical equipment, including electric generators, engineer/construction, and material handling equipment and for the crankcase lubrication of high-speed, high output, super/turbocharged diesel engines used in all ground equipment at ambient temperatures above -25 °C (-13 °F). These oils are also used in power transmissions, engineer/commercial construction, and material handling equipment hydraulic systems, and in nonhypoid gearbox applications in tactical and combat ground equipment. The oils are intended for use, as defined by manufacturers, in meeting service classification CD/SE. See Appendix H for vehicle components applications.

(b) Limitations: Other than under emergency conditions, these engine oils should not be used for the lubrication of administrative ground vehicles powered by gasoline engines. Also, they are not recommended for use in large stationary diesel engines containing silver bearing surfaces (see MIL-L-9000). When considered for power transmission or gearbox application, lubricant performance must be evaluated prior to its use. Although intended for use at temperatures above -25 °C (-13 °F), specific grades are temperature limited above this value, therefore caution must be exercised in selecting the proper grade for the ambient temperatures to be encountered. For MIL-L-2104 Lubricating Oil used as an engine oil, the maximum recommended operation temperature (oil sump) for sustained use is 121 °C (250 °F) with an operation temperature limit of 132 °C (270 °F) for short periods (not to exceed 15 min.). For use as a transmission fluid, an operating temperature limit of 149 °C (300 °F) is recommended. Grade 10, OE/HDO-10 is not recommended for use in DDC 2 cycle diesel engines.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The engine oils covered by this specification are petroleum products, synthetically prepared products or a combination of the two types of products. They may be virgin or rerefined stocks or a combination thereof. The stocks shall be compounded with such functional additives (detergents, dispersants, oxidation inhibitors, corrosion inhibitors, anti-wear agents, pour point depressants, anti-foam agents, etc.) as are necessary to meet specified requirements. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.1.2 MIL-L-2105, Lubricating Oil, Gear, Multipurpose.

(a) Intended use: The gear lubricating oils covered by this specification are intended for automotive gear units such as differentials and manual transmissions, heavy duty industrial type enclosed gear units, steering gears, and fluid lubricated universal joints of automotive ground equipment, when ambient temperatures are above -54 ^{o}C (-65 ^{o}F). The oils meet the GL-5 service classification. See Appendix H for vehicle components applications.

(b) Limitations: These lubricants are not for use in automatic transmission or power steering systems. Caution must be used in selecting the proper grade for expected ambient temperatures. For MIL-L-2105 Lubricating Oil a maximum operating oil temperature of 135 ^{o}C (275 ^{o}F) for sustained operation is recommended with a limit of 149 ^{o}C (300 ^{o}F) for short periods (not to exceed 15 min.).

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The gear lubricants covered by this specification are petroleum products, synthetically prepared or a combination of the two types of products. They may be virgin or rerefined stocks or a combination thereof. The stocks shall be compounded with such functional additives (extreme pressure agents, corrosion inhibitors, anti-stain agents, anti-chatter additives, anti-foam agents, pour point depressants, etc.) as are necessary to meet specified requirements. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.2100 shall be used. See FED-STD-313 for additional information.

2.1.3 MIL-L-6082, Lubricating Oil, Aircraft Reciprocating Engine (Piston).

(a) Intended use: The lubricating oil covered by this specification is intended for use in aircraft reciprocating engines and for blending type IIA and IIB oils under MIL-L-22581 (not covered by this handbook).

(b) Limitations: This oil shall not be used for automotive applications. This is a non detergent oil. See appendix G.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The lubricating oil shall be a refined petroleum product and may contain approved pour point depressants in the maximum amount of 1 percent by weight. Additives other than pour point depressant, shall not be used.

2.1.4 MIL-L-7808, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base.

(a) Intended use: This lubricant is intended for use in specific models of aircraft turbine engines, helicopter transmissions, accessory and auxiliary equipment, auxiliary power units and other types of equipment requiring a synthetic base oil. Also the lubricating oil is used for engine lubrication of specific gas turbine powered ground equipment. It is intended for temperatures above -54 °C (-65 °F).

(b) Limitations: This oil is not suitable for automotive applications other than as stated above.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituents materials: The composition of this lubricating oil is not limited except that organometallic compounds of titanium and silicone antifoam agents are prohibited. If the lubricating oil contains a tricresyl phosphate additive, not more than one percent of the tricresyl phosphate shall be ortho isomer. For limits in trace element content, refer to the specification.

2.1.5 MIL-L-7870, Lubricating Oil, General Purpose, Low Temperature.

(a) Intended use: The oil covered by this specification is intended for use wherever a general purpose, low temperature, lubricating oil is required. It is specially designed for use where an oil of low evaporation, possessing rust protective properties is desired.

(b) Limitations: Not to be used in engine applications. This is a low detergent oil. See Appendix G.

(c) Stock numbers: Refer to Appendix F for stock numbers.

(d) Constituent materials: The oil shall be of a fraction of petroleum refined to meet the requirements of the specification, and containing additive materials to impart corrosion protection and oxidation resistance properties.

2.1.6 MIL-L-9000, Lubricating Oil, Shipboard Internal Combustion Engine, High Output Diesel.

(a) Intended use: The lubricating oil covered by this specification is intended for use in advance design high-output shipboard main propulsion and auxiliary diesel engines using fuel conforming to MIL-F-16884, and for use in large stationary diesel engines containing silver bearing surfaces.

(b) Limitations: This oil is not suitable for the crankcase lubrication of gasoline engines.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The engine oil covered by this specification is a petroleum product, compounded with such functional additives (detergents, dispersants, oxidation inhibitors, corrosion inhibitors, anti-wear agents, pour point depressants, anti-foam agents, etc.) as are necessary to meet specified requirements.

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

(a) Intended use: The engine oils covered by this specification are intended for preservation and break-in use for all reciprocating spark-ignition (gasoline) engines and compression-ignition (diesel) engine in all types of ground equipment at temperatures above -25 °C (-13 °F). As a preservative media, the oils are intended to protect engine parts from deterioration during shipment and storage. The oils are also used in a preservative application with other vehicle components such as fuel systems[1/], power transmission systems, and gearboxes. The oils are completely operational and need not be drained until the first scheduled oil change. The oils meet the service classification CD/SE.

(b) Limitations: Although intended for use at temperatures above -25 °C (-13 °F) use of specific grades are temperature-limited. Caution must be exercised in selecting the proper grade for the ambient temperatures to be encountered, and, when placing stored equipment into operation, use of the proper grade must be verified. Grade 10 is not recommended for use in DDC 2 cycle diesel engines.

(c) Stock numbers: Refer to appendix F for stock numbers. (The revised specification is of a different performance level than the products under the provided NSN. Consult with DLA for verification of the NSN in appendix F for this specification.)

(d) Constituent materials: The engine oils covered by this specification are petroleum products, synthetically prepared products or a combination of the two types of products. They may be virgin or rerefined stocks or a combination thereof. The stocks shall be compounded with such functional additives (detergents, dispersants, oxidation inhibitors, corrosion inhibitors, anti-wear agents, pour point depressants, anti-foam agents, etc.) as necessary to meet specified requirements. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.1.8 MIL-L-23699, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base.

(a) Intended use: This lubricant is intended for use in specific models of aircraft gas turbine engines, helicopter transmissions, and other aircraft machine gear boxes within approximate temperature range of -40 °C to 200 °C (-40 °F to 392 °F). The lubricating oil is also used for engine lubrication of specific gas turbine powered ground equipment.

(b) Limitations: This oil is not suitable for automotive applications other than as stated above.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent material: The composition of the lubricating oil is not limited, except that organic compounds of titanium are prohibited. If a tricesyl phosphate additive is used, it shall not contain more than one percent of the ortho isomer of tricresyl phosphate.

1/ Refer to MIL-STD-281.

2.1.9 MIL-L-46152, Lubricating Oil, Internal Combustion Engine, Administrative Service.

(a) Intended use: The oils covered by this specification are intended for the crankcase lubrication of commercial type vehicles used for administrative (post, camp, and station) service typical of, (1) gasoline engines in passenger cars and light to medium duty trucks operating under manufacturer warranties, and (2) lightly super/turbocharged diesel engines operated in moderate duty. The oils are intended for use, as defined by manufacturers, in meeting service classifications SG and CC,when temperatures are above -35 °C (-31 °F).

(b) Limitations: The oils covered by this specification are not intended for use in high-output diesel engines and, as such, should not be used in conjunction with tactical and combat equipment. Specific grades are temperature limited above -35 °C (-31 °F). Caution must be used in selecting the proper grade for conditions to be encountered.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The engine oils covered by this specification are petroleum products, synthetically prepared products or a combination of the two types products compounded with such functional additives (detergents, dispersants, oxidation inhibitors, corrosion inhibitors, anti-wear agents, pour point depressants, anti-foam agents, etc.) as are necessary to meet specified requirements. Base stocks used in compounding these oils may be a virgin material, a re-refined material or a combination of the two types of materials. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.1.10 MIL-L-46167, Lubricating Oil, Internal Combustion Engine, Arctic.

(a) Intended use: The engine oil covered by this specification is for crankcase lubrication of gasoline and diesel engines in all types of ground equipment including electric generators, engineer/construction and material handling equipment. The oil is intended for use under all conditions of service when ambient temperatures are in the range of 4 °C to -54 °C (40 °F to -65 °F). In addition, the oil is for use in arctic regions as an all weather (year-round) power transmission fluid for military tactical and combat ground equipment. The oils are intended for use as defined by manufacturers in meeting service classification SE/CD. See appendix H for vehicle components application.

(b) Limitations: Unless special authorization is provided, the oil is not to be used in place of standard operational engine oils in regions where arctic lubricants are not required.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The engine oils covered by this specification are petroleum products, synthetically prepared products or a combination of the two types of products compounded with such functional additives (detergents, dispersants, oxidation inhibitors, corrosion inhibitors, anti-wear agents, pour point depressants, anti-foam agents, etc.) as are necessary to meet specified requirements. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

Table I. Property requirements for engine oils and gear lubricants.

Specification MIL-L	2104 & 21260				2105			7808	9000	23699	46152					46167	VV-L-765			
Grade	10W	30	40	15W/40	75W	80W/90	85W/140				10W	30	5W/30	10W/30	15W/40		80	90	140	250
Viscosity, Kinematic, cSt @ 100°C																				
Min	5.6	9.3	12.5	12.5	4.1	13.5	24.0	3.0*	11.9	5.0*	5.6	9.3	9.3	9.3	12.5	5.6	NR	14*	25*	43*
Max	<7.4	<12.5	<16.3	<16.3	NR	<24.0	<41.0	NR	<14.5	5.5*	<7.4	<12.5	<12.5	<12.5	<16.3	NR	NR	25*	43*	87*
@ -40°C																				
Max	NR	NR	NR	NR	NR	NR	NR	NR	NR	13000	NR	NR	NR	NR	NR	8800	87 ‡	NR	NR	NR
@ -55°C																				
Max	NR	NR	NR	NR	NR	NR	NR	17000**	NR	NR	NR	NR	NR	NR	NR	75000	NR	NR	NR	NR
Viscosity, Apparent, cP																				
@ -15°C																				
Min	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Max	NR	NR	NR	3500	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	3500	NR	†21,700	NR	NR	NR
@ -18°C																				
Min	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Max	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
@ -20°C																				
Min	NR	NR	NR	3500	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	3500	NR	NR	NR	NR	NR
Max	3500	NR	NR	NR	NR	NR	NR	NR	NR	NR	3500	NR	NR	3500	NR	NR	NR	NR	NR	NR
@ -25°c																				
Min	3500	NR	NR	NR	NR	NR	NR	NR	NR	NR	3500	NR	NR	3500	NR	NR	NR	NR	NR	NR
Max	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	3500	NR	NR	NR	NR	NR	NR	NR
@ -30°c																				
Min	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	3250	NR	NR	NR	NR	NR	NR	NR
Temperature for Apparent Viscosity of 150,000 cP °C (Max)	NR	NR	NR	NR	-40	-26	-12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Viscosity Index (Min)	X	75	80	X	NR	NR	NR	NR	NR	NR	X	75	X	X	X	X	NR	50	50	50
Borderline Pumping Temperature, °C (Max)	-25	NR	NR	-20	NR	NR	NR	NR	NR	NR	-25	NR	-30	-25	-20	NR	NR	NR	NR	NR
Pour Point, °C (Max)	-32	-18	-15	-23	NR	NR	NR	NR	-12	-54	-32	-18	-40	-32	-23	-55	-34.4	-17.8	1.7	15.6
Stable Pour Point, °C (Max)	-32	NR	NR	-23	NR	NR	NR	NR	NR	NR	-32	NR	-40	-32	-23	-55	NR	NR	NR	NR
Channel Point, °c (Max)	NR	NR	NR	NR	-45	-35	-20	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Flash Point, °C (Max)	205	220	225	215	150	165	180	204	199	246	205	220	200	205	215	220	177	190	204	204
Phosphorus, Mass % (Max)	X	X	X	X	X	X	X	NR	NR	NR	0.14	0.14	0.14	0.14	0.14	X	NR	NR	NR	NR
Foaming Characteristics																				
Initial Sequence (24°C)																				
End Aeration, ml(Max)		25				20		NR	NR	25		25					NR	NR	NR	NR
End Setting, ml(Max)		0				NR		NR	NR	0		0					NR	NR	NR	NR
Intermediate Sequence (93°C)																				
End Aeration, ml(Max)		150				50		NR	NR	25		150					NR	NR	NR	NR
End Setting, ml(Max)		0				NR		NR	NR	0		0					NR	NR	NR	NR
Final Sequence (24°C)																				
End Aeration, ml(Max)		25				20		NR	NR	25		25					NR	NR	NR	NR
End Setting, ml(Max)		0				NR		NR	NR	0		0					NR	NR	NR	NR

* Value given is for 98.9°C (210°F)
** Value given is for -53.9°C (-65°F).
Measurements are made at 35 minutes, 3 hours and 72 hours

‡ Value given is for 37.8°C (100°F)
† Value given is for -17.8°C (0°F)
X Report
NR NOT REQUIRED

2.2 POWER TRANSMISSION/HYDRAULIC FLUIDS

(a) A list of important properties with typical values are given on Table II.

2.2.1 MIL-H-5606, Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance.

(a) Intended use: The primary intended use of this fluid is in aircraft applications such as automatic pilots, shock absorbers, brakes, flap control mechanisms, missile hydraulic servo-controlled systems, and other hydraulic systems using synthetic sealing material. This fluid has limited use in ground equipment since it does not provide for rust protection. This oil is dyed red for identification purposes. The recommended operating temperature ranges are -54 to 71 °C (-65 to 160 °F) in open systems and -54 to 135 °C (-65 to 275 °F) in closed systems. For sealed systems pressurized with inert gas, a maximum operating oil temperature of 260 °C (500 °F) can be tolerated for short periods (not to exceed 15 min.).

(b) Limitations: This material has a rather high rate of evaporation and should not be used as a general purpose high temperature hydraulic fluid. Shipment and storage of systems filled with this fluid require drain and refill with MIL-H-6083, Hydraulic Fluid, Petroleum Base, for preservation and testing. This fluid is not interchangeable with any other type or grade of hydraulic fluid. The flash point of this product could be below 100 °C.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: This hydraulic fluid consists of light petroleum fractions, a viscosity index improver, an oxidation inhibitor, and TCP anti-wear agents.

2.2.2 MIL-H-6083, Hydraulic Fluid, Petroleum Base for Preservation and Operation.

(a) Intended use: The primary intended uses of this fluid are, (1) as an operation and preservative hydraulic fluid in ground equipment such as in recoil mechanisms and other combat and combat support equipment, and (2) as a preservative fluid for aircraft hydraulic systems and components. This fluid is dyed red for identification purposes. The operating temperature ranges are -54 to 135 °C (-65 to 275 °F). See appendix H for vehicle component application.

(b) Limitations: The rust preventative additive somewhat increases the viscosity of this fluid and also limits its high temperature capability and consequently, it is not generally suited as an aircraft hydraulic fluid, except in those systems specifically designed for this fluid. It is not interchangeable with any other type or grade of hydraulic fluids. The flash point of these products could be below 100 °C.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: This fluid is the rust inhibited version of MIL-H-5606. No constituent material as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.2.3 MIL-H-46001, Hydraulic Fluid, Petroleum Base, for Machine Tools.

(a) Intended use: Hydraulic fluids covered by this specification are intended for use in hydraulic systems of metal working machine tools. This fluid is available in the following viscosity grades:

Grade 1	28.8-35.2 cSt at 40 °C (104 °F)
Grade 2	41.4-50.6 cSt at 40 °C (104 °F)
Grade 3	61.2-74.8 cSt at 40 °C (104 °F)
Grade 4	165 to -- cSt at 40 °C (104 °F)

The selection of hydraulic fluids should be based on the recommendation of the equipment manufacturer. These hydraulic fluids may also be used in applications requiring corrosion inhibited and oxidation resistant lubricating oils. Grades 1, 2 and 3 possess good anti-wear properties.

(b) Limitations: These fluids are not interchangeable with each other. Grade 4 should not be used where anti-wear properties are critical.

(c) Stock numbers: Refer to appendix F for current stock numbers.

(d) Constituent materials: This hydraulic fluid consists of a refined petroleum oil, with additives as necessary. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.2.4 MIL-H-46170, Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base.

(a) Intended use: Type one is intended for use in recoil mechanisms and battle tank turret hydraulic systems. This fluid has superior fire resistant characteristics compared to MIL-H-6083 fluids and has been evaluated and found satisfactory for use in the M-60/M-48 series tank. If used in other combat vehicles, a study should be made to determine its applicability, particularly in the area of seal compatibility and low temperature operability in such system. Since this fluid is rust inhibited, it may be used as a preservative medium for hydraulic systems and components. Type two is a preservative fluid for aircraft hydraulic systems and components. This fluid is dyed red for identification purposes. See appendix H for vehicle component application.

(b) Limitations: For retrofit of hydraulic system containing MIL-H-6083, draining of MIL-H-6083 should be as complete as possible. Contamination of MIL-H-46170 with MIL-H-6083 or MIL-H-5606 seriously affects the fire resistant characteristics of this fluid. This fluid cannot be used in self-propelled artillery due to its viscosity at -54 °C (-65 °F).

(c) Stock numbers: Refer to appendix F for current stock numbers.

(d) Constituent materials: This fluid consists of a synthetic hydrocarbon (alpha olefin polymer) base stock and additives to meet the technical requirements of the finished product.

2.2.5 MIL-B-46176, Brake Fluid, Silicone, Automotive, All Weather, Operational and Preservative.

(a) Intended use: This fluid is intended for use as an operational and preservative fluid in automotive hydraulic brake systems at ambient temperatures ranging from 55 to -55 °C (131 to -67 °F) and fluid temperatures ranging from 205 to -55 °C (401 to -67 °F). This fluid is dyed purple for identification purposes. This specification supersedes MIL-H-13910, Hydraulic Fluid, Polar-Type, Automotive Brake, All-Weather (Nonpreservative) and MIL-P-46046, Preservative Fluid, Automotive Brake System and Components. This fluid is compatible with VV-B-680, Brake Fluids. This fluid also supersedes VV-B-680 brake fluid for use within DA.

(b) Limitations: This fluid shall not be mixed with other types of brake fluids other than VV-B-680.

(c) Stock Number: Refer to appendix F for stock numbers.

(d) Constituent materials: This brake fluid is a silicone fluid containing additives to meet the technical requirements of the finished product.

2.2.6 MIL-H-83282, Hydraulic Fluid, Fire Resistant Synthetic Hydrocarbon Base, Aircraft.

(a) Intended use: This fluid is intended for use in automatic pilots, shock absorbers, air compressor gearboxes, brakes, flap control mechanism, missile hydraulic servo-controlled systems, and other hydraulic systems using synthetic sealing materials. The recommended operating temperature range is from -40 to 204 °C (-40 to 400 °F). Although designed for aircraft use, this fluid has applications in ground equipment.

(b) Limitations: This fluid is not rust inhibited. Contamination of this fluid with MIL-H-5606 will result in a significant loss in its fire resistant properties.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: This fluid consists of a synthetic hydrocarbon (Alpha olefin polymer) base stock and additives to meet the technical requirements of the finished product. These products are essentially the same as MIL-H-46170 (see 2.2.4) except that this contains a rust inhibitor.

2.2.7 DOD-L-85734, Lubricating Oil, Helicopter Transmission System, Synthetic Base.

(a) Intended use: This lubricating oil is for use in helicopter transmissions only within the temperature range of -40 to 135 °C (-40 to 275 °F).

(b) Limitations: This lubricant is not to be mixed with oils other than DOD-L-85734. No flushing is necessary when changing to MIL-L-7808 or MIL-L-23699.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The composition of the lubricant is not limited, except that organic compounds of titanium are prohibited. If a tricvesyl phosphate additive is used, it shall not contain more than one percent of the ortho isomer of tricvesyl phosphate.

2.2.8 VV-B-680, Brake Fluid, Automotive.

(a) Intended use: This brake fluid is intended for use as an operating fluid in automotive hydraulic brake systems at ambient temperatures ranging from 55 °C (131 °F) to -35 °C (-31 °F), and fluid temperatures from 205 °C (401 °F) to -35 °C (-31 °F).

(b) Limitations: This fluid is not authorized for use in DA vehicle brake systems. The replacement brake fluid is MIL-B-46176.

(c) Stock numbers: No Army interest.

(d) Constituent material: This fluid consist of a high molecular weight polyglycol base, glycol ether solvents and corrosion inhibitors.

2.2.9 Commercial Automatic Transmission Fluids (ATF).

(a) Intended use: The selection of an automatic transmission fluid for use in administrative fleet vehicles should be in accordance with the vehicle manufacturer's recommendation. The automatic transmissions of General Motors Corporation's, Chrysler's, and American Motors Corporation's vehicles require the use of a transmission fluid that contains special friction modifying agents. In these vehicles, transmission fluids qualified under General Motor's "DEXRON" or "DEXRON II" specification should be used. Ford transmissions however, have unique frictional requirements and therefore require the use of fluids corresponding to the Ford Type "F" specification. The Ford Type "F" fluid is not interchangeable with the "DEXRON" or "DEXRON II" fluids. Mixing of these two fluids will result in degraded transmission operation. Some Ford vehicles (1977 and later) are using ESP-M2C138-CJ fluid which is compatible with "DEXRON II". Check the vehicle manufacturer's recommendation before any change in the transmission fluids is made.

(b) Limitations: Use of commercial ATF products should be limited to commercial administrative vehicles unless specifically required by Military lubrication orders.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: These fluids are generally petroleum products compounded with such functional additives (anti-oxidants, extreme pressure agents, anti-squawk agents, corrosion inhibitors, dispersants, etc.) as are necessary to meet specified requirements.

TABLE II. Important properties for some hydraulic fluids.

	MIL-H-5606	MIL-H-6083	MIL-H-46170	MIL-H-83282	MIL-H-46001			
Type/Grade					1	2	3	4
Viscosity (cSt)								
-54 (°C), max	2,500	3,500	13,000 1/	10,250 1/	NR			
-40 (°C), max	600	800	2,600	2,200	NR			
40 (°C), min	13.2	13.0	19.5	14.0	28.8	41.4	135	165
100 (°C), min	4.90	4.3 1/	3.4	3.5	35.2	50.6	61.2	74.8
135 (°C)	NR	NR	2.1 1/	2.0 1/	NR			
205 (°C), min	NR	NR	NR	1.0	NR			
VI	NR	NR	NR	NR	90			
Specific gravity (gm-ml)	0.84 1/	0.86 1/	0.85 1/	0.82 1/	0.87	0.88	0.88	0.88
Bulk modulus (psi), min	NR	NR	200,000	200,000	NR			
Galvanic corrosion	NR	Pass	Pass	NR	Pass			
Rust protection (100 hrs)	Fail, NR	Pass	Pass	Fail, NR	Pass 2/			
Oxidation corrosion test (Method 5308, FTMS 791) or modification	Pass 5308 at 135 °C	Pass 5308 at 121 °C	Pass 5308 at 121 °C	Pass 5308 at 135 °C	NR			
Rubber compatibility Swell (vol. percent)	19-30	19-28	15-25	18-30	NR			
Water percent, max	0.01	0.05	0.05	0.01	NR			
Color, Max	Dyed red	Dyed red	Type II dyed red	Dyed red	2.0	3.0	3.0	5.0
Low temperature stability (72 hrs)	Pass	Pass	Pass	Pass	NR			
Four ball wear (mm), max								
1 (kg)	NR	NR	NR	0.21	NR			
10 (kg)	NR	0.30	0.30	0.30	NR			
40 (kg)	1.0	1.0	0.60	0.60	NR			
Pump wear, mg., max	NR	NR	NR	NR	50	50	50	NR
Water sensivity	NR	Pass	Pass	NR	NR			
Evaporation loss % max	20 % (70 °C, 6 hrs)	70 % (99 °C, 22 hrs)	5.0 % (149 °C, 22 hrs)	20.0 % (205 °C, 6.5 hrs)	NR			
High temperature stability	NR	NR	NR	Pass	NR			
Copper Corrosion	2e	3a	NR	NR	NR			
High temperature, high pressure spray ignition	NR	NR	Pass	Pass				
Wick ignition, cycles	NR	NR	NR	70				
Pour point (°C), max	-60	-59	-54	-55	-12	-12	-12	-6
Auto ignition temperature (°C), min	226 1/	226 1/	343	345	NR			
Flash point (°C), min	82	82	218 (type I) 204 (type II)	205	188	196	196	221
Fire point (°C), min	NR	NR	246	245	216	218	218	246
Neutralization No., max (mg/KOH per g)	0.20	0.20	0.20	0.10	1.5	1.5	1.5	0.20
Shear stability	Pass	Pass	NR	NR	NR			
Foaming characteristics								
At 24 °C 5 min								
End aeration, vol (ml)	65	65	65	65	NR			
End setting vol (ml)	None	None	None	None	100			
At 93 °C 5 min								
End aeration, vol (ml)	NR	65	65	NR	NR			
End setting vol (ml)	NR	None	None	NR	25			
At 24 °C 5 min								
End aeration, vol (ml)	NR	65	65	NR	NR			
End setting vol (ml)	NR	None	None	NR	100			
Solid particle contamination 3/								
Automatic counter					NR			
Allowable number (max)								
5-15	10,000	10,000	10,000	10,000				
16-25	1,000	10,000	10,000	1,000				
26-50	150	250	250	150				
51-100	20	50	50	20				
Over-100	5	10	10	5				

NR - Not Required
1/ Typical Values
2/ Only for 24 hrs with trubine rust test
3/ Cincinnati Milacrom, Procedure A - Test

2.3 LUBRICATING GREASES

(a) A list of important properties with typical values are given in Table III.

2.3.1 VV-G-632, Grease, Industrial, General Purpose.

(a) Intended use: Operating temperatures for each of 3 grades are as follows: Grade 1: -23 to 49 °C (-10 to 120 °F), Grade 2: -18 to 54 °C (0 to 130 °F), and Grade 3: -12 to 60 °C (10 to 140 °F). All three grades are for use in applications calling for the respective grade of grease, which are usually sliding metal on metal environments.

(b) Limitations: None of the three grades are inhibited against oxidation or corrosion under adverse conditions. This grease should not be used in place of MIL-G-10924, Grease, Automotive and Artillery. Caution is advised in using this grease in nonspecified applications.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The grease is a mineral lubricating oil base, thickened with a calcium soap of one or more of the higher fatty acids, with or without additives. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.3.2 VV-G-671, Grease, Graphite.

(a) Intended use: Operating temperatures for each of 3 grades are as follows: Grade 1: -23 to 49 °C (-10 to 120 °F), Grade 2: -18 to 54 °C (0 to 130 °F), and Grade 3: -12 to 60 °C (10 to 140 °F). All 3 grades are for use in applications calling for graphite grease of the consistency specified for the respective grades.

(b) Limitations: The use of this grease in nonspecified applications should be done only after evaluating its compatibility with all involved materials. CAUTION: Graphite is an electrical conductor and is cathodic to all of the common metals. Its conductive property results in galvanic corrosion of metal structures to which it has been applied when an electrolyte is present.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: Each grade contains approximately 5 percent graphite and specifically a mineral lubricating oil thickened with a calcium soap of one or more of the higher fatty acids. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.3.3 VV-G-679, Grease, Railway.

(a) Intended use: Lubrication of friction type driving journals, crankpins, and driving rod cups on steam locomotives provided with grease collars and grease cups.

(b) Limitations: The use of this grease in nonspecified applications should be done only after evaluating its compatibility with all involved materials.

(c) Stock numbers: None given.

(d) Constituent materials: A refined cylinder stock mineral oil and a sodium soap thickener.

2.3.4 MIL-G-4343 Grease, Pneumatic System.

(a) Intended use: As a lubricant between rubber and metal parts of pneumatic systems or other mechanisms requiring rubber to metal lubrication.

(b) Limitations: The use of this grease in nonspecified applications should be done only after evaluating its compatibility with all involved materials.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: Essentially, but not limited to, gelling agent and a suitable liquid lubricant.

2.3.5 MIL-G-6032, Grease, Plug Valve, Gasoline and Oil Resistant.

(a) Intended use: The grease is intended for use in tapered plug valves. The two types provide for the use of high pressure lubrication equipment or for those valves which require a stick type lubricant. The grease may also be used as a gasket lubricant or seal for general plug valve service in systems where gasoline, oil, alcohol, or water resistance is required.

(b) Limitations: This material is not suitable for use with strong acids, alkali, or hydrogen peroxide.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: Animal,vegetable,synthetic oil,or a mixture of these, and a suitable gelling agent shall comprise the grease. The grease shall contain no solid fillers such as graphite,mica, sulfur, clay, asbestos, or chalk.

2.3.6 MIL-G-10924, Grease, Automotive and Artillery.

(a) Intended use: Lubrication and surface corrosion protection of automotive and artillery equipment operated within the temperature range -54 to 180 ^{o}C (-65 to 356 ^{o}F). Examples are wheel bearings, universal joints, chassis suspension points, and truck fifth wheels. This grease may also be used in applications, within the temperature range where a No. 2 consistency grease with oxidation resistant and corrosion prevention properties are desirable.

(b) Limitations: Not to be used on food handling or processing equipment.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: Petroleum oil, rerefined oil, synthetic oil or combinations thereof, and a soap or clay thickener with additives to achieve the performance requirements of the specification. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.3.7 MIL-G-18458, Grease Wire Rope-Exposed Gear.

(a) Intended use: For lubrication and corrosion protection of running ropes and exposed gears.

(b) Limitations: The use of this grease in nonspecified applications should be done only after evaluating its compatibility with all involved materials.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: A petroleum oil and soaps, asphalts, waxes, or other agents to meet the specification document requirements. The grease shall contain no benzene, chlorinated compounds, or hydrolyzable chlorine derivatives.

2.3.8 MIL-G-21164, Grease, Molybdenum Disulfide, for Low and High Temperatures.

(a) Intended use: As a lubricant for accessory splines, heavily loaded sliding surfaces, or for anti-friction bearings where molybdenum disulfide will prevent or delay seizure in the event of inadequate lubrication.

(b) Limitations: The use of this grease in nonspecified applications should be done only after evaluating its compatibility with all involved materials. Minimum usable temperature is -73 ^{o}C (-100 ^{o}F).

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The grease shall consist of a suitable liquid lubricant, a gelling agent, and molybdenum disulfide conforming to MIL-M-7866 in the concentration range 4.5 to 5.5 weight percent.

2.3.9 MIL-G-23549, Grease, General Purpose.

(a) Intended use: A molybdenum disulfide grease for extended use at temperatures up to 177 ^{o}C (350 ^{o}F) and for brief periods of use at temperatures up to 204 ^{o}C (400 ^{o}F).

(b) Limitations: The use of this grease in nonspecified applications should be done only after evaluating its compatibility with all involved materials.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: While not limited it shall contain a high viscosity mineral oil with a non-soap thickener, 5 percent molybdenum disulfide conforming to MIL-M-7866, and a corrosion inhibitor.

2.3.10 MIL-G-23827, Grease, Aircraft and Instrument, Gear and Actuator Screw, NATO Code Number G-354, Metric.

(a) Intended use: The grease is intended for use in ball,roller and needle bearings, gears and on sliding and rolling surfaces of such equipment as instruments, cameras, electronic gear and aircraft control systems. It is suitable for rolling and sliding surfaces of equipment having low motivating power (low torque equipment). Its extremely low volatility is of advantage in preventing oil fogging in optical instruments. This grease is also intended for general use on aircraft gears, actuator screws and other equipment requiring a lubricant with high load carrying capacity over a temperature range of -73 to 121 ^{o}C.

(b) Limitations: Caution is advised when using this grease in nonspecified applications.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The grease shall consist essentially of a gelling agent, a low temperature liquid lubricant, and an extreme-pressure additive and any other chemical addition agent required to meet the requirements of this specification. The composition of the lubricant is not otherwise limited but substantial proportions of non-petroleum materials will be required to meet the volatility and low temperature requirements of this specification.

2.3.11 MIL-G-24139, Grease, Multipurpose, Water Resistant.

(a) Intended use. In ball and roller bearings, it is usable at temperatures ranging from 0 to 107 ^{o}C (32 to 225 ^{o}F) for continuous running and for moderate periods up to 121 ^{o}C (250 ^{o}F).

(b) Limitations: The use of this grease in nonspecified applications should be done only after evaluating its compatibility with all involved materials.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: A petroleum oil and gelling agent.

2.3.12 DOD-G-24508, Grease, High Performance, Multipurpose (Metric, Formerly MIL-G-24508).

(a) Intended use: A lubricant for ball and roller bearings operating continuously at up to 149 ^{o}C (300 ^{o}F) and intermittently up to 177 ^{o}C (350 ^{o}F) for periods up to 4 hours in any 24-hour period.

(b) Limitations: The use of this grease in nonspecified applications should be done only after evaluating its compatibility with all involved materials.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The grease consists essentially of a wide temperature range liquid lubricant and suitable gelling agent. No silicones of any type are permitted.

2.3.13 MIL-G-46003, Grease, Rifle.

(a) Intended use: This material is intended for the lubrication of rifles and other small arms only when used under conditions of sustained rain.

(b) Limitations: For temperatures between 2 to 38 °C (35 to 100 °F). This grease is not to be used except for small arms weapons under sustained rain.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent material: Soap, oil, and additives.

2.3.14 MIL-G-46178, Grease, Helicopter, Drive Shaft Coupling.

(a) Intended use: This grease is intended for preservation and operational use in the flexible drive shaft couplings of H-1 series helicopters at ground ambient temperatures at or above -54 °C (-65 °F). As a preservative material this grease is intended to protect lubricated parts from deterioration during shipment or storage.

(b) Limitations: To be used only in H-1 helicopter's part.

(c) Stock numbers: None given.

(d) Constituent material: Synthetic base oil with or without additives as necessary to meet specification. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.3.15 MIL-G-46886, Grease, Silicone.

(a) Intended use: Two grades, "Light" and "Medium" consistency, are described by the specification document and to be used as lubricants.

(b) Limitations: This grease is limited to uses where a nonhydrocarbon lubricant of either "Light" or "Medium" consistency can be used.

(c) Stock numbers: None given.

(d) Constituent materials: Polymethyl phenyl silicone fluid and a lithium soap.

2.3.16 MIL-G-81322, Grease, Aircraft, General Purpose, Wide Temperature Range.

(a) Intended use: A general purpose grease intended for lubrication of aircraft accessories operating at high speeds over a wide temperature range. It is also used during recoil mechanism assembly and in other artillery items.

(b) Limitations: Caution is advised when using this grease in nonspecified applications.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The grease consists of a wide temperature range liquid and a high melting point gelling agent.

2.3.17 MIL-G-81937, Grease, Instrument, Ultra-Clean.

(a) Intended use: As a lubricant for bearing in instruments and related components such as synchros and gyros which have small tolerances with respect to clearance and require a clean uniform grease.

(b) Limitations: Caution is advised when using this grease in nonspecified applications.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The grease is to consist of a gelling agent and a low temperature liquid lubricant. No silicone oils or extreme pressure additives are permitted. Certain esters of the dibasic organic acids containing 6 to 10 carbon atoms are known to be suitable oils.

TABLE III. Important properties with typical values for greases.

	VV-G-632			VV-G-671			VV-G-679	MIL-G-4343	MIL-G-6032		MIL-G-10924
	Grade 1	Grade 2	Grade 3	Grade 1	Grade 2	Grade 3			Type I	Type II	
Penetration Unworked/worked	NR/310-340	NR/265-295	NR/220-250	NR/310-340	NR/265-295	NR/220-250	20-35/NR	NR/260-300	20 min/ 76 max	23 min/20-42	NR/265-295
After month storage	NR	NR	NR	NR	NR	NR	NR	4	NR	3	6
Unworked/worked points change	NR	NR	NR	NR	NR	NR	NR	±30	NR	23/NR	NR/265-295
Worked stability (100,000 strokes)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-25 + 60
Dropping point °C (°F) min	85(185)	85(185)	85(185)	85(185)	85(185)	85(185)	218(425)	163(325)	127(260)	127(260)	138(280)
Evaporation in hours	NR	NR	NR	NR	NR	NR	NR	22	NR	NR	22
Test temp °C (°F)/wt percent loss, max	NR	NR	NR	NR	NR	NR	NR	99(210)2.5	NR	NR	99(210)6
Oil separation in hours	NR	NR	NR	NR	NR	NR	NR	30	NR	NR	24
Test temp °C (°F)/w percent loss, max	NR	NR	NR	NR	NR	NR	NR	99(210)5	NR	NR	25(77)5
Weld, load, kg min	NR	NR	NR	160	160	160	NR	NR	NR	NR	NR
Load wear index, min	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	28
4 ball wear scar max (mm)	NR	NR	NR	0.600	0.600	0.600		NR	NR	NR	0.60
Low temperature properties Apparent viscosity °C (°F)	NR	NR	NR	NR	NR	NR	NR	-54(-65)	NR	NR	-54-65
Poise/shear rate (sec $^{-1}$)	NR	NR	NR	NR	NR	NR	NR	5000/20	NR	NR	9500-20000/10000 max
Temperature °C (°F)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-54(-65)
Starting/running torque (g-cm)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	Report
Corrosion Copper strip D 4048	1b	1b	1b	1b	1b	1b	1b	NR	NR	NR	1b
Rust prevention D 1743	NR	NR	NR	NR	NR	NR	NR	2	NR	NR	1

NR - Not required

TABLE III. Important properties with typical values for greases. (Cont'd)

	MIL-G-18458	MIL-G-21164	MIL-G-23549	MIL-G-24139	DOD-G-24508	MIL-G-46886		MIL-G-81322	MIL-G-81937
						Type I	Type II		
Penetration Unworked/worked	NR/200-300	NR/260-310	NR/270-315	NR/250-310	NR/265-320	NR/300-400	NR/260-300	NR/265-320	200/265-300
After months storage	NR	6	6	NR	6	NR	NR	6	6
Unworked/worked points change	NR	200/±30	±30	NR	NR/±30	NR	NR	200/±30	NR/±30
Worked stability (100,000 strokes)	NR	375 max	NR	355 max	NR	NR	NR	350 max	375 max
Dropping point °C (°F) min	66(150)	163(325)	232(450)	149(300)	232(450)	190(374)	190(374)	232(450)	177(350)
Evaporation in hours	NR	22	22	NR	22	24	24	22	22
Test temp °C (°F)/wt percent loss, max	NR	99(210)2	177(350)7	NR	177(350)12	150(300)3	150(300)3.0	177(350)12	121(250)2.5
Oil separation in hours	50	30	30	NR	24	24	24	30	30
Test temp °C (°F)/wt percent loss, max	66(150)10	99(210)5	177(350)6	NR	177(350)10	150(300)5	150(300)2.8	177(350)10	99(210)5
Load wear index, min	30	50	50	NR	30	NR	NR	30	NR
4 ball wear scar max (mm)	NR	NR	NR	NR	1.30	NR	NR	1.30	NR
Low temperature properties									
Apparent viscosity °C (°F)	NR	NR	NR	0(32)	NR	NR	NR	NR	NR
Poise/shear rate (sec $^{-1}$)	NR	NR	NR	750/200	NR	NR	NR	NR	NR
Temperature °C (°F)	NR	-73(-100)	NR	-29(-20)	-29(-20)	NR	NR	-54(-65)	-54(-65)
Starting/running torque (g-cm)	NR	10000/1000	NR	4500/1500	4500/1500	NR		10000/1000	3000/500
Corrosion									
Copper strip D 1261	NR	NR	NR	Pass	NR	NR	NR	NR	NR
Copper strip D 4048	NR	1b	1a	NR	1b	NR	NR	1b	1b
Rust prevention D 1743	NR	2	NR	NR	2	NR	NR	2	2

NR - Not required

2.4 CORROSION PREVENTATIVE AND SPECIALTY COMPOUNDS

2.4.1 O-I-490, Inhibitor, Corrosion, Liquid Cooling System.

(a) Intended use: The corrosion inhibitor is intended for use in the cooling system of liquid cooled internal combustion engines; specifically to inhibit water. It is intended for use at the optimum rate of 1 ounce of the inhibitor to 2 quarts of water (30 cc per 1.9 L). This inhibitor may be used with water - ethylene glycol antifreeze mixtures provided the glycol is inhibited with a borax base type inhibitor.

(b) Limitations: This corrosion inhibitor shall not be used in the cooling system of liquid cooled aircraft engines.

(c) Stock Number: Refer to appendix F for stock numbers.

(d) Constituent material: This compound is a dry inhibitor mixture of borax, phosphate and mercaptobenzothiazole.

2.4.2 O-L-160, Leak Preventive Compound, Radiator.

(a) Intended use: The cooling system leak preventive compound is intended as a temporary seal of small pinhole leaks in the radiator and cooling system of internal combustion engines.

(b) Limitations: The compound is not intended to stop seepage of the coolant at the circulation pump shaft seal.

(c) Stock Number: Refer to appendix F for stock numbers.

(d) Constituent material: This compound consist of a water soluble resin plus solid materials that fills small leaks in an automobile cooling system.

2.4.3 P-D-680, Dry Cleaning Solvent.

(a) Intended use: The product is intended for use as a cleaning solvent for automotive parts. Type I has a flash point of 38 ^{o}C (100 ^{o}F) and Type II has a flash point of 59 ^{o}C (138 ^{o}F).

(b) Limitations: Not to be used near open flame.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent material: This product is a petroleum distillate.

2.4.4 VV-L-800, Lubricating Oil, General Purpose, Preservative, Water Displacing, Low Temperature.

(a) Intended use: The lubricating oil, general purpose, preservative, is intended for use in the lubrication and protection against corrosion of certain small arms and automatic weapons and whenever a general purpose, water displacing, low temperature lubricating oil is required. See appendix H for vehicle components application.

(b) Limitations: The oil loses its Newtonian properties at very low temperatures as indicated by the viscosity requirements so that its use at temperatures below -40 °C (-40 °F) is limited by a number of machine design factors and should be proved, for any specific item application, by test before adoption.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: Petroleum oil plus additives. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.4.5 VV-P-216, Penetrating Oil.

(a) Intended use: Penetrating oil covered by this specification is intended for use in the freeing of corrosion-seized parts without damage to such parts.

(b) Limitations: Aerosol cans should not be exposed to direct sunlight, radiators, fires, hot water, or other sources of heat.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent material: Synthetic oil or a light mineral oil, or a mixture of these oils, with or without additives.

2.4.6 MIL-C-372, Cleaning Compound, Solvent (for Bore of Small Arms and Automatic Aircraft Weapons).

(a) Intended use: The bore cleaner covered by this specification is a highly penetrating volatile liquid and is intended for use in cleaning the bores of small arms and automatic aircraft weapons. The material provides a temporary rust resistant coating for the cleaned surfaces.

(b) Limitations: This material is designed to remove primer salts and general soil deposits. It is not effective in removing hard carbon deposits. Also do not use in extended storage applications.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent material: This consists of light petroleum distillates and additives.

2.4.7 MIL-L-3150, Lubricating Oil, Preservative, Medium.

(a) Intended use: This oil is intended for preservation of ferrous and nonferrous surfaces, particularly where lubrication under light loads is required, such as gun mounts. See appendix H for component applications.

(b) Limitations: Not to be used under 0 °C (32 °F), or under medium or heavy loads.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: Petroleum oil plus additives. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.4.8 MIL-C-10597, Compound, Cleaning, Conditioner and Inhibitor for Engine Cooling System.

(a) Intended use: The cleaning compound is intended to clean the interiors of cooling systems, to neutralize residual cleaning acids, and to coat the interiors with a silicate.

(b) Limitations: The cleaning compound should not be used as a routine maintenance procedure each time antifreeze is drained. It should be used only when necessary to clean rusted or clogged cooling systems.

(c) Stock number: Refer to appendix F for stock numbers.

(d) Constituent material: This is a cleaning kit, consisting of an acid cleaner, a neutralizer, a conditioner and an inhibitor. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.4.9 MIL-C-11090, Cleaning Compound, Degreasing and Depreserving Solvent, Self-Emulsifying.

(a) Intended use: This compound is intended for use in removing oils, greases, asphalt,tars,and preservative type materials from metallic and painted surfaces.

(b) Limitations: Not to be used for removal of wax type materials.

(c) Stock Number: Refer to appendix F for stock numbers.

(d) Constituent material: This compound consists of a solvent, containing naphtha and kerosene, a detergent mixture and diacetone-diethylene triamine condensate.

2.4.10 MIL-L-11734, Lubricating Oil, Synthetic (For Mechanical Time Fuzes).

(a) Intended use: This lubricating oil is intended for use in mechanical time fuzes at ambient temperatures from -54 to +52 ^{o}C (-65 to 125 ^{o}F).

(b) Limitations: This material should be used for low pressure applications only.

(c) Stock number: Refer to appendix F for stock numbers.

(d) Constituent materials: Synthetic base plus additives.

2.4.11 MIL-A-11755, Antifreeze, Arctic Type.

(a) Intended use: Arctic type antifreeze is intended for use in the cooling system of liquid cooled internal combustion engines for protection against freezing in regions where the ambient temperature remains, for extended periods

of time, close to -40 °C (-40 °F), but may drop as low as -68 °C (-90 °F). This material may also be used as a heat transfer liquid for military application where low temperatures are encountered.

(b) Limitations: This material is designed to be used as packaged and should never be diluted with water.

(c) Stock Number: Refer to appendix F for stock numbers.

(d) Constituent material: This compound is a pre-mixed arctic grade anti-freeze, consisting of ethylene glycol, water, various glycol ethers and inhibitors.

2.4.12 MIL-L-14107, Lubricating Oil, Low Temperature, Weapons.

(a) Intended use: The lubricating oil covered by this specifications is intended primarily for aircraft and ground weapons to insure efficient firing at low temperatures.

(b) Limitations: Not to be used at ambient temperatures above 0 °F (-18 °C).

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: A suitable base stock containing additive materials necessary to meet the requirements of this specification.

2.4.13 MIL-C-16173, Corrosion Preventive Compound, Solvent Cutback, Cold Application.

(a) Intended use: This compound is intended for the protection of interior or exterior metal surfaces exposed to outdoor weather conditions where a "dry-to-touch" film is required.

(b) Limitations: Conditions dictate which of the four grades are to be used.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent material: This compound is a preservative compound formulated with a volatile solvent which forms a dry protective film for metal surfaces.

2.4.14 MIL-L-46000, Lubricant, Semi-Fluid, Automatic Weapons.

(a) Intended use: The synthetic lubricant covered by this specification is intended for use in the operation of the M16, M61, M39, and related types of automatic weapons under conditions of extreme pressure in the temperature range of -54 to 127 °C (-65 to 260 °F).

(b) Limitations: The low temperature limitation is set by equipment design. This is an item with limited shelf life (1 year max).

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: Bis 2-ethyl hexyl sebacate and lithium stearate as a gelling agent and additives.

2.4.15 MIL-L-46150, Lubricant, Weapons, Semifluid (High-load Carrying Capacity).

(a) Intended use: This lubricant is intended for use in the 7.62 mm GAU-2^{B}/A machine gun in the temperature range of -34 to 121 ^{o}C (-29 to 250 ^{o}F).

(b) Limitations: It may be used for actions requiring an extreme pressure lubricant with low kinetic coefficient of frictions. Do not use it in food processing or food handling equipment.

(c) Stock number: Refer to appendix F for stock numbers.

(d) Constituent material: This material contains 75% lubricating oil, semi-fluid conforming to MIL-L-46000 specification, and 25% polytetra-fluoroethylene conforming to L-P-403 specification.

2.4.16 MIL-L-63460, Lubricant, Cleaner and Preservative for Weapons and Weapon Systems.

(a) Intended use: This material is approved for the cleaning, lubrication and short term preservation (less than thirty days) of both large and small caliber weapons where MIL-C-372 (RBC), VV-L-800 (PL-S), MIL-L-3150 (PL-M), MIL-L-14107 (LAW), and MIL-L-46000 were used. The ambient temperature use range is -54 to 65 ^{o}C (-65 to 149 ^{o}F).

(b) Limitations: Non-weapon uses of this material must be verified by experimentation. Do not use in weapon systems for preservation over 30 days.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent material: Description of the product is made based on intended use and performance, since different constituent materials may be used.

2.4.17 MIL-P-46002, Preservative Oil, Contact and Volatile Corrosion Inhibited.

(a) Intended use: The volatile corrosion inhibited lubricating oil covered by this specification is intended for use in preservation of enclosed systems where the volatile components will provide protection above the oil level. It can also be used as a contact preservative.

(b) Limitations: It is not intended for use as an operational preservative oil and should not be used in applications where rubber components are present. It is not effective unless an adequate reservoir of oil can be maintained. It is not to be introduced into storage or engine fuel tanks.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent material: This compound consists of a petroleum oil base stock plus various types of rust inhibitors and other additives to meet the requirements of the specifications. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communication Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.4.18 MIL-A-46153, Antifreeze, Ethylene Glycol, Inhibited, Heavy Duty, Single Package.

(a) Intended use: Inhibited ethylene glycol antifreeze is intended for use in the cooling system of liquid-cooled internal combustion engines, other than aircraft, for protection against freezing in ambient temperatures as low as -48 °C (-55 °F), when diluted to 60 percent by volume with water. It may also be used as a coolant in some types of automatic guns as water-cooled machine guns.

(b) Limitations: This material should not be used under arctic conditions and should not be packaged in metal containers.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent material: This is a conventional antifreeze concentrate containing ethylene glycol, water and inhibitors.

2.4.19 MIL-C-51047, Compound, Antiseepage, for Cooling System, Internal Combustion Engine.

(a) Intended use: The antiseepage compound is intended for sealing cracks and crevices in the cooling system of internal combustion engines, especially wet sleeve engines, and for stopping seepage of coolant into the cylinder combustion chamber and into the crankcase of the engine. The compound is also intended for sealing small pinhole leaks in the radiator and cooling system of internal combustion engines.

(b) Limitations: The compound is not intended to stop seepage of the coolant at the circulating pump's shaft seal. The compound is not intended to replace, but must be used in conjunction with, a corrosion inhibitor meeting the requirements of O-I-490.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent material: This compound consists of ground nuts shells plus resinous and antidust materials.

2.4.20 VV-L-751, Lubricating Oil, Chain, Wire-Rope, and Exposed Gear.

(a) Intended use: These oils are intended for use as lubricants and corrosion preventatives for chains, cables, wire, ropes and exposed gears. The intended temperature range for each grade is as follows:

Grade 1:	-29 to -1 °C (-20 to 30 °F)
Grade 2:	-1 to 27 °C (30 to 80 °F)
Grade 3:	27 to 54 °C (80 to 130 °F)

See appendix H for vehicle components application.

(b) Limitations: To be used in lubrication of chain, wire, ropes and exposed gears. Do not use it in food processing or handling equipment.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent material: Consists of petroleum base material with or without additives as necessary to meet specifications. No constituent base stock materials considered to be carcinogenic as defined under Hazard Communications Standard (HCS) 29 CFR 1910.1200 shall be used. See FED-STD-313 for additional information.

2.4.21 MIL-A-53009, Additive, Antifreeze Extender, Liquid Cooling System.

(a) Intended use: The additive is intended for use in used MIL-A-46153 antifreeze and in water at a concentration of three percent (one-half quart additive per seventeen quart antifreeze or water). Used antifreeze is defined as antifreeze that tests green to yellow when tested as specified in TB 750-651 using MIL-T-36812, Test Kit, Reserve Alkalinity, Antifreeze. Additive is to be used in lieu of O-I-490 in all military vehicles or equipment using MIL-A-46153 antifreeze or water.

(b) Limitations: The additive is not intended for use in commercial antifreeze.

(c) Stock numbers: Refer to appendix F for stock numbers.

(d) Constituent materials: The additive is an aqueous solution of sodium metaborate, potassium silicate and sodium mercaptobenzothiazole.

2.5 SOLID FILM LUBRICANTS

2.5.1 MIL-L-8937, Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting.

(a) Intended use: This solid film lubricant is intended for sliding motion types of application, such as plain spherical bearings, hinges, cam surfaces, gears, gun elevating mechanisms, and gunsights.

(b) Limitations: This material should not be used with oils or greases unless field use indicates otherwise. Since this lubricant requires curing at 149 ^{o}C (300 ^{o}F) for 1 hour, it should not be applied to alloys whose properties are adversely affected by exposure to these conditions. These materials should only be applied outdoors or under a hood having a face velocity of 200 ft^3/min.

(c) Curing conditions: Room temperature 30 minutes, bake at 149 ^{o}C (300 ^{o}F) for 1 hour.

(d) Stock numbers: Refer to appendix F for stock numbers.

(e) Constituent materials: Consists of lubricating pigments and a vehicle (see definition) which contains heat curing resins and solvents.

2.5.2 MIL-L-23398, Lubricant, Solid Film, Air Drying, Corrosion Inhibiting, NATO Code Number S-749.

(a) Intended use: This dry solid film lubricant is intended for bonding on steel, titanium, aluminum, and aluminum alloys where conventional lubricants are difficult to apply. This is an air dried material which can be applied to parts of complete assemblies where curing by heating is not possible, such as plain spherical bearings, recoil mechanisms, and gunsights. This material will provide a low friction surface to reduce wear and prevent galling and seizing of rubbing parts.

(b) Limitations: This material should not be used with oils or greases unless field use indicates otherwise. Caution must be exercised to prevent overheating of spray cans, or use in areas where potential ignition sources exist. These materials should only be applied outdoors or under a hood having a face velocity at 200 cu. ft/min.

(c) Curing conditions: Room temperature for 6 hours.

(d) Stock numbers: Refer to appendix F for stock numbers.

(e) Constituent material: Consists of lubricating pigments with a vehicle which contains an air curing resin and solvents; however, it shall contain no graphite, powdered metal or fluorocarbon solvents.

2.5.3 MIL-L-46010, Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting.

(a) Intended use: This solid film lubricant is intended for use on aluminum, aluminum alloys, copper and copper alloys, steel, stainless steel, titanium, and chromium and nickel plated surfaces. This material is useful where temperatures may range from -68 to 204 ^{o}C (-90 to 400 ^{o}F). It is useful, in mechanisms that are lubricated for life, and also in mechanisms operated at infrequent intervals. It is useful in operations consisting of reciprocating motion, loaded to 15 psi or less, where contamination with conventional fluid lubricants is probable. It is generally suitable for sliding motion applications such as plain and spherical bearings, hinges, threads, cam surfaces, gun elevating mechanisms, and gunsights.

(b) Limitations: This lubricant should not be used on materials which would be adversely affected by the 204 ^{o}C (400 ^{o}F) curing temperature. It should not be used in operations consisting of rotary motion above 100 rpm under heavy loads where the possibility of conventional fluid lubricant contamination exists. The cured lubricant film is resistant to conventional fluid lubricants, but the high fluid pressures developed in heavily loaded sleeve type bearings drastically reduces the wear life provided by the solid film lubricant. It should not be used on bearings containing rolling elements. These materials should only be applied outdoors or under a hood having a face velocity of 200 ft^3/min.

(c) Curing conditions: Room temperature, 30 minutes, bake at 204 ^{o}C (400 ^{o}F) for 1 hour.

(d) Stock numbers: Refer to appendix F for stock numbers.

(e) Constituent material: Consists of lubricating pigments other than graphite or powdered metals, and a vehicle containing heat curing resins and solvents.

2.5.4 MIL-L-46147, Lubricant, Solid Film, Air-Cured, Corrosion Inhibiting.

MIL-L-46147 was cancelled 4 March 1986 and replaced by MIL-L-23398 (see 2.5.2).

PRODUCTS AND CUSTODIAN ACTIVITY

Paragraph Reference	Product Specification	Custodian Activity
2.1	LUBRICATING ENGINE AND GEAR OILS	---
2.1.1	MIL-L-2104, Lubricating Oil, Internal Combustion Engine, Tactical Service	ME
2.1.2	MIL-L-2105, Lubricating Oil, Gear, Multipurpose	ME
2.1.3	MIL-L-6082, Lubricating Oil, Aircraft Reciprocating Engine	AS
2.1.4	MIL-L-7808, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	11
2.1.5	MIL-L-7808, Lubricating Oil, General Purpose, Temperature ..	20
2.1.6	MIL-L-9000, Lubricating Oil, Shipboard Internal Combustion Engine, High Output Diesel	SH
2.1.7	MIL-L-21260, Lubricating Oil, Internal Combustion Engine, Preservative and Break-In	ME
2.1.8	MIL-L-23699, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	AS
2.1.9	MIL-L-46152, Lubricating Oil, Internal Combustion Engine, Administrative Service	ME
2.1.10	MIL-L-46167, Lubricating Oil, Internal Combustion Engine, Arctic	ME
2.2	POWER TRANSMISSION/HYDRAULIC FLUIDS	---
2.2.1	MIL-H-5606, Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance	11
2.2.2	MIL-H-6083, Hydraulic Fluid, Petroleum Base for Preservation and Operation	ME
2.2.3	MIL-H-46001, Hydraulic Fluid, Petroleum Base, for Machine Tools	ME
2.2.4	MIL-H-46170, Hydraulic Fluid, Rust Inhibited, Resistant, Synthetic Hydrocarbon Base	ME
2.2.5	MIL-B-46176, Brake Fluid, Silicone, Automotive, All Weather, Operational and Preservative	ME
2.2.6	MIL-H-83282, Hydraulic Fluid, Fire Resistant Synthetic Hydrocarbon Base, Aircraft	AS
2.2.7	DOD-L-85734, Lubricating Oil, Helicopter Transmission Systems, Synthetic Base	AS
2.2.8	VV-B-680, Brake Fluid, Automotive	ME
2.2.9	Commercial Automotive Transmission Fluids (ATF)	
2.3	LUBRICATING GREASES	---
2.3.1	VV-G-632, Grease, Industrial, General Purpose	ME
2.3.2	VV-G-671, Grease, Graphite	ME
2.3.3	VV-G-679, Grease, Railway	---
2.3.4	MIL-G-4343, Grease, Pneumatic System	AS
2.3.5	MIL-G-6032, Grease, Plug Valve, Gasoline and Oil Resistant .	AS
2.3.6	MIL-G-10924, Grease, Automotive and Artillery	ME
2.3.7	MIL-G-18458, Grease, Wire Rope-Exposed Gear	SH
2.3.8	MIL-G-21164, Grease, Molybdenum Disulfide, for Low and High Temperatures	AS
2.3.9	MIL-G-23549, Grease, General Purpose	AS

PRODUCTS AND CUSTODIAN ACTIVITY

Paragraph Reference	Product Specification	Custodian Activity
2.3.10	MIL-G-23827, Grease, Aircraft and Instrument, Gear and Actuator Screw, as NATO Code Number G-354, Metric	AS
2.3.11	MIL-G-24139, Grease, Multipurpose, Quiet Service	SH
2.3.12	DOD-G-24508, Grease, High Performance, Multipurpose, (Metric, Formerly MIL-G-24508)	SH
2.3.13	MIL-G-46003, Grease, Rifle	AR
2.3.14	MIL-G-46178, Grease, Helicopter, Drive Shaft Coupling	ME
2.3.15	MIL-G-46886, Grease, Silicone	MI
2.3.16	MIL-G-47219, Grease, Lubricating, Halofluorocarbon	MI
2.3.17	MIL-G-81322, Grease, Aircraft, General Purpose, Wide Temperature Range	AS
2.3.18	MIL-G-81937, Grease, Instrument, Ultra-Clean	AS
2.4	CORROSION PREVENTATIVES AND SPECIALITY COMPOUNDS	--
2.4.1	O-I-490, Inhibitor, Corrosion, Liquid Cooling System	ME
2.4.2	O-L-160, Leak Preventative Compound, Radiator	GSA
2.4.3	P-D-680, Dry CLeaning Solvent	ME
2.4.4	VV-L-800, Lubricating Oil, General Purpose, Preservative, Water Displacing, Low Temperature	ME
2.4.5	VV-P-216, Penetrating Oil	YD
2.4.6	MIL-C-372, Cleaning Compound, Solvent (for Bore of Small Arms and Automatic Aircraft Weapons)	MR
2.4.7	MIL-L-3150, Lubricating Oil, Preservative, Medium	ME
2.4.8	MIL-C-10597, Compound, Cleaning, Conditioner and Inhibitor, for Engine Cooling System	ME
2.4.9	MIL-C-11090, Cleaning Compound, Degreasing and Depreserving Solvent, Self-Emulsifying	MR
2.4.10	MIL-L-11734, Lubricating Oil, Synthetic (For Mechanical Time Fuzes)	AR
2.4.11	MIL-A-11755, Antifreeze, Arctic Type	ME
2.4.12	MIL-L-14107, Lubricating Oil, Low Temperature, Weapons	AR
2.4.13	MIL-C-16173, Corrosion Preventive Compound, Solvent Cutback, Cold-Application	SH
2.4.14	MIL-L-46000, Lubricant, Semi-fluid, Automatic Weapons	AR
2.4.15	MIL-L-46150, Lubricant, Weapons, Semi-Fluid (High Load Carrying Capacity)	AR
2.4.16	MIL-L-63460, Lubricant, Cleaner and Preservative For Weapons and Weapon Systems	AR
2.4.17	MIL-P-46002, Preservative Oil, Contact and Volatile Corrosion Inhibited	ME
2.4.18	MIL-A-46153, Antifreeze, Ethylene Glycol, Inhibited, Heavy Duty, Single Package	ME
2.4.19	MIL-C-51047, Compound, Antiseepage, for Cooling System, Internal Combustion Engine	ME
2.4.20	VV-L-751, Lubricating Oil, Chain Wire Rope Exposed Gear ...	ME
2.4.21	MIL-A-53009, Additive, Antifreeze Extender, Liquid Cooling System	ME

PRODUCTS AND CUSTODIAN ACTIVITY

Paragraph Reference	Product Specification	Custodian Activity
2.5	SOLID FILM LUBRICANTS	—
2.5.1	MIL-L-8937, Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting	AS
2.5.2	MIL-L-23398, Lubricant, Solid Film, Air Drying	AS
2.5.3	MIL-L-46010, Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting	ME

CUSTODIAN ACTIVITY SYMBOLS

AS	Commander Naval Air Systems Command ATIN: AIR 51122 Washington, DC 20361
AR	Commander U.S. Army Armament Research and Development Center ATIN: SMCAR-ESC-AS Dover, NJ 07801-5001
ME	Commander U.S. Army Belvoir Research, Development, and Engineering Center ATIN: STRBE-TSE Fort Belvoir, VA 22060-5606
MI	Commander U.S. Army Missile ATIN: AMSMI-EDS Redstone Arsenal, AL 35898-5270
MR	Director U.S. Army Laboratory Command Army Materials Technology Laboratory ATIN: SLCMT-MST-ES Watertown, MA 02172-0001
Sh	Commander Naval Sea Systems Command (SEA 55Z3) DOD Standardization Program and Documents Division Department of the Navy Washington, DC 20362
YD	Commanding Officer Naval Construction Battalion Center Code 156 Prot Hueneme, CA 93043-5000
11	Air Force ASD/ENES Wright-Patterson AFB, OH 45433-6503
20	AFWAL/MLSE Standardization Manager Wright Patterson AFB OH 45433-6523

CHAPTER III

PRODUCT LISTING OF MILITARY AND NATO SYMBOLS

3.1 Lubricants, power transmission and hydraulic fluids, greases, and corrosion preventatives are generally identified by military symbols and in some instances, NATO Code Number designations. To provide a ready reference for all specification products, table IV lists all military specifications included in chapter II with their respective grade, military and NATO designations. The products are grouped into the following classes: (1) Lubricating engine and gear oils, (2) Power transmission/hydraulic fluids, (3) Lubricating greases, (4) Corrosion preventatives, (5) Specialty compounds, and (6) Solid film lubricants.

3.2 International standardization agreements. Certain provisions of this document are the subject of international standardization agreements (NATO STANAG 1135 Annex "C" "Interchangeability Chart of NATO Standardization Fuels, Lubricants, and Associated Products"; NATO STANAG 2845 "Guide Specifications for NATO Army Fuels, Lubricants, and Associated Products", STANAG 3149 "Minimum Quality Surveillance for Petroleum Products"). When change notice, revision, or cancelation of this document is proposed which will affect or violate the international agreement concerned, the preparing activity shall take appropriate reconciliation action through international standardization channels, including departmental standardization offices, if required.

TABLE IV. List of Military Symbols and NATO Code Numbers.

Product	Specification	Grade	Symbols	
			MILITARY	NATO
Lubricating engine & gear oils				
Lubricating oil, internal combustion engine, tactical service	MIL-L-2104	10 30 40 15W/40	OE/HDO-10 OE/HDO-30 OE/HDO-40 OE/HDO-15/40	O-237 O-238 NR O-1236
Lubricating oil, gear, multipurpose	MIL-L-2105	75W 80W/90 85W/140	GO-75 GO-80/90 GO-85/140	O-186 O-226 O-228
Lubricating oil, aircraft turbine engine, synthetic base	MIL-L-7808	NR	NR	O-148
Lubricating oil, shipboard internal combustion engine, high output diesel	MIL-L-9000	NR	9250	O-278
Lubricating oil, internal combustion engine preservative and break-in	MIL-L-21260	10 30 40 15W/40	PE-10-1 PE-30-1 PE-40-1 PE-15/40-1	C-640 C-642 NR NR
Lubricating oil, aircraft turbine engine, synthetic base	MIL-L-23699	NR	NR	O-156
Lubricating oil, internal combustion engine, administrative service	MIL-L-46152	10W 30 5W/30 10W/30 15W/40	NR NR NR NR NR	NR NR NR NR NR
Lubricating oil, internal combustion engine, arctic	MIL-L-46167	0W/20	OEA	O-183
Lubricating greases				
Grease, industrial, general purpose	VV-G-632	NR	NR	NR
Grease, graphite	VV-G-671	NR	GG1, 2, 3	G-408
Grease, railway	VV-G-679	NR	NR	NR

TABLE IV. List of Military Symbols and NATO Code Numbers. (Cont'd)

Product	Specification	Grade	Symbols	
			MILITARY	NATO
Grease, pneumatic system	MIL-G-4343	NR	GPS	G-392
Grease, plug valve, gasoline and oil resistant	MIL-G-6032	NR	GRC	G-363
Grease, automotive and artillery	MIL-G-10924	NR	GAA	G-403
Grease, wire rope-exposed gear	MIL-G-18458	NR	NR	NR
Grease, molybdenum disulfide	MIL-G-21164	NR	GMD	G-353
Grease, general purpose	MIL-G-23549	NR	GGP	NR
Grease, aircraft, and instrument, gear and actuator screw, NATO Code, metric	MIL-G-23827	NR	NR	G-354
Grease, multipurpose	MIL-G-24139	NR	NR	G-450
Grease, High performance ball and roller bearing	DOD-G-24508	NR	NR	NR
Grease, Rifle	MIL-G-46003	NR	NR	NR
Grease, helicopter, drive shaft coupling	MIL-G-46178	NR	NR	NR
Grease, silicone	MIL-G-46886	NR	NR	NR
Grease, aircraft, general purpose, wide temperature range	MIL-G-81322	NR	WTR	G-395
Grease, instrument, ultra-clean	MIL-G-81937	NR	NR	NR
Corrosion preventatives				
Leak preventive, compound, radiator	O-L-160	NR	NR	NR
Cleaning compound with conditioner and inhibitor for engine cooling system	MIL-C-10597	NR	NR	NR

TABLE IV. List of Military Symbols and NATO Code Numbers. (Cont'd)

Product	Specification	Grade	Symbols	
			MILITARY	NATO
Corrosion preventatives (cont'd)				
Antifreeze, arctic type	MIL-A-11755	NR	NR	NR
Antifreeze, ethylene glycol inhibited, heavy duty, single package	MIL-A-46153	NR	NR	S-750
Additive, Antifreeze, Entender,Liquid & Cooling System	MIL-A-53009	NR	NR	NR
Compound, antiseepage, for cooling system, internal combustion engine	MIL-C-51047	NR	NR	NR
Power Transmission/hydraulic oils				
Hydraulic fluid, petroleum base; aircraft, missile, and ordnance	MIL-H-5606	NR	OHA	H-515
Hydraulic fluid, petroleum for base; preservation and operation	MIL-H-6083	NR	OHT	C-635
Hydraulic fluid, petroleum base; machine tools	MIL-H-46001	NR	NR	NR
Hydraulic fluid, rust inhibited, fire resistant, synthetic base	MIL-H-46170	NR	FRH	H-544
Brake fluid, silicone automotive all weather, operational and preservative	MIL-B-46176	NR	BFS	H-547
Brake fluid automotive	VV-B-680	NR	HB	H-542
Hydraulic fluid, fire resistant synthetic hydrocarbon base, aircraft	MIL-H-83282	NR	NR	H-537

TABLE IV. List of Military Symbols and NATO Code Numbers. (Cont'd)

Product	Specification	Grade	Symbols	
			MILITARY	NATO
Specialty compounds				
Dry cleaning solvent	P-D-680 - 38 °C flash	NR	SD-1	S-752
	P-D-680 - 59 °C flash	NR	SD-2	S-753
Lubricating oil, general purpose, preservative, water displacing, lo temperature	VV-L-800	NR	PL-S	O-190
Penetrating oil	VV-P-216	NR	NR	NR
Cleaning compound, solvent	MIL-C-372	NR	RBC	NR
Lubricating oil preservative,	MIL-L-3150	NR	PL-M	O-198
Cleaning compound, degreasing and depreserving, solvent, self-emulsifying	MIL-C-11090	NR	NR	NR
Lubricating oil, low temperature, weapon	MIL-L-14107	NR	LAW	O-157
Corrosion preventive compound solvent, cutback, cold-application	MIL-C-16173	NR	CT	C-620
Lubricant, semi-fluid, automatic weapon	MIL-L-46000	NR	LSA	O-158
Lubricant, Weapons, Semi-Fluid	MIL-L-46150	NR	LSA-T	NR
Preservative oil, contact and volatile corrosion inhibited	MIL-P-46002	NR	NR	NR
Lubricating oil, chain wire rope, exposed gear	VV-L-751	light medium	CWIIA CWIIC	O-199 O-203

TABLE IV. List of Military Symbols and NATO Code Numbers. (Cont'd)

Product	Specification	Grade	Symbols	
			MILITARY	NATO
Specialty compounds - Cont'd				
Lubricant, Cleaner and Preservative for Weapons and Weapons Systems	MIL-L-63460	NR	CLP	S-758
Solid film lubricants				
Lubricant, solid film, heat cured, corrosion inhibited	MIL-L-8937	NR	NR	S-1738
Lubricant, solid film, air drying	MIL-L-23398	NR	NR	S-749
Lubricant, solid film, heat cured, corrosion inhibiting	MIL-L-46010	NR	NR	NR

NR - None recorded

CHAPTER IV

PRODUCT SHELF LIFE AND RE-TEST FREQUENCIES.

4.1 GENERAL. The loss of essential characteristics in a product, unavoidably or otherwise, is a serious matter. Even if it is known to have occurred, the appropriate disposition of the product can be determined only by a technically qualified person and offers only undesirable alternatives which normally involve loss of time, money, material, and the overall efficiency of supply operations. Changes occurring while a product lies in storage become more marked as the product ages. The changes may be initiated or hastened by the conditions of storage, and are not normally observable by personnel handling the product. Therefore, their discovery, before issue, is dependent upon adequate laboratory control programs. Table V is a series of charts providing a detailed breakdown of the type of tests required for each class of product. These tests are those most likely to reveal contamination which may have occurred during product handling or storage. Table V-A through V-E, designate SERVICE, NATO and ASCC prescribed B-2 tests for specific products. When a product being tested exceeds the specification limits due to contamination, the procedures outlined in Chapter 3 and Chapter 10 of MIL-HDBK-200 should be followed. The information on the tables in this chapter have been extracted from MIL-HDBK-200, however, MIL-HDBK-200 and the respective specifications take precedence over these tables. Use MIL-HDBK-200 and the specifications when conducting quality surveillance testing.

TABLE V - A Type B-2 tests for lubricating oils.

TEST REQUIREMENTS	SPECIFICATION						
	MIL-L-2104	MIL-L-2105	MIL-L-3150	MIL-L-6082	MIL-L-7808	MIL-L-7870	MIL-L-9000
APPEARANCE (WORKMANSHIP)	X		X		X	X	X
COLOR						X	
VISC. @ 210 °F (100 °C)	X	X		X	X		
@ 100 °F (40 °C)			X		X	X	
@ -40 °F (-40 °C)					X		
@ -65 °F (-54 °C)					X		
SPECIFIC GRAVITY				X			
FLASH POINT	X	X		X	X	X	X
POUR POINT	X		X	X		X	X
NEUT. OR ACID NUMBER					X		
COPPER CORROSION		X	X	X		X	
CORROSION & OXID. STABILITY					X		
EVAPORATION LOSS			X			X	
PRECIPITATION NUMBER						X	
PERCENT OR SULFATED ASH				X			X
FOAM TEST	X	X			X		X
PARTICULATE CONT. OR TRACE SEDIMENT				X	X		X
TRACE METALS					X		
CARBON RESIDUE				X			
SULFUR				X			
SAPONIFICATION NUMBER				X			
LOAD CARRYING CAPACITY					X		
MIN. RETEST FREQUENCY (MONTHS)	24	24	24	36	36	36	36
VISUAL CHECK FREQUENCY (MONTHS)	12	12	12	12	12	12	--

TABLE V - A Type B-2 tests for lubricating oils. (cont'd)

TEST REQUIREMENTS	SPECIFICATION						
	MIL-L-11734	MIL-L-14107	MIL-L-21260	MIL-L-23699	MIL-L-46152	MIL-L-46167	MIL-L-9000
APPEARANCE (WORKMANSHIP)	X	X					X
COLOR							
VISC. @ 210 °F (100 °C)		X	X	X	X		
@ 100 °F (40 °C)	X	X		X		X	
@ -40 °F (-40 °C)			X		X		
@ -65 °F (-54 °C)	X 1/	X					
SPECIFIC GRAVITY							
FLASH POINT		X	X	X	X	X	X
POUR POINT	X	X	X	X	X	X	X
NEUT. OR ACID NUMBER				X			
COPPER CORROSION							
CORROSION & OXID. STABILITY	X 2/	X 2/		X			
EVAPORATION LOSS		X		X			
PRECIPITATION NUMBER		X					
PERCENT OR SULFATED ASH							X
FOAM TEST		X	X	X	X	X	X
HYDROLYTIC STABILITY		X					
PARTICULATE CONT. OR TRACE SEDIMENT				X			X
TRACE METALS				X			
CARBON RESIDUE							
SULFUR							
SAPONIFICATION NUMBER							
LOAD CARRYING CAPACITY				X			
MIN. RETEST FREQUENCY (MONTHS)	36	24	24	36	24	24	36
VISUAL CHECK FREQUENCY (MONTHS)	—	12	12	12	—	—	—

TABLE V - A Type B-2 tests for lubricating oils. (CONT'D)

TEST REQUIREMENTS	SPECIFICATION		
	DOD-L-85734	VV-L-751	VV-L-800
APPEARANCE (WORKMANSHIP)		X	X
COLOR			X
VISC. @ 210 °F (100 °C)	X	X	
@ 100 °F (40 °C)	X		X
@ -40 °F (-40 °C)	X		X
@ -65 °F (-54 °C)			X
SPECIFIC GRAVITY			
FLASH POINT	X	X	X
POUR POINT	X	X	X
NEUT. OR ACID NUMBER	X		
COPPER CORROSION			X
CORROSION & OXID. STABILITY	X		
EVAPORATION LOSS	X 2/		X
PRECIPITATION NUMBER			X
PERCENT OR SULFATED ASH			
FOAM TEST	X		
WATER CONTENT		X	
PARTICULATE CONT. OR TRACE SEDIMENT	X		
TRACE METALS	X		
CARBON RESIDUE			
SULFUR			
SAPONIFICATION NUMBER			
LOAD CARRYING CAPACITY	X		
MIN. RETEST FREQUENCY (MONTHS)	24	36	24
VISUAL CHECK FREQUENCY(MONTHS)	12	12	12

1/ Per temp in spec
2/ If capabilities exists.

TABLE V - B Type B-2 tests for greases and semi-fluid lubricants.

TEST REQUIREMENTS	SPECIFICATION											
	MIL-G-4343	MIL-G-6032	MIL-G-10924	MIL-G-18458 4/	MIL-G-21164	MIL-G-23549	MIL-G-23827	MIL-G-24139	DOD-G-24508	MIL-L-46000	MIL-G-46003	MIL-L-46150
APPEARANCE (WORKMANSHIP)	X	X	X	X		X	X	X	X		X	X
ODOR	X		X		X		X	X	X		X	
PENETRATION (UNWORKED)		X			X		X					
PENETRATION (WORKED)	X	X	X	X	X	X	X	X	X	X	X	
WORKED STABILITY			X				X	X	X			
DROPPING OR MELTING POINT	X	X	X		X	X	X	X	X		X	
OIL SEPARATION	X		X	X	X	X	X		X			
EVAPORATION LOSS (OR BLEED)	X		X		X	X	X		X	X		X
COPPER CORROSION	X	X	X		X	X	X	X	X	X	X	X
OXID. STABILITY (100 HR)								X		X 5/		
RUST PREVENTATIVE PROPERTIES	X		X		X		X		X	X	X	X
WATER RESISTANCE					X		X	X	X		X	
FREE-ACIDITY (FREE ALKALI)												
MOLYBDENUM DISULFIDE CONTENT					X	X						
BOILING WATER INMERSION						X						
WATER CONTENT												
DIRT (PARTICULATE)							X	X	X			
LOAD CARRYING CAPACITY 1/			X	X	X	X	X		X	X		X
MIN. RETEST FREQUENCY (MONTHS)	24	24	24	24	24	24	24	24	24	24	24	24
VISUAL CHECK FREQUENCY(MONTHS)	--	6 3/	12	--	--	--	--	--	--	--	--	--

TABLE V - B Type B-2 tests for greases and semi-fluid lubricants. (cont'd)

TEST REQUIREMENTS	SPECIFICATION						
	MIL-G-46178	MIL-G-46886	MIL-G-81322	MIL-G-81937	VV-G-632	VV-G-671 2/	VV-G-679
APPEARANCE (WORKMANSHIP)	X	X	X	X		X	X
ODOR	X		X	X			X
PENETRATION (UNWORKED)				X			X
PENETRATION (WORKED)	X	X	X	X	X	X	
WORKED STABILITY	X		X	X			
DROPPING OR MELTING POINT	X	X	X	X	X	X	X
OIL SEPARATION	X		X	X			
EVAPORATION LOSS (OR BLEED)	X	X	X	X	X		
COPPER CORROSION	X		X	X	X	X	X
OXID. STABILITY (100 HR)		X 5/		X			
RUST PREVENTATIVE PROPERTIES	X		X	X			
WATER RESISTANCE	X		X	X			
FREE-ACIDITY (FREE ALKALI)					X	X	X
MOLYBDENUM DISULFIDE CONTENT							
BOILING WATER INMERSION							
WATER CONTENT						X	
DIRT (PARTICULATE)	X	X	X	X			
LOAD CARRYING CAPACITY 1/	X		X			X	
MIN. RETEST FREQUENCY (MONTHS)	24	24	24	24	24	24	24
VISUAL CHECK FREQUENCY(MONTHS)	--	--	--	--	--	12	--

1/ WHEN CAPABILITY EXISTS
2/ ALSO ASH CONTENT
3/ EXAMINE EVERY 6 MONTHS FOR HARDENING
4/ ALSO VOLATILE MATTER
5/ PER TIME CITED IN SPEC

TABLE V - C. Type B-2 tests for hydraulic and brake fluid.

SPECIFICATION TEST REQUIREMENT	MIL-H-5606	MIL-H-6083	MIL-H-46001	MIL-H-46170	MIL-B-46176	MIL-H-83282	VV-B-680 3/
APPEARANCE (WORKMANSHIP)	X	X	X	X			X
COLOR	X	X	X	X		X	
VISC AT 210 DEG F (OR 100 DEG C)	X			X	X	X	X
VISC AT 130 DEG F							X 1/
VISC AT 100 DEG F (OR 40 DEG C)	X	X	X	X		X	
VISC AT - 40 DEG F (-45 DEG C)	X	X		X		X	
VISC AT -65 DEG F (OR -54 DEG C)	X	X		X	X 1/		
SPECIFIC GRAVITY			X				
FLASH POINT	X	X	X	X	X	X	X
POUR POINT	X	X	X	X		X	
NEUT NUMBER (ACID/BASE NUMBER)	X	X	X	X		X	
COPPER CORROSION	X	X					
PH							X
EVAPORATION LOSS	X	X				X	X
WATER CONTENT	X	X		X		X	
FOAMING TENDENCY	X	X	X	X		X	
PART. CONT. AND/OR TRACE SEDIMENT	X	X		X		X	
RUST PREVENTION			X	X			
LUBRICITY (STEEL-ON-STEEL WEAR) 2/	X	X		X		X	
MINIMUM RETEST FREQUENCY (MONTHS)	24	24	24	24	24	24	24
VISUAL CHECK FREQUENCY (MONTHS)	12	--	--	--	--	12	12

1/ PER TEMP IN SPEC.
2/ IF CAPABILITY EXISTS.
3/ ALSO BOILING POINT.

TABLE V - D Type B-2 tests for lubricants (including solid film lubricants).

SPECIFICATION TEST REQUIREMENT	MIL-L 8937 2/	MIL-L-23398 2/	MIL-L-46010	MIL-L-63460
APPEARANCE (WORKMANSHIP)	X	X		X
VISC AT -65 DEG F (OR -54 DEG C)				X
FLASH POINT				X
POUR POINT				X
ADHESION	X	X		
THERMAL STABILITY	X	X		
ENDURANCE LIFE	X	X		
LOAD CARRYING CAPACITY 1/				X
MINIMUM RETEST FREQUENCY (MONTHS)	12	12	12 3/	36
VISUAL CHECK FREQUENCY (MONTHS)	6	6	--	--

1/ IF CAPABILITY EXISTS
2/ TEST IF CAPABILITY EXISTS, OTHERWISE DISCARD AT 12 MONTHS
3/ NO TESTING, DISCARD AT 12 MONTHS

TABLE V - E Type B-2 Tests for miscellaneous products (specialty, cutting fluids, anti-seize, etc).

SPECIFICATION TEST REQUIREMENT	VV-P-216 3/	MIL-C-16173 1/	MIL-P-46002	MIL-A-46153 4/	P-D-680
APPEARANCE (WORKMANSHIP)	X	X	X	X	X
VISC AT 210 DEG F (OR 100 DEF C)			X		
VISC AT 100 DEG F (OR 40 DEG C)			X		
DISTILLATION					X
FLASH POINT	X		X	X	X
POUR POINT	X		X		
CORROSION	X	X	X		X 1/
PH				X	
STABILITY		X			
EVAPORATION (OR BLEED) 2/			X		
ASH CONTENT		X			
PRECIPITATION NUMBER			X		
FIIM APPEARANCE		X			
DRYING RATE		X			
MINIMUM RETEST FREQUENCY (MONTHS)	36	36	24	24	48
VISUAL CHECK FREQUENCY (MONTHS)	—	—	—	6	12

1/ PER SPECIFICATION
2/ IF CAPABILITY EXISTS
3/ ALSO SURFACE TENSION AND INTERFACIAL TENSION
4/ ALSO RESERVE ALKALINE AND FREEZING POINT

CHAPTER V

NON-STANDARD OR PROPRIETARY PRODUCTS AND ADDITIVE MATERIALS

5.1 It is the general policy within DOD, as stated in MIL-STD-838, that every consideration should be made by developers to use existing standard lubricants, power transmission/hydraulic fluids, and corrosion preventatives. It is most important that similar or duplicative material be precluded from entering the military supply system. Military and Federal specification products are designed to satisfy requirements for equipment operating through-out the world. Indiscriminate use of commercial non-standard and proprietary products can lead to a variety of problems creating not only increased logistics and supply difficulties but more important, performance malfunction of equipment systems. Army field activities are required to follow the procedure outlined in AMC Reg 750-11, paragraph 6.C3. The Belvoir R,D & E Center will coordinate and approve all listings of lubricants, fluids, and associated products under the appropriate lube order/lubrication instruction documents insuring that standard products are used or that there is adequate justification for using nonstandard products. In addition AR 703-1,para. 4.4, has assigned responsibility for the evaluation of Aftermarket fuels and lubricants additives to this Center, Belvoir, R,D&E Center. Evaluation of these type of products will be performed based on the factors listed in this chapter.

5.2 Automotive engine oils meeting military specifications have been so formulated to provide satisfactory performance of both liquid and air-cooled internal combustion engines operating under a wide range of environmental and operational conditions. Performance objectives for engine oils can be essentially classified as lubrication, sealing, cooling (functioning as a heat transfer fluid), maintaining cleanliness, and protecting against wear and corrosion. Examples of specific performance characteristics are detergency/dispersancy, absence of sludge formation, protection from bearing corrosion, adequate anti-rust protection, high-temperature stability, adequate low temperature fluidity, good anti-wear protection and resistance to foaming. These characteristics are only attained by a careful selection of lubricant base-stock components and specific additive combinations which usually include but are not limited to antioxidants, detergent/dispersants, pour-point depressant, Viscosity Index (VI) improver, anti-foam agent, anti-wear additives, and rust preventative/corrosion inhibitors. This careful balance of additive components is finalized into a formulation only after extensive laboratory and engine dynamometer testing has insured the maximum responsiveness of the total additive package to the particular lubricant basestock in meeting the performance levels defined by the particular specification. In addition to being defined by military specifications, engine oil performance requirements are also described in SAE publications J 183c and J 304c. A summarized listing of the industry standardized performance levels for commercial automotive engine oils is provided in Appendix B.

5.3 When formulating specification oils, extensive and costly testing is required to insure the compatibility and effectiveness of the additive-basestock combination. Once an oil is qualified, the particular additive package used as well as lubricant basestock source and refining treatment (hydrofinishing, acid treat, clay filtration, etc.) are closely controlled in respect to both types and specific quantities. This stringent control insures that the performance and property characteristics of purchased products are identical to those of the oil

qualified. Additions of other non-blended or "new" ingredients to a finished oil can reduce or possibly impair the effectiveness of the approved additive system. Recently an increase in the advertisement and marketing of automotive oil additive concentrates, "aftermarket additives", has been evident. These additives should not be used to supplement military crankcase oils. Although aftermarket additives are intended to improve performance, they may be incompatible with fully formulated military specification oils resulting in a diminished or complete loss of protection.

5.4 Even though the use of aftermarket additives is less than desirable, the possibility exists that some products may demonstrate beneficial effects. To avoid the exclusion of such additives, a "Guide For Evaluating Aftermarket Fuel and Lubricant Additives - Procedures and Policies" has been developed. For potential consideration of any additive ingredients, two specific goals must be demonstrated by the prospective candidate aftermarket additive. These are the following:

(a) The aftermarket additive must demonstrate a measurable level of improvement over the finished formulated referenced oil. This improvement should be reflected but not limited to specific performance benefits such as increased fuel economy, decreased engine wear, cleaner engine operation (i.e., reduced valve sticking, etc.) and extended oil change intervals.

(b) The aftermarket additives must not create any adverse side effects resulting from its introduction into a fully-formulated engine oil. These side effects are due to potential non-miscibility or incompatibility of the aftermarket additive with the chemistry of the fully-blended additive package and basestock fractions. This incompatibility could create performance problems due to the antisynergistic effects leading to deposits in critical oil passage regions, piston ring plugging, water emulsification and sludge formation, and loss in lubrication due to excessive thickening.

These requirements are in AR 703-1, paragraph 4.4. The guide provides specific procedures to be followed and testing required to meet these goals prior to potential procurement of an aftermarket additive. Copies of the Guide can be obtained from Belvoir R, D, and E Center, ATTN: STRBE-VF, Ft. Belvoir, VA 22060-5606.

CHAPTER VI

TENTH PERCENTILE MINIMUM AMBIENT TEMPERATURE FOR DEFINING SATISFACTORY LOW TEMPERATURE PROPERTIES OF LUBRICANTS.

6.1 SCOPE

6.1.1 This chapter covers a method to assess the low temperature operability limit of lubricating oils.

6.2 METHODOLOGY

6.2.1 Minimum daily temperatures compiled from weather stations were statistically evaluated to determine the probability for various temperature occurrences. A method of reporting this probability is with the use of percentiles which evaluate the compiled distribution and report the temperatures corresponding to their probabilities of occurrence. To predict limiting low ambient temperatures, the 10th percentile minimum temperature values have been selected as a realistic guide. By definition, the 10th percentile minimum temperature predicts a 10 percent chance that the daily minimum will be lower than the predicted value, or a 90 percent chance that the daily minimum will be no lower than the predicted value.

6.3 APPLICATION

6.3.1 The 10th percentile minimum temperature values for the United States and OCONUS areas are tabulated and presented in tables VI and VII. Satisfactory operation should be achieved in most cases if the intended use at low temperature is specified at or below the 10th percentile minimum temperature.

6.3.2 As an illustration on how to use the tables, lets choose the month of December in the state of Alabama. Table VI will indicate that 90 percent of the time the temperatures will be -6 ^{o}C or above. So the lubricant to be used should have an intended use temperature of -6 ^{o}C or lower, like grades 10W, 15W/40 and 30 in MIL-L-2104, Lubricating Oil, Internal Combustion Engine, Tactical Service.

TABLE VI. United States 10th percentile minimum temperature, °C.

State	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Alabama	13	4	-3	-6	-7	-3	-2
Alaska: 1/							
Northern	-7	-25	-37	-45	-49	-47	-42
Southern	-1	-11	-13	-18	-32	-32	-29
South East	1	-4	-11	-16	-19	-13	-12
Arizona:							
N 34° LAT	1	-4	-12	-14	-17	-16	-12
S 34° LAT	13	7	0	-2	-4	-3	-1
Arkansas	9	2	-4	-7	-11	-7	-3
California: 2/							
N & S Coast	6	4	0	-2	-2	-1	-1
Interior & SE	6	1	-6	-8	-11	-7	-6
Colorado:							
E 105° LONG	4	-2	-12	-14	-19	-15	-12
W 105° LONG	-3	-8	-18	-25	-30	-24	-16
Connecticut	4	-1	-7	-16	-17	-16	-9
Delaware	8	2	-3	-10	-11	-10	-5
Florida	17	7	1	-1	-3	-1	4
Georgia	12	3	-2	-6	-7	-6	-2
Idaho	2	-4	-13	-18	-21	-18	-13
Illinois	5	-1	-9	-19	-21	-18	-11
Indiana	6	-1	-7	-16	-18	-16	-9
Iowa	4	-2	-13	-23	-26	-22	-16
Kansas	4	-2	-11	-15	-19	-12	-13
Kentucky	7	1	-6	-13	-14	-11	-6
Louisiana	14	5	-1	-3	-4	-2	1
Maine	1	-3	-10	-23	-26	-26	-18
Maryland	8	2	-3	-10	-12	-10	-4
Massachusetts	3	-2	-7	-16	-18	-17	-10
Michigan	1	-2	-11	-20	-23	-23	-18
Minnesota	-1	-4	-18	-30	-34	-31	-24
Mississippi	13	3	-3	-6	-6	-4	-1
Missouri	8	1	-7	-14	-16	-13	-8
Montana	-1	-7	-18	-24	-30	-24	-21
Nebraska	3	-3	-13	-18	-22	-19	-13
Nevada:							
N 38° LAT	-2	-7	-14	-17	-22	-18	-13
S 38° LAT	14	8	0	-3	-4	-2	1
New Hampshire	1	-3	-8	-18	-21	-21	-12
New Jersey	8	2	-3	-11	-12	-11	-6
New Mexico	5	-2	-11	-14	-17	-14	-11
New York	1	-3	-8	-21	-24	-24	-16
N Carolina	6	-1	-7	-10	-11	-9	-5

TABLE VI. United States 10th percentile minimum temperature, °C. (cont'd)

State	Sept	Oct	Nov	Dec	Jan	Feb	Mar
North Dakota	1	-4	-20	-27	-31	-29	-22
Ohio	4	-1	-7	-16	-17	-15	-9
Oklahoma	9	1	-8	-12	-13	-8	-7
Oregon:							
E 122o LONG	-1	-6	-11	-14	-19	-21	-9
W 122° LONG	4	0	-4	-5	-7	-4	-3
Pennsylvania	0	-3	-8	-19	-20	-21	-15
Rhode Island	6	1	-3	-12	-13	-13	-7
S Carolina	13	5	-1	-5	-5	-3	-2
South Dakota	3	-4	-14	-24	-27	-24	-18
Tennessee	7	1	-5	-9	-11	-9	-4
Texas:							
N 31° LAT	9	3	-6	-9	-13	-9	-7
S 31° LAT	16	9	2	-2	-3	-1	2
Utah	4	-2	-11	-14	-18	-14	-8
Vermont	3	-3	-8	-20	-23	-24	-15
Virginia	8	2	-3	-9	-11	-9	-4
Washington:							
E 122° LONG	2	-2	-8	-11	-18	-11	-8
W 122° LONG	3	0	-3	-3	-7	-4	-3
West Virginia	3	-3	-8	-15	-16	-14	-9
Wisconsin	2	-3	-14	-24	-28	-24	-18
Wyoming	1	-4	-15	-18	-26	-19	-16

1/ Details of state division are as indicated:
* Northern Region: Area north of the 62° LAT.
* Southern Region: Area bordered on the north by the 62° LAT, bordered on the east by the 141° LONG., and bordered on the south by the 56° LAT.
* Southeastern Coast and Aleutian Islands: Area bordered on the north by Canada, bordered on the west by the 141° LONG., and the remaining area bordered on the north by the 56° LAT.

2/ Details of state division by county as indicated:

California, North Coast - Alameda, Contra Costa, Del Norte,Humboldt, Lake Marin, Mendocino, Monterey, Napa, San Benito, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, Sonoma, Trinity

California, Interior - Alpine, Amador, Butte,Calaveras, Colusa, El Dorado, Fresno, Glenn, Kern (except that portion lying east of the Los Angeles County Aqueduct), Kings, Lassen, Madera, Mariposa, Merced, Modoc, Nevada, Placer, Plumas, Sacramento, San Joaquin, Shasta, Sierra, Siskiyou, Stanislaus, Sutter, Tehama, Tulare, Tuolumne, Yolo, Yuba

California, South Coast - Los Angeles (except that portion north of the San Gabriel Mountain range and east of the Los Angeles County Aqueduct), Orange, San Diego, San Luis Obispo, Santa Barbara, Ventura

California, Southeast - Imperial, Inyo, Kerm (that portion lying east of the Los Angeles County Aqueduct), Los Angeles (that portion north of the San Gabriel Mountain range and east of the Los Angeles County Aqueduct), Mono, Riverside, San Bernardino

TABLE VII. OCONUS 10th percentile minimum temperatures, °C.

Country	Oct	Nov	Dec	Jan	Feb	Mar	April
Austria	-1	-5	-12	-10	-9	-6	-1
Belgium	0	-3	-9	-7	-6	-6	-3
Denmark	-1	-3	-6	-7	-7	-7	-3
France	0	-2	-9	-9	-5	-5	-1
Germany	-2	-5	-13	-13	-12	-9	-5
Greece	5	0	-3	-3	-2	-1	3
Iceland	-1	-5	-7	-9	-7	-7	-4
Italy	1	-3	-6	-8	-7	-3	-1
Korea	1	-6	-13	-20	-15	-7	-1
Luxembourg	1	-3	-7	-7	-6	-4	-2
Netherlands	0	-2	-8	-8	-6	-5	-2
Norway	-6	-14	-16	-18	-18	-16	-6
Portugal	8	4	1	1	1	1	5
Turkey	-1	-6	-10	-16	-16	-6	-1

CHAPTER VII

REFERENCES

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CHAPTER VIII

COMMON TERMS AND DEFINITIONS

8.1 ACID NUMBER

The quantity of base, expressed in milligrams of potassium hydroxide, that is required to neutralize the acidic constituents in one gram of sample.

8.2 ADDITIVE

Any material added to a lubricant to improve its suitability for service. It may improve a property already possessed by the lubricant or give it properties not naturally possessed. (Additives are the "other ingredients imparting special properties" referred to in the definition of lubricating grease. Typical examples are antioxidants, corrosion inhibitors, and "EP" or antiweld additives.)

8.3 ANTICHATTER AGENT

An additive which limits noise in limited slip differentials.

8.4 ANTIFOAM AGENT

An additive which decreases the foaming tendency of an oil.

8.5 ANTIFREEZE

A substance added to a liquid to lower its freezing point.

8.6 ANTIOXIDANT (OXIDATION INHIBITOR)

An additive which retards oxidation.

8.7 ANTISEEPAGE COMPOUND

A compound that when used in an automotive cooling system will stop seepage of the coolant from small openings.

8.8 ANTISYNERGISTIC

The undesirable result obtained when the combination of two or more lubricant additives produces a reduction in the beneficial contribution made by each additive.

8.9 ANTIWEAR AGENT

An additive which prevents destructive metal-to-metal contact between moving parts.

8.10 APPARENT VISCOSITY

The ratio of shear stress to rate of shear of a non-Newtonian fluid, calculated from Poiseuille's equation and measured in poises.

8.11 APPEARANCE

Those characteristics of a product which are observable by visual inspection only. This general item includes various characteristics described under bulk appearance, texture, bloom, luster, cloudiness and color.

8.12 AUTO-IGNITION TEMPERATURE (AIT)

The minimum temperature which must be maintained in order for a test fluid to spontaneously ignite.

8.13 AUTO-OXIDATION

A spontaneous reaction between organic compounds and atmospheric oxygen, which can be catalyzed by an extraneous component.

8.14 BASE MATERIAL (STOCK)

A petroleum, synthetic, or combination fluid which constitutes the bulk of a lubricating oil.

8.15 BASE NUMBER

The amount of acid, expressed in terms of the equivalent number of milligrams of potassium hydroxide, required to neutralize all basic constituents present in one gram of sample.

8.16 BLEEDING

The separation of liquid lubricant from a lubricating grease for any cause.

8.17 BLENDING

Blending is the process of mixing two (2) or more lubricant components for the purpose of obtaining desired physical and/or chemical properties. It is distinguished from compounding, which is the mixing of one (1) or more lubricant components with other components (not normally considered to be lubricants in themselves) for the purpose of obtaining desired physical and/or chemical properties, not usually obtainable by blending.

8.18 BMEP

Brake Mean Effective Pressure is the theoretical-constant-pressure, which can be exerted during each power stroke to produce work equal to the brake work.

8.19 BOILING POINT

The temperature at which the vapor pressure of a liquid becomes equal to the external pressure.

8.20 BORDERLINE PUMPING TEMPERATURE

The lowest temperature at which an engine oil can be continuously and adequately supplied to the oil pump inlet of a passenger car engine.

8.21 BOUNDARY LUBRICATION

That state of lubrication in which the lubricant films, that tend to separate two surfaces, are of molecular dimensions only.

8.22 BRIGHT STOCKS

Heavy or high-viscosity base oils used for blending lubricants.

8.23 BULK APPEARANCE

Visual appearance of grease when the undisturbed surface is viewed in an opaque container. Bulk appearance should be described in the following terms: Smooth - a surface relatively free of irregularities. Rough - a surface composed of many small irregularities. Grainy - a surface composed of small granules or lumps of constituent soap particles. Cracked - showing surface cracks of appreciable magnitude. In describing such a lubricating grease, the number and size of the cracks should be included in the description. Bleeding showing free oil on the surface of the lubricating grease (or in the cracks of a cracked grease). Also refers to how a product looks in terms of hazy, cloudy and color.

8.24 CAVITATION CORROSION

A special form of erosion corrosion which is caused by the formation and collapse of vapor bubbles in a liquid near a metal surface.

8.25 CENTISTOKE (cSt)

A unit of kinematic viscosity.

8.26 CHANNELING

1. A term used in connection with lubricating greases to describe the (usually desirable) tendency to form a channel by working down of lubricating grease in a bearing, leaving shoulders of unworked grease which serve as seal and reservoir.

2. A term used in connection with lubricants to describe the low temperature tendency of these materials to form a structure sufficiently strong to resist flow under gravitational forces. (Similar to, but not identical with the pour point of liquid lubricants, it is measured by Method 3456 of Federal Test Method Standard 791.)

8.27 COMPLEX SOAP

A soap wherein the soap crystal or fiber is formed by co-crystallization of two or more compounds: 1. The normal soap (such as metallic stearate or oleate). 2. The complexing agent. (Examples of complexing agents are the metallic salts of short-chain organic acids such as acetic, lactic, or the inorganic salts such as the carbonates or chlorides. The complexing agent brings about a change in grease characteristics usually recognized by an increase in dropping point.)

8.28 CONSISTENCY (HARDNESS)

The degree to which a plastic material such as lubricating grease resists deformation under the application of force. It is therefore a characteristic of plasticity, as viscosity is a characteristic of fluidity. Consistency is usually tested by either ASTM D 1092, Apparent Viscosity, or ASTM D 217, Cone Penetration.

8.29 COOLANT

Any liquid used specifically for the purpose of removing heat from one surface to another as in an automotive cooling system.

8.30 CORROSION

The gradual destruction and/or pitting of a metal surface due to chemical attack. (see also FRETTING.)

8.31 CORROSION INHIBITOR

An additive which prevents or reduces corrosion of a material.

8.32 CURING

It is the hardening of the solid film lubricant.

8.33 CORROSION PREVENTATIVES

Materials used to prevent or retard corrosion of metals in various types of systems.

8.34 DETERGENT

An additive which prevents, reduces or controls the buildup of deposits such as varnish or lacquer.

8.35 DETERIORATION LIMIT

Requirements established in terms of minimum and/or maximum values for physical, chemical, and performance characteristics which must be exhibited after a specified time period by the lubricant prior to issuing the product to a using activity.

8.36 DISPENSABILITY

The property of a grease that governs the ease with which it may be transferred from its container to its point of application. Most used in discussion of dispensing in grease systems, where it includes both the properties of PUMPABILITY and FEEDABILITY.

8.37 DISPERSANTS

An additive which disperses, and holds in solution, sludge and contaminants.

8.38 DROPPING POINT

The temperature at which a drop of material falls from the orifice of the test apparatus under the conditions of ASTM D 566 and ASTM D 2265.

8.39 DRY-FILM LUBRICANT

Any class of lubricants wherein the reduction of friction and wear during sliding is caused by making the shearing take place within the crystal structure of a material with low shear strength in one particular plane. Examples include graphite, molybdenum disulfide, and certain soaps.

8.40 ELASTOMER

An elastic, rubberlike material.

8.41 EMULSIBILITY

The tendency of a substance to form an emulsion; i.e., a collodial mixture of two immiscible fluids one being dispersed in the other in the form of fine droplets.

8.42 ENGINE OIL

A base material (stock) fortified with additives - corrosion inhibitors, detergents, dispersants, anti-wear agents, pour depressants, viscosity index (V.I.) improvers, oxidation inhibitors, and anti-foam agents - which is used to lubricate internal-combustion (spark-ignition and compression-ignition) engines. In performing this function, the engine oil reduces friction and wear between moving parts, seals between cylinder walls and pistons, transfers heat from crucial areas, prevents or minimizes corrosive attack, and engine deposits.

8.43 EVAPORATION LOSS

That portion of a lubricant which volatilizes under the effects of temperature, pressure, and time. Such loss can occur in use or in storage. A widely used test method is ASTM D 972 or ASTM D 2887.

8.44 EXTREME PRESSURE (EP) AGENT

An additive which increases the load-carrying capacity of an oil or grease.

8.45 FEEDABILITY

The ability of a lubricating grease to flow to the suction of a dispensing pump at a rate at least equal to pump delivery capacity. (Some lubricating greases do not feed satisfactorily and cause cavitation at the inlet to a dispensing pump. In such cases, feedability can often be made satisfactory by the use of follower plates.)

8.46 FLUIDITY

Reciprocal of viscosity, ease of flowing.

8.47 FRETTING CORROSION

A type of corrosion cause by slight movements of unprotected metal surfaces left in contact either in a corroding atmosphere or under heavy stress.

8.48 GALVANIC CORROSION

A type of corrosion caused by placing two dissimilar metals in a corrosive or conductive solution in contact with each other so that the potential difference produced allows electrons to flow between them.

8.49 GEAR OIL

A base lubricating oil material (stock) fortified with additives oxidation inhibitors, extreme pressure (EP) agents, anti-foam agents, corrosion inhibitors, pour depressants, anti-stain agents, anti-chatter agents, and viscosity index (VI) improvers - which is used to lubricate automotive gear units (differentials and transmissions), heavy duty industrial enclosed gears, steering gears, and fluid universal joints. In performing this function, the oil reduces friction between moving parts, transfers heat from critical areas, and prevents or minimizes corrosive attack.

8.50 GEL

A jelly-like substance formed by the coagulation of a colloidal solution into a solid phase.

8.51 GREASE

A lubricant composed of a lubricating fluid thickened to form a semisolid.

8.52 HEAT TRANSFER

The ability of an oil, grease, coolant or lubricant fluid to remove heat from one surface and transfer it to another.

8.53 HOMOGENIZATION

The process of subjecting a lubricating grease to intimate mixing and intensive shearing action, the end result of which is to obtain a more uniform and higher degree of dispersion.

8.54 HYDRAULIC FLUID

A fluid suitable for use in hydraulic systems.

8.55 HYDRODYNAMIC (FLUID FILM) LUBRICATION

That state of lubrication in which the shape and relative motion of the sliding surfaces causes the formation of a continuous fluid film under sufficient pressure to prevent any contact between the surfaces. It is commonly called fluid film lubrication.

8.56 HYDROLYTIC STABILITY

Resistance to chemical reaction with water.

8.57 HYDROMECHANICAL LUBRICATION

Lubrication of combination fluid-mechanical driven systems where the oil functions both as the lubricant and as the power transmission fluid.

8.58 HYDROSTATIC LUBRICATION

That state of lubrication in which the lubricant is supplied to a plain bearing under sufficient external pressure to separate the opposing surfaces by a continuous lubricant film.

8.59 INCIPIENT FAILURE

Engine/transmission and bearing conditions that are indicative of future component failure.

8.60 INCOMPATIBILITY

A condition where a mixture of two (2) products shows a physical property or service condition that is markedly inferior to those of either product before mixing.

8.61 INHIBITOR

Any substance which slows, prevents, or modifies chemical reactions such as corrosion or oxidation.

8.62 INSOLUBLES

Components of a lubricant (greases or oils) that cannot be dissolved in prescribed reagents. Components of a lubricating grease that are insoluble in the prescribed reagents, used in an analytical procedure, should be indicated when insolubles are specified. Additional identifying analytical tests are required to determine the nature and composition of insolubles, which consist of fillers, additives, certain types of thickeners, inadvertent impurities, or in case of used lubricants, the products of combustion, dirt,or wear metals.

8.63 INTERCHANGEABILITY

The ability of one product to be substituted for another product without loss of operational or performance characteristics.

8.64 INTEROPERABILITY

The ability of systems, units or forces to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together.

8.65 KINEMATIC VISCOSITY

The ratio of absolute viscosity to the density of a fluid. The unit of kinematic viscosity is the stoke. Viscosity in stokes, multiplied by density at the test temperature, equals the absolute viscosity in poise.

8.66 LUBRICATING GREASE

A solid to semifluid product of a dispersion of a thickening agent in a liquid lubricant. Other ingredients, imparting special properties, may be included.

8.67 LUBRICATING GREASE STRUCTURE

The physical arrangement of the component particles of a lubricating grease thickener, additive, if any, and liquid lubricant. It is the nature and stability of this arrangement that determines the appearance, texture, and physical properties of lubricating grease.

8.68 LUSTER

The intensity of light reflected by lubricating grease; its sheen or brilliance. Luster should be described as follows: bright - reflects light with a relatively strong intensity; dull - reflects light with a relatively weak intensity. Some greases with a high water content may have a dull luster. Certain thickeners and fillers give a grease a characteristic dull luster.

8.69 MILITARY SYMBOL

The identifying letters and/or numbers assigned to products.

8.70 NATO CODE NUMBERS

The identifying letters and/or numbers allocated to a product when it meets the requirements of a specification which has been accepted under the NATO Standardization Agreement.

8.71 NATO STANAG

North Atlantic Treaty Organization Standardization Agreement. The record of an agreement among several or all the member nations to adopt like or similar military equipment, ammunition supplies, and stores; and operational, logistic, and administrative procedure.

8.72 NEUTRAL OILS

Oils obtained from the upper stages of the vacuum distillation process and usually have viscosities at 100 ^{o}F (38 ^{o}F) lower than 700 SSU (approximately 151 cSt). The name came about because the oils were treated by a neutralization process, usually caustic neutralization, after a sulfuric acid treatment. Since, the products were neutralized, they were called neutral oils.

8.73 NEUTRALIZATION NUMBER

A measure of the acidity or basicity of a liquid. It is defined as milligrams of potassium hydroxide required to neutralize the acidity in one gram of fluid or the equivalent of the basicity expressed in a similar manner.

8.74 NEWTONIAN BEHAVIOR

The property of a fluid where rate of shear is proportional to shear stress.

8.75 NEWTONIAN FLUID

A fluid whose viscosity does not change with rate of flow.

8.76 NLGI (NATIONAL LUBRICATING GREASE INSTITUTE) NUMBER

A numerical scale for classifying the consistency range of lubricating greases, and based on the ASTM D 217 penetration number. NLGI grades are in order of increasing consistency (hardness) as follows:

NLGI NUMBER	ASTM WORKED PENETRATION
000	445-475
00	400-430
0	355-385
1	310-340
2	265-295
3	220-250
4	175-205
5	130-160
6	85-115

8.77 NON-NEWTONIAN BEHAVIOR

The property possessed by some fluids and many plastic solids, including lubricating grease, of having a variable relationship between shear stress and rate of shear. (Non-Newtonian materials, therefore, do not possess a viscosity as defined by Newton, but rather an apparent viscosity, the quantitative value of which may vary widely with varying shear rate. Conventional types of viscometers with uncontrolled shear rates will not satisfactorily measure non-Newtonian materials.)

8.78 NON-SOAP THICKENER

Any of several specially treated or synthetic materials, excepting the metallic soaps of long-chain fatty acids, which can be either thermally or mechanically dispersed in liquid lubricants to form lubricating grease. Also called synthetic thickener. Certain types are called inorganic thickeners.

8.79 NUCLEATE BOILING

Occurs when the two phase boundary layer adjacent to the heating surface is stable and the surface heat transfer coefficient increases continuously with heater temperature. Vapor bubbles form continuously at the heat surface at an increasing rate and over a larger area.

8.80 OILINESS

The property of being able to reduce friction due to the presence of an adsorbed film.

8.81 OXIDATION

A chemical reaction of elements and compounds with an oxidizing agent such as oxygen, resulting in the formation of oxidation products, which results in a change in properties.

8.82 OXIDATION INHIBITOR

An additive which reduces the oxidative or thermal degradation of an oil.

8.83 OXIDATION STABILITY

The resistance of lubricants to chemical reaction with oxygen. The absorption and reaction of oxygen may lead to deterioration of lubricants. Several testing methods are in use, including Method 2504 of Federal Test Method Standard 791 and ASTM D 942.

8.84 PARTICULATE CONTAMINATION

Fluid or grease contamination resulting from dust or dirt ingestion.

8.85 pH

A means of expressing the degree of acidity or basicity of a solution. The pH of a solution is commonly considered to be the negative logarithm (to the base 10) of the hydrogen ion concentration, whereby values below 7.0 indicate an increasingly acidic solution and values above 7.0 an increasingly alkaline (basic) solution.

8.86 PENETRATION

Of lubricating grease is the depth, in tenths of a millimeter, that a standard cone penetrates the sample in a standard cup under prescribed conditions of weight, time, and temperature. The penetration depends on whether or not the consistency has been altered by handling or agitation.

8.87 PIGMENTS

Insoluble materials which impart color to the mixing medium or to coating materials.

8.88 PLASTICITY

That property of apparently solid material that enables it to be permanently deformed under the application of force, without rupture. (Plastic flow differs from fluid flow in that the shearing stress must exceed a yield point before any flow occurs.)

8.89 POLYMER

Chemical compounds formed from the combination of two or more components into a continuous or random orientation. Polymers are frequently used as lubricant additives for friction modifiers, pour point depressants, viscosity index (VI) improvers, or tackiness agents.

8.90 POUR DEPRESSANT

An additive which allows an oil to flow more freely at lower temperatures than can be obtained with the bare material.

8.91 PUMPABILITY

The ability of a lubricating grease to flow under pressure through the line, nozzle, and fitting of a grease dispensing system. It is best indicated by the apparent viscosity at moderate rate of shear. See NLGI Tentative Method for Matching Lubricating Grease Flow Properties with Lubricating Grease Dispensing Pump Delivery Behavior at Low Temperatures, NLGI Spokesman, May, 1960, page 47.)

8.92 RECLAIMED

A material recovered from a previously used lubricant by means of a reclaiming process. Reclaiming implies the use of physical methods (settling, filtration, centrifuging etc.) to obtain a reusable product from the used lubricant.

8.93 RECYCLING

A generic term for processing used oil to regain useful material.

8.94 RE-REFINED

A material recovered from a previously used lubricant by means of a re-refining process. Re-refining implies the use of both physical (setting, filtration, centrifuging, etc.) and chemical (hydrotreating, solvent extracting, acid treatment, etc.) methods to obtain a high quality, reuseable material (base stock/finished oil) from the used lubricant.

8.95 RESERVE ALKALINITY

Reserve alkalinity is used in production quality control and in specifications to indicate the amount of alkaline (basic) inhibitors present in the product and in used solutions to indicate the amount of remaining inhibitors in automotive coolant and engine oils.

8.96 RESIN

The binder in a solid film lubricant that holds the pigment in place after it is cured. Cure is the process of evaporating the solvent and polymerizing the resin.

8.97 RE-TEST FREQUENCY

A planned orderly schedule for the testing and re-testing of petroleum and related products to detect incipient deterioration and prevent the receipt of off-specifications products by consuming activities.

8.98 SEAL

A material or device designed to prevent leakage between parts, moving or static.

8.99 SERVO CONTROL

A control actuated by a feed-back system which compares the output with the reference signal and makes corrections to reduce the difference.

8.100 SERVO MECHANISM

Any mechanism which uses power magnification and in which there is incorporated a means of relating the speed and travel of the input and output.

8.101 SHEARING

Slipping or sliding of one part of a substance relative to an adjacent part. In a solid, such action involves cutting or breaking of the crystal structure, but in a fluid or plastic, shearing does not necessarily destroy the continuous nature of the substance.

8.102 SHEAR RATE

The rate of slip within a substance engaging in flow. The average or mean shear rate in a pipe or tube is the average velocity divided by the radius of the tube. It therefore, has the dimensions of the reciprocal of time and is usually expressed in the unit of reciprocal seconds (sec-1). The mean shear rate is reported in the determination of apparent viscosity in ASTM D 1092.

8.103 SHEAR STABILITY, FLUIDS

The ability of liquids to retain their viscosity and not be permanently mechanically broken down. Specific examples are hydraulic fluids and crankcase oils which are expected to retain specific viscosity characteristics, not thin out; and thus resist the mechanical action of their environment.

8.104 SHEAR STABILITY, GREASES

The ability of a lubricating grease to resist changes in consistency (hardness) during mechanical working. Working may be in any of several types of laboratory machines or may be in actual service. This may also be called mechanical stability.

8.105 SHEAR STRESS

The force required to cause shearing in a substance. In fluids, the relation of the shear stress to the shear rate is the viscosity of the substance.

8.106 SHELF LIFE

The length of time that a product can be stored without significant deterioration.

8.107 SIMULATED SERVICE TEST

A method that evaluates the interaction of a lubricant or corrosion preventative with metal test specimens under controlled laboratory conditions.

8.108 SOAP

A grease thickener formed by the reaction of a fatty acid and an alkali.

8.109 SOLID FILM LUBRICANTS

The solid film lubricants consist of a lubricative pigment in a properly thinned resin system with or without additives, as needed, to meet the requirements of the subject specification.

8.110 SPECIFICATION LIMIT

Requirements established by the specification which defines in terms of minimum and maximum values of the physical, chemical, and performance characteristics to be exhibited by the lubricant.

8.111 SPECTROMETRIC OIL ANALYSIS

A method of determining the concentration of various chemical elements in an oil sample by means of emission or absorption spectroscopy; primarily to detect the presence of abnormal amounts of wear metals in the sample to indicate the potential failure of components containing those metals.

8.112 SQUEEZE-FILM LUBRICATION

That state of lubrication in which surfaces thickly coated or flooded with lubricant move toward each other at sufficient speed to develop fluid pressure sufficient to support a load of short duration. Because of viscosity (or apparent viscosity), the lubricant cannot immediately flow away from the area of contact. This action occurs, for example, between gear teeth and between wrist pins and their bushings.

8.113 STABILITY

Resistance to permanent change of properties under normal storage and use conditions.

8.114 STARTING TORQUE

A measure of the rotary force necessary to initiate engine operation.

8.115 SYNERGISTIC

The result of using two or more lubricant additives whose combination in a lubricant produce a beneficial or desirable result in excess of the combined individual contribution of each additive.

8.116 SYNTHETIC FLUID

A material which, by definition, is nonpetroleum, but which may contain nonfunctional amounts of petroleum. Specifically, this permits petroleum to be used as a carrier for a constituent, i.e., for an additive, etc., but excludes petroleum used for any benefit of its properties per se. Because of economics and availability, many synthetic lubricants are made from petroleum derived components (i.e., petro-chemicals), but this need not be the case.

8.117 SYNTHETIC GREASE

A grease incorporating a non-soap thickener and/or a grease composition resulting from the replacement of a normal petroleum lubricating oil by a special fluid, such as the silicones or organic esters.

8.118 TCP

Tricresyl phosphate, an antiwear additive, generally used in hydraulic fluid formulations.

8.119 TEXTURE

That property of lubricating grease which is observed when a small separate portion of it is pressed together and then slowly drawn apart. Texture should be described in the following terms: Brittle - has a tendency to rupture or crumble when compressed. Buttery - separates in short peaks with no visible fibers. Long fiber - shows tendency to stretch or string out into a single bundle of fibers. Short fiber - shows short breakoff with evidence of fibers. Resilient - capable of withstanding moderate compression without permanent deformation or rupture. Stringy - shows tendency to stretch or string out into long fine threads, but with no visible evidence of fiber structure. Other terms such as smooth, rough, grainy, etc., are defined under bulk appearance.

8.120 THERMAL STABILITY

Resistance to permanent changes in properties caused solely by heat.

8.121 THICKENING AGENT

The solid particles that are relatively uniformly dispersed to form the structure of lubricating grease in which the liquid is held by surface tension and other physical forces. (The solid particles may be fibers, as in the case with various metallic soaps, or plates or spheres, as is the case with some of the non-soap thickeners. The only general requirements are that the particles should be extremely small and that they be capable of uniform dispersion in the liquid lubricants.)

8.122 THIXOTROPY (IN LUBRICATING GREASE AND SOME OILS.)

That property which is manifested by a decrease in consistency, or softening, as a result of shearing, followed by an increase in consistency, or hardening, beginning after shearing is stopped. (Thixotropic age hardening is a relatively prolonged process proportional to aging time and is seldom, if ever, complete, whereas the apparent viscosity increase that occurs in non-Newtonian systems with decreasing shear rate is instantaneous and fully reversible. Lubricating grease is both thixotropic and non-Newtonian.)

8.123 TOLERANCE LIMITS

Range of values that a particular property is allowed to deviate. This range is typically assigned after testing is completed. The tolerance limits are used for quality assurance when the same materials are used.

8.124 VEHICLE (SOLID FILM)

It is the solvent system which carries the resin components of solid film lubricants.

8.125 VISCOSITY

The viscosity of a lubricant is a measure of its resistance to flow. When comparing two oils, the higher viscosity oil will be thicker and flow at a slower rate than the lower viscosity oil, i.e., the higher viscosity oil has more resistance to flow. Since flow is of such vital importance, viscosity is one of the most commonly measured properties.

8.126 VISCOSITY INDEX (VI)

An empirical number that indicates the effect of change of temperatures on the viscosity of an oil. A high viscosity index signifies a smaller change in viscosity with change in temperature than a lower index.

8.127 VISCOSITY INDEX IMPROVER

An additive which alters the viscosity-temperature relationship of the base material, commonly referred to as VI improver.

8.128 WATER RESISTANCE

The ability of a lubricating grease to withstand the addition of water to the lubricant system without adverse effects.

8.129 WEAR

The removal of materials from surfaces in relative motion. Abrasive wear - removal of materials from surfaces in relative motion by a cutting or abrasive action of a hard particle (usually a contaminant). Adhesive wear - removal of materials from surfaces in relative motion as a result of surface contact. Galling and scuffing are extreme cases. Corrosive wear - removal of materials by chemical action.

8.130 WORKING

Subjecting lubricating grease to any form of agitation or shearing action beyond simple transfer to a test apparatus.

8.131 YIELD POINT (OR YIELD VALUE)

The minimum force required to produce flow of a plastic material (lubricant). It can be estimated by the intercept on the shear stress axis of the shear stress-shear rate curve, by extrapolation of the straight portion of the curve.

CHAPTER IX

ACRONYMS AND ABBREVIATIONS

9.1. AMCP - Army Materiel Command Publication
9.2. AMC - Army Materiel Command
9.3. API - American Petroleum Institute
9.4. AR - Army Regulation
9.5. ASCC - Air Standardization Coordination Committee
9.6. ASLE - American Society Lubricating Engineers
9.7. ASTM - American Society for Testing and Materials
9.8. ATF - Automatic Transmission Fluid
9.9. BMEP - Brake Mean Effective Pressure
9.10 CCL - Chemical and Coating Laboratory
9.11. CFR - Coordinatng Fuels Research
9.12. CID - Cubic Inch Displacing
9.13. cP - centipoise
9.14. CRC - Coordinating Research Council
9.15. cSt - centistoke
9.16. DDA - Detroit Diesel Allison known as Allison Transmission Division
9.17. DOD - Department of Defense
9.18. E.P. - Extreme Pressure
9.19. FTMS - Federal Test Method Standard
9.20. FTM - Federal Test Method
9.21. GM - General Motors
9.22. gm - gram
9.23. kg - kilogram
9.24. KOH - potassium hydroxide
9.25. mg - miligram
9.26. ml - milliliter
9.27. mm - millimeter
9.28. NATO - North Atlantic Treaty Organization
9.29. NLGI - National Lubricating Grease Institute
9.30. N.R. - Not Required
9.31. ppm - parts per million
9.32. psi - pounds per square inch
9.33. REO - Reference Engine Oil
9.34. RGO - Reference Gear Oil
9.35. SAE - Society Automotive Engineers
9.36. seq. - sequence
9.37. TCP - Tricresyl Phosphate
9.38. VI - Viscosity Index

Custodians:
Army - ME
Navy - YD
Air Force - 68

Review activities:
Army - MR, AR, AT, AL, SM, AV, NS
Navy - AS
DLA - GS
Air Force - 20, 82

Preparing activity:
Army - ME

Project 9150-0776

User Activities
Army - MI
Navy - MC, SH

APPENDIX A

VISCOSITY MEASUREMENT AND CLASSIFICATION OF ENGINE OILS

10. VISCOSITY AND HOW IT IS MEASURED

10.1 The viscosity of a lubricant is a measure of its resistance to flow. When comparing two oils, the higher viscosity oil will be thicker and flow at a slower rate than the lower viscosity oil, i.e., the higher viscosity oil has more resistance to flow. Since flow is of such vital importance, viscosity is one of the most commonly measured properties of an engine oil. Many instruments and techniques have been developed to measure viscosity. For this purpose military specifications require the use of two standard procedures developed by the American Society for Testing and Materials (ASTM). The following is a brief description of the ASTM procedures.

10.2 ASTM D 445 - This method determines viscosity by measuring the time for a volume of oil to flow by gravity through a small diameter tube (glass capillary viscometer). Viscosities determined by this method are called kinematic viscosities and are reported in units known as centistokes (cSt).

10.3 ASTM D 2602 - This method determines the apparent viscosities of oils at low temperatures. An electric motor drives a rotor which is closely fitted inside a cylinder. Oil is placed between the rotor and cylinder. When the rotor is turned with a constant force, its speed is a function of the oil viscosity. The viscosity of the oil under test is determined by comparing the rotor speed to previously determined rotor speeds for reference oils of known viscosity. Viscosities determined by this method are reported in units known as centipoise (cP).

10.4 ASTM D 4684 - This method determines the borderline pumping temperature of engine oils. Two standard torques are applied to a rotor and the speed of rotation measured. From these results at three or more temperatures, the borderline pumping temperature (the highest temperature at which a 30 Pa·s yield stress or 30000 cP viscosity) is determined.

10.5 Another important measurement is the rate of change in oil viscosity with a change in temperature. An arbitrary scale called Viscosity Index (VI) has been developed to characterize the viscosity-temperature behavior of oils.

10.6 As can be seen from figure 1.1, low VI oils change more with temperature than oils having a higher VI. The VI of oils are calculated using ASTM D 2270.

APPENDIX A

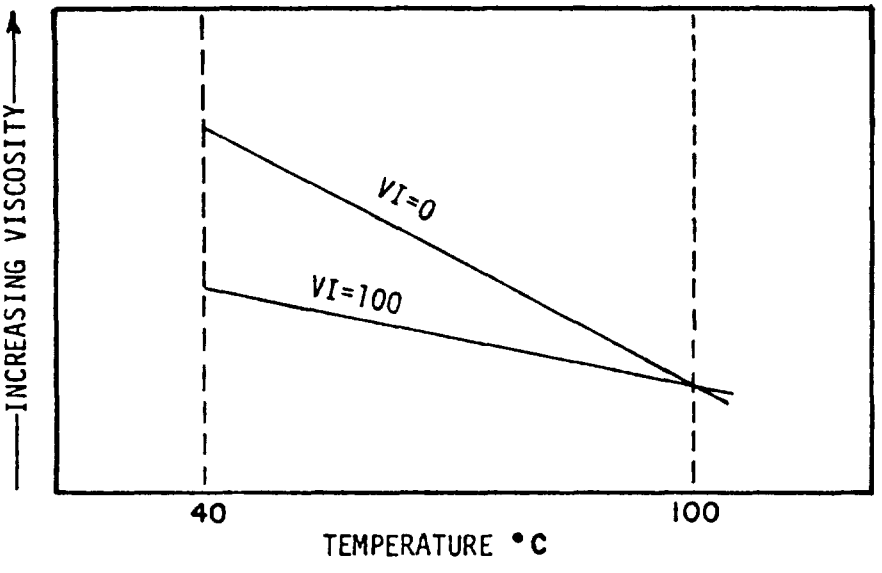


FIGURE 1.1 Temperature-viscosity behavior.

X-3446

20. VISCOSITY CLASSIFICATION OF ENGINE OILS

20.1 In September 1980, SAE revised the classification system to better define low-temperature characteristics. This was accomplished by establishing maximum viscosity requirements for specific W grades at different low- temperatures rather than the previous single temperature of -18 °C. Also, a maximum borderline pumping temperature was included. For each W grade to measure an oils ability to flow to the engine oil pump inlet and provide adequate lubrication during engine start-up. The revised system is shown by table VIII. An example of the viscosity- temperature relationship for SAE 10W, SAE 30 and SAE 10W-30 oils using the revised system is shown by figure 1.2.

TABLE VIII. SAE Viscosity Classifications.

SAE Viscosity Grade	Viscosity (cP) at Temperature (°C) Max	Borderline Pumping Temperature (°C) Max	Viscosity (cSt) at 100 °C Min	Viscosity (cSt) at 100 °C Max
0W	3250 at -30	-35	3.8	NA
5W	3500 at -25	-30	3.8	NA
10W	3500 at -20	-25	4.1	NA
15W	3500 at -15	-20	5.6	NA
20W	4500 at -10	-15	5.6	NA
25W	6000 at -5	-10	9.3	NA
20	NA	NA	5.6	9.3
30	NA	NA	9.3	12.5
40	NA	NA	12.5	16.3
50	NA	NA	16.3	21.9

NA - None assigned.

20.2 Military specifications classify or grade oils based on the SAE systems. Also, the military system includes a VI requirement to control the characteristics of single grade oils (30 and 40) where the SAE system only establishes the 100 °C viscosity range. The classifications for specifications MIL-L-2104 andd MIL-L-46152 are given in table IX and an example of the VI requirement for grade 30 oil is shown 1.3. It should be noted that military grade 10 or 10W oils meet the SAE classification for a grade SAE 10W-20 oil. Typical temperature-viscosity data for various grade military oils are shown in figure 1.4 and 1.5.

TABLE IX. MIL-L-2104 and MIL-L-46152 viscosity grades.

Specification	MIL-L-2104				MIL-L-46152				
Viscosity Grades	10	30	40	15W-40	10W	30	5W-30	10W-30	15W-40
Viscosity at 100° C, cSt									
Minimum	5.6	9.3	12.5	12.5	5.6	9.3	9.3	9.3	12.5
Maximum	<7.4	<12.5	<16.3	<16.3	<7.4	<12.5	<12.5	<12.5	<16.3
Viscosity at Temperature Apparent, Centipoise @ °C									
Minimum	3500@-25	NR	NR	3500@-20	3500@-25	NR	3250@-30	3500@-25	3500@-20
Maximum	3500@-20	NR	NR	3500@-15	3500@-20	NR	3500@-25	3500@-20	3500@-15
Borderline Pumping Temperature °C (Maximum)	-25	NR	NR	-20	-25	NR	-30	-25	-20
Viscosity Index, Minimum	NR	75	80	NR	NR	75	NR	NR	NR

NR - No requirement.

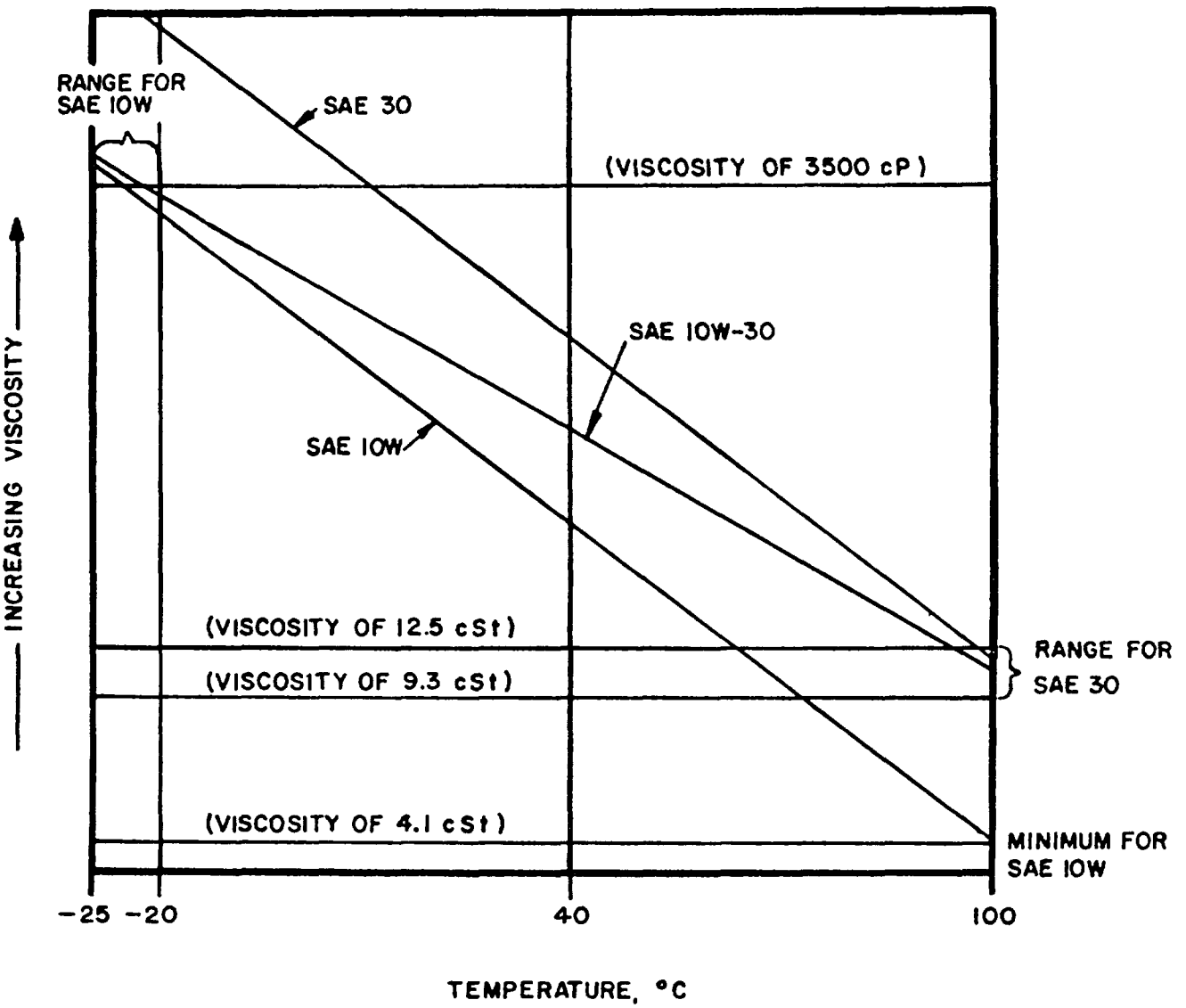


FIGURE 1.2 Temperature-viscosity relationship for SAE 10W, 30, and 10W-30 oils (September 1980 classification system).

X-3745

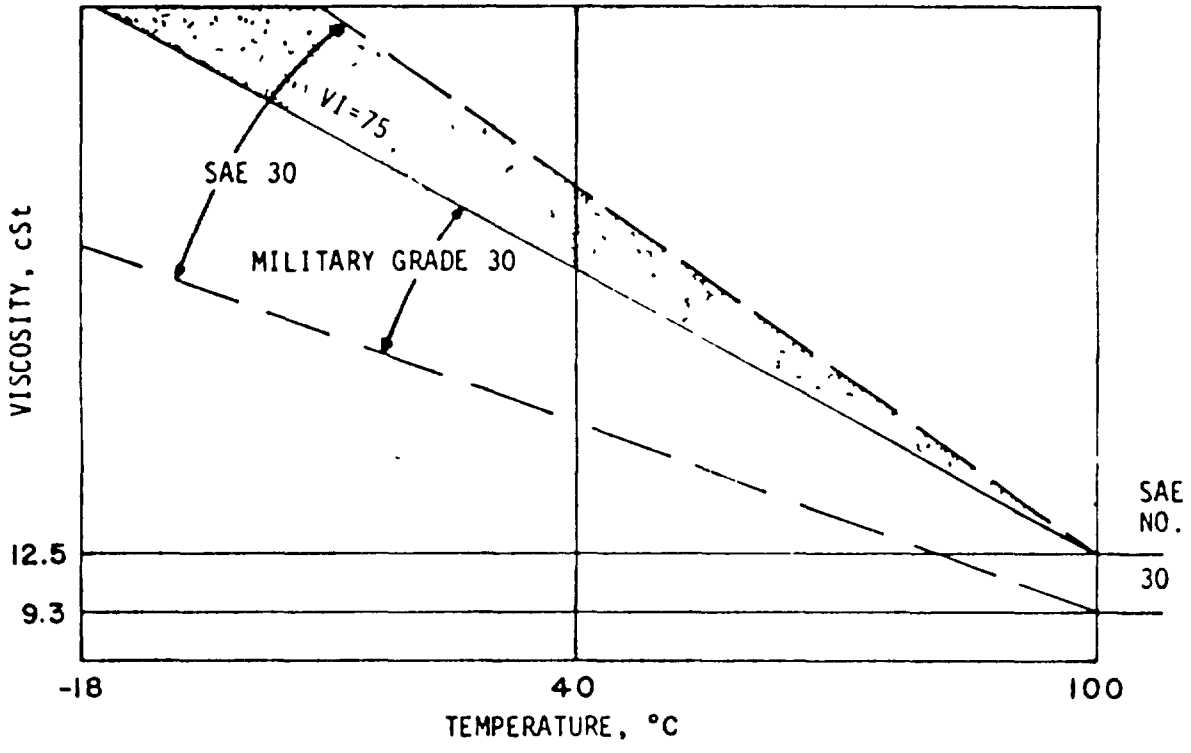


FIGURE 1.3 Temperature-viscosity relationship of SAE 30 and Military Grade 30 oil.

X-3448

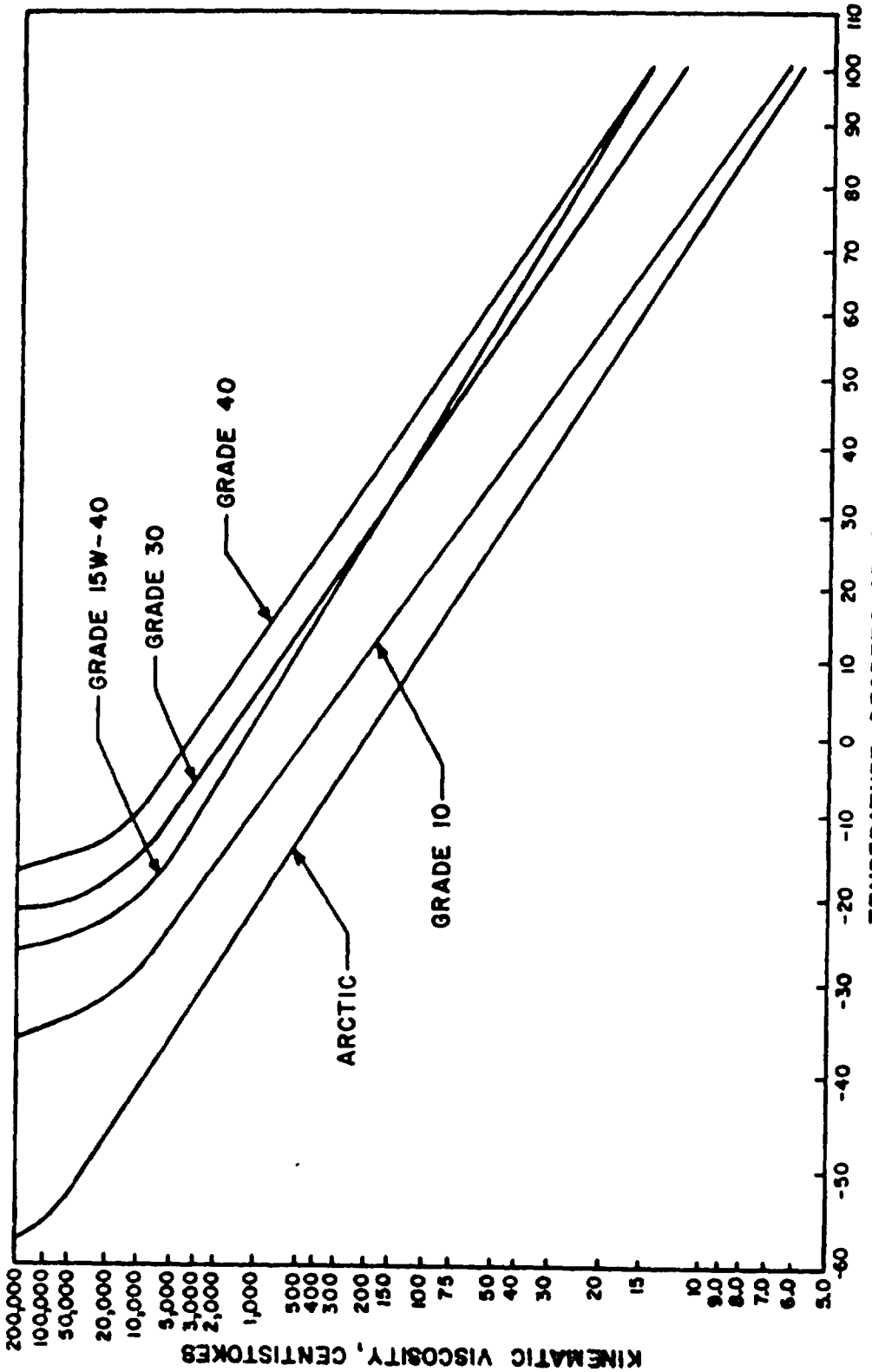
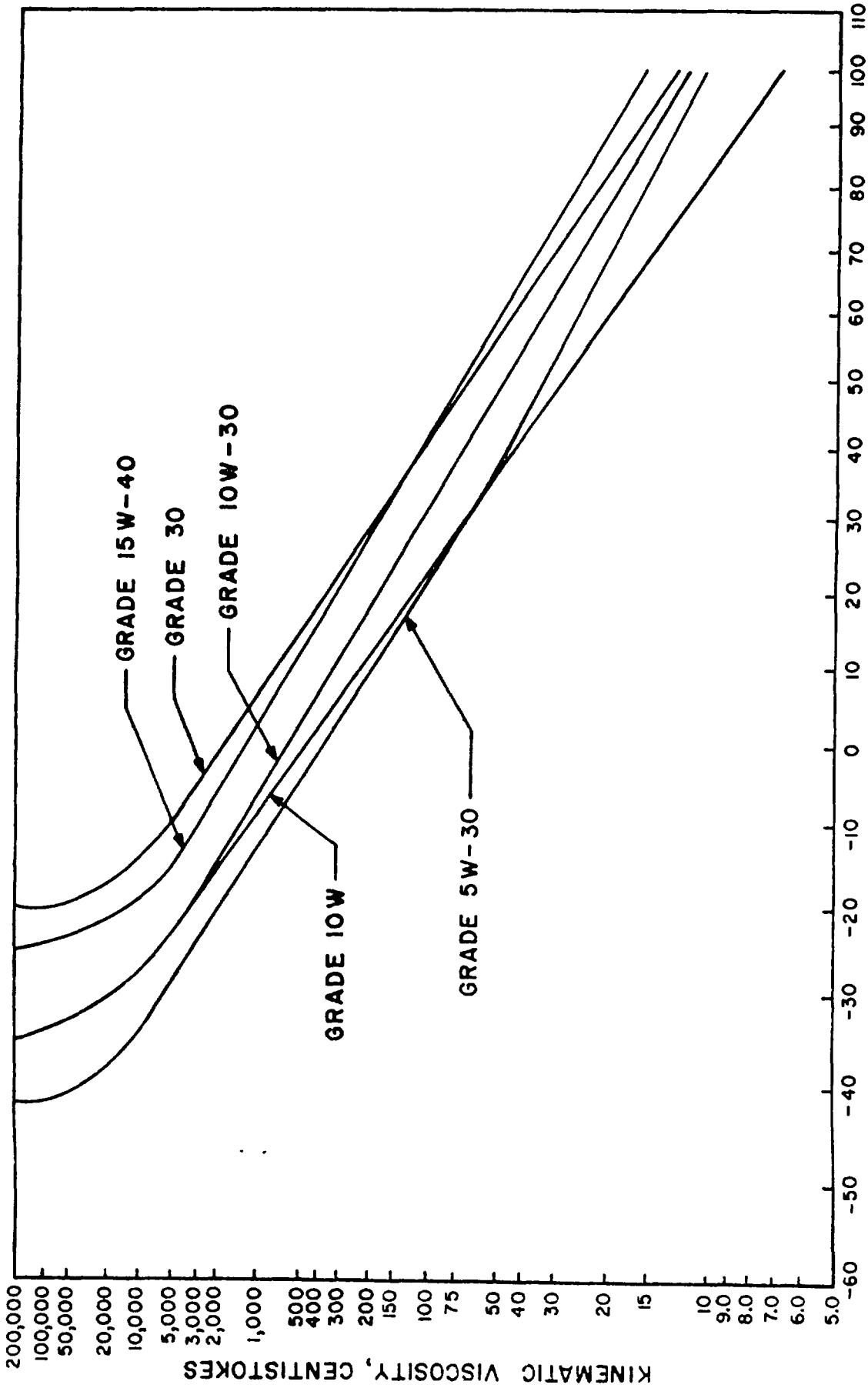


FIGURE 1.4, Typical temperature-viscosity data for MIL-L-2104 & MIL-L-46167 engine oil.



X-3450D

FIGURE 1.5. Typical temperature-viscosity data for MIL-L-46152 engine oil.

30. HOW MULTIVISCOSITY OILS ARE MADE

30.1 To meet the classification's low and high temperature requirements, it is necessary to control the viscosity-temperature behavior of the oil. This is accomplished by the careful selection of base stocks and the use of additives called viscosity improvers. Examples of the effect of base stocks and viscosity improvers on the characteristics of fully formulated oils can be seen from the data presented in table X and XI.

30.2 Here the multiviscosity properties of the grade 10 (SAE 10W-20) oil was obtained from the viscosity properties of the selected base stocks. In the case of the grade 10W-30 and 15W-40 oils, the multiviscosity properties could not be obtained completely from the base stocks and it was necessary to modify the oil's viscosity-temperature characteristics by using a viscosity improver additive.

30.3 The above examples were for conventional oils blended using petroleum base stocks. Recently, several manufacturers have marketed multiviscosity oils which use synthetic base stocks. These oils are made in the same manner as the conventional petroleum oil, i.e., from selected synthetic base stocks and viscosity improvers when required. The viscosity properties for several synthetic oils are given in table XII. Also the viscosity-temperature relationship for three of these oils and a conventional SAE 10W-30 oil are shown in figure 1.6.

TABLE X. Base stock viscosities.

Base stock	A	B	C
Viscosity, cSt			
At 100 C	5.1	10.4	30.9
At 40 C	30.4	93.7	478.8

TABLE XI. Composition and properties of finished oil.

Viscosity grade	10	30	40	10W-30	15W-40
Base stock (percent of product)	(91.2)	(91.2)	(91.2)	(87.7)	(87.7)
A percent of total stock	92	0	0	100	40
B percent of total stock	8	100	85	0	60
C percent of total stock	0	0	15	0	0
Additive (percent of product)	(8.8)	(8.8)	(8.8)	(12.5)	(12.3)
Viscosity improver	---	---	---	3.7	3.5
Performance 1/	8.8	8.8	8.8	8.8	8.8
Finished oil properties					
Viscosities					
At 100 C, cSt	6.2	11.4	13.5	10.0	14.2
At 40 C, cSt	40.2	105.2	130.4	61.0	106.9
At -18 C, cP	2300.0	NT	NT	2100.0	5500.0
Viscosity index	107	94	94	148	136

1/ Functional performance additives such as detergents, antiwear agents, corrosion inhibitors, etc.

NT - Not tested

TABLE XII. Viscosity properties for synthetic engine oils.

Oil Code	A	B	C[1/]	D[1/]
SAE number	0W-20	0W-20	10W-30	10W-40
Viscosity				
At 100 °C, cSt	6.1	6.4	10.2	14.6
At 40 °C, cSt	27.1	32.1	53.3	84.1
At -18 °C, cP	743.0	836.0	1210.0	2270.0
Viscosity index	155.0	150.0	181.0	180.0

1/ Contains viscosity improver additive.

40. RELATIONSHIP TO OVERALL OIL PERFORMANCE

40.1 This is the area where most people have a misconception of the meaning of the viscosity classification. Many people feel the viscosity labeling completely describes the properties and performance of an oil. The viscosity classification does not describe oil quality and when used to imply quality it can result in damage to engines. As an example, multiviscosity oils were developed primarily for passenger car service where they have provided excellent performance and gained wide acceptance because of their seasonal versatility. It is important to note this service generally limits the oils to use in gasoline engines. Equivalent performance does not hold true for diesel engines. The same multiviscosity oils which have served well for passenger cars have had a history of poor performance in diesel powered equipment. However, the multiviscosity grade 15W/40 has had wide acceptance for use in diesel powered equipment due to improved additive technology. This grade has been added to MIL-L-2104 to provide for less seasonal changes where possible.

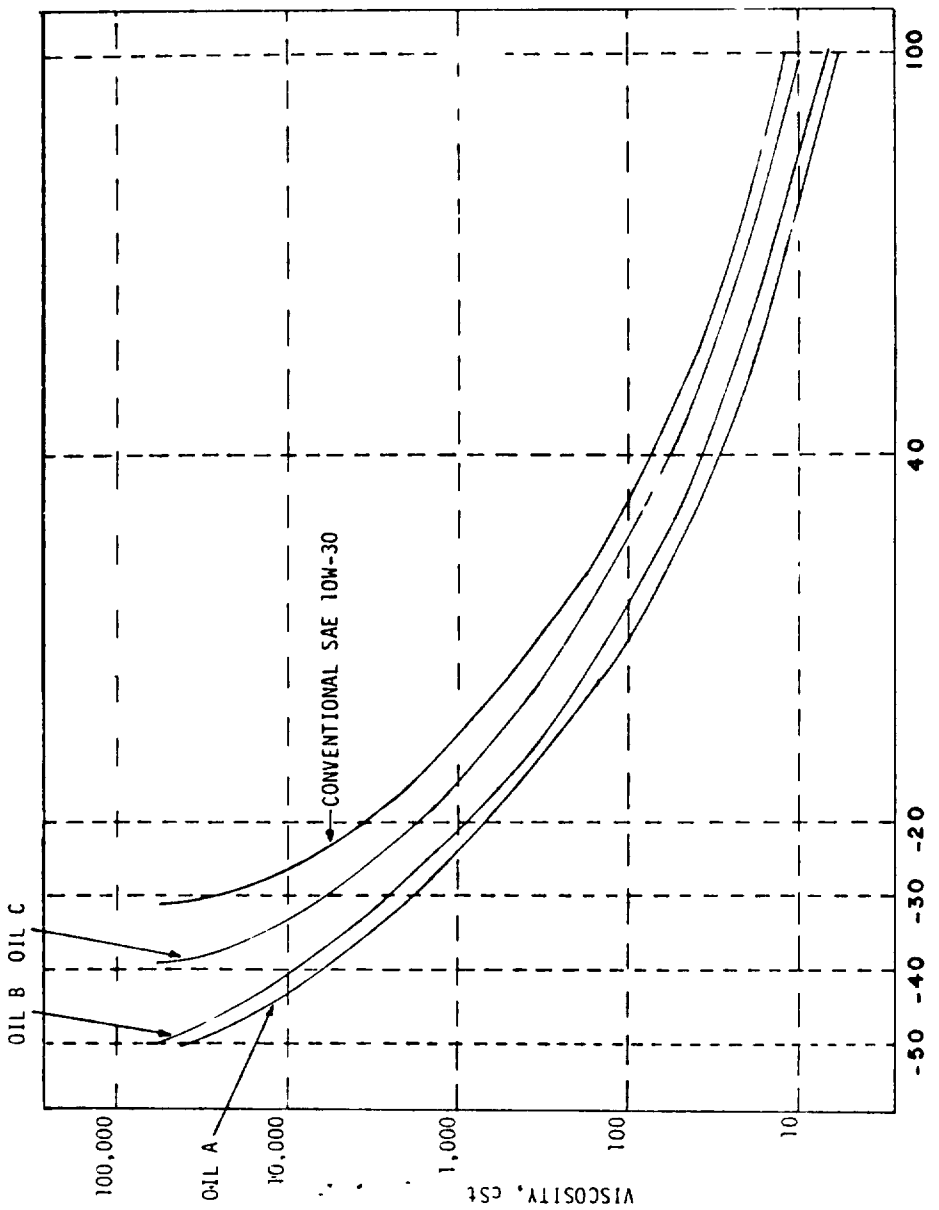


FIGURE I.6 Temperature-viscosity relationship for synthetic and conventional oils.

X-3451

APPENDIX B

PERFORMANCE MEASUREMENT AND CLASSIFICATION OF ENGINE OILS

10. ENGINE OIL PERFORMANCE AND HOW IT IS MEASURED

10.1 Engine oil performance defines a lubricant's ability to resist degradation, control deposits, and prevent corrosion and wear during its service life. Since oil performance is so greatly influenced by the engine environment, a series of engine laboratory tests have been developed to evaluate and define its performance. The following provides a brief summary of current test procedures used to evaluate lubricant performance:

TABLE XIII. Summary of engine oil test procedures.

Test Method	Description
L-38 **	This method was designed to evaluate oils for resistance to oxidation, corrosion, and deposition when subjected to high temperature operation. A single cylinder CLR gasoline engine is operated under constant speed, air-fuel ratio and fuel flow conditions for 40 hours.
Sequence II-D**	This method was designed to evaluate the rusting characteristics of crankcase oils during short-trip service under typical winter conditions. The procedure involves the continuous operation of an Oldsmobile 350 CID engine for 32 hours.
Sequence III-E**	This method was designed to evaluate the high temperature oil thickening and deposition characteristics as well as engine wear related high speed, relatively high temperature turnpike operation. The procedure involves 64 hours of dynamometer operation of a 3.8 liter engine.
Sequences V-E**	This method was designed to evaluate the low temperature deposition characteristics of engine oils. This test simulates a combination of low speed, low temperature, "stop-and-go" city driving, and moderate turnpike operation. The test is conducted under cyclic conditions for 288 hours using Ford 2.3 liter engine.

TABLE XIII. Summary of engine oil test procedures.(cont'd)

Test Method	Description
1G2 **	This test is used to evaluate the effect of oils on the ring-sticking, wear, and deposits in diesel engines operated at high outputs.The procedure involves the operation of a special single cylinder diesel engine for a total of 480 hours at a fixed speed and Btu input.
1H2 **	This test is used to evaluate the effect of oils on the ring-sticking, wear, and deposits in diesel engines operated at low to medium outputs. The procedure involves the operation of a special single cylinder diesel engine for a total of 480 hours at a fixed speed and BTU input.
6V53T (FTM 354)*	This method is used to evaluate the ring-sticking, wear, and deposition characteristics of oils operating in a two-cycle diesel engine in arctic environment. The test involves the cyclic operation of a 6V53T, two-cycle diesel engine for 240 hours. This test is run at derated conditions of FTM 355T.
6V53T (FTM 355T)*	This method is used to evaluate the ring-sticking,wear and deposition characteristic of oils operating in a two-cycle diesel engine in non arctic environment. The test involves the cyclic operation of a 6V-53T, two-cycle diesel engine for 240 hours.

* FTMS 791
** ASTM

20. COMMERCIAL ENGINE OIL PERFORMANCE CLASSIFICATIONS

20.1 In 1947, the American Petroleum Institute (API) adopted the first classification which included three types of oils (regular, premium, or heavy duty). This system was replaced in 1952 by classifications by engine type i.e., *ML, MM, and MS for gasoline engine oils and DF, DM and DS for diesel engine oils. The "M" and "D" in classifications were revised in 1955 and again in 1960 which remained in effect until the current system was introduced in 1971. Under the current system, oils are designated SA, SB, SC, SD, SE, SF, SG, CA, CB, CC, CD, and CE and apply to passenger cars, gasoline and diesel powered trucks, gasoline and diesel powered off-highway equipment. Table XIV gives a description of each classification and table XV provides the performance criteria for the latest classifications - SF, SG, CC, CD, and CE.

TABLE XIV. Description of commercial performance classifications.

Letter Designation	API Engine Service Description	ASTM Engine Oil Description
SA *	Utility Gasoline and Diesel Engine Service-Service typical of engines operarted under such mild conditions that the protection afforded by compounded oils is not required. This classification has no performance requirements.	Oil without additive except that it may contain pour and foam depressants.
SB *	Minimum Duty Gasoline Engine Service- Service typical of engines operated under such mild conditions that only minimum protection afforded by compounding is desired. Oils designed for this service has been used since the 1930's and provide only antiscuff capability, and resistance to oil oxidation and bearing corrosion.	Provides some anti-oxidant and anti-scuff capabilities.
SC *	1964 Gasoline Engine Warranty Service- Service typical of gasoline engines in 1964-1967 models of passenger cars and trucks operating under engine manufacturers' warranties in effect during those model years. Oils designed for this service provide control of high and low temperature deposits, wear, rust, and corrosion in gasoline engines.	Oil meeting the 1964 1967 requirements of the automibile manufacturers. Intended primarily for use in passenger cars. Provides low temperature antisludge and anti-rust performance.
SD	1965 Gasoline Engine Warrany Maintenance Service- Service typical of gasoline engines in 1968 through 1970 models of passenger cars and some trucks operating under engine manufacturers warranties in effect during those model years. Also may apply to certain 1971 and/or later models, as specified (or recommended) in the owners manuals. Oils designed for this service provide	Oil meeting the 1968-1971 requirements of the automobile manufacturers. Intended primarily for use in passenger cars. Provides low temperature antisludge and anti-rust performance.

TABLE XIV. Description of commercial performance classifications.(cont'd)

Letter Designation	API Engine Service Description	ASTM Engine Oil Description
	more protection against high and low temperature engine deposits, wear, rust, and corrosion in gasoline than oils which are satisfactory for API Engine Service Classification SC and may be used when API SC is recommended.	
SE	1972 Gasoline Engine Warranty Maintenance Service Service typical of gasoline engines in passenger cars and some trucks beginning with 1972 and certain 1971 models operating under engine manufacturers' warranties. Oils designed for this service provides more protection against oil oxidation, high temperature engine deposits, rust, and corrosion in gasoline engines than oils which are satisfactory for API Gasoline Engine Warranty Maintenance Classifications SD or SC and may be used when either of these classifications are recommended. Oil meeting the 1972 requirements of the automobile manufacturers. Intended primarily for use in passenger cars. Provides high temperature antioxidation, low temperature antisludge, and antirust performance.	Oil meeting the 1972 requirements of the automobile manufacturers. Intended primarily for use in passenger cars. Provides high temperature antioxidation, low temperature anti-sludge,and anti-rust performance.
SF	1980 Gasoline Engine Warranty Maintenance Service Service typical of gasoline engines passenger cars and some trucks beginning with the 1980 model operating under engine manufacturers' recommended maintenance procedures. Oils developed for this service provide increased oxidation stability and improved anti-wear performance relative to oils which meet the minimum requirements for API Service Category SE. These oils also provide protection against engine deposits, rust, and corrosion. Oils meeting API Service Categories SF maybe used where API Service Categories SE, SD, or SC are recommended.	Oil meeting the 1980 warranty requirements of the automobile manufacturers. Intended primarily for use in gasoline engine passenger cars Provides protection against sludge, varnish, rust, wear, and high temperature thickening

TABLE XIV. Description of commercial performance classifications.(cont'd)

Letter Designation	API Engine Service Description	ASTM Engine Oil Description
SG	1988 Gasoline Engine Warranty Maintenance Service Service typical of gasoline engines in passenger cars, vans, and light trucks beginning with the 1989 model year operating under manufacturers' recommended maintenance procedure. Category SG quality oils include the performance properties of API category CC. (Certain manufacturers of gasoline engines require oils also meeting API category CD). Oils developed for this service provide improved control of engine deposits, oil oxidation, and engine wear relative to oils developed for previous categories. Oils meeting API Service Category SG may be used where API Service Categories SF, SE, SF/CC, or SE/CC are recommended.	Oil meeting the performance requirements measured in the following gasoline and diesel engine tests: The IID gasoline engine test has correlated with vehicles used in short-trip service prior to 1978, particularly with regard to rusting. The IIIE gasoline engine test has been correlated with vehicles used in high-temperature service prior to 1988, particularly with reagard to oil thickening and valve train wear. The VE gasoline engine test has been correltaed with vehicles used in stop-and-go service prior to 1988, particularly with regard to sludge and valve train wear. The L-38 gasoline engine test is used to measure copper-lead bearing weight loss and piston varnish under high-temperature operating conditions.The 1H2 diesel engine test is used to measure high-temperature piston deposits.
CA *	Light Duty Diesel Engine Service Service typical of diesel engines operated in mild to moderate duty with high quality fuels. Occasionally has included gasoline engines in mild service. Oils designed for this service were widely used in the 1940s and	Oil meeting the requirements of MIL-L-2104. For use in gasoline and naturally aspirated diesel engines operated on low sulfur fuel. The MIL-L-2104Bspecification was issued in 1954.

TABLE XIV. Description of commercial performance classifications.(cont'd)

Letter Designation	API Engine Service Description	ASTM Engine Oil Description
	1950s. These oils provide protection from bearing corrosion and from high temperature deposits in normally aspirated diesel engines when using fuels of such quality that they impose no unusual requirements for wear and deposit protection.	
CB *	Moderate Duty Diesel Engine Service - Service typical typical of diesel engines operated in mild to moderate duty, but with quality fuels which necessitate more protection from wear and deposits. Occasionally has included gasoline engines in mild service. Oils designed for this service were introduced in 1949. Such oils provide protection from bearing corrosion and from high temperature deposits in normally aspirated engines with higher sulfur fuels.	Oil for use in gasoline and naturally aspirated diesel engines.Includes MIL-L-2104A oils where the diesel engine test was run using high high sulfur fuel.
CC	Moderate Duty Diesel and Gasoline Engine Service Service typical of lightly supercharged diesel engines operated in moderate to severe duty and has included certain heavy duty, gasoline engines. Oils designed for this service were introduced in 1961 and used in many trucks and in industrial and construction equipmentand farm tractors. These oils provide protection from high temperature deposits in lightly supercharged diesels and also from rust, corrosion and low temperature deposits in gasoline engines.	Oil meeting requirements of MIL-L-2104B. Provides low temperature antisludge, antirust, and lightly supercharged diesel engine performance. The MIL-L-2104B specification was issued in 1964.

TABLE XIV. Description of commercial performance classifications.(cont'd)

Letter Designation	API Engine Service Description	ASTM Engine Oil Description
CD	Severe Duty Diesel Engine Service Service typical of supercharged diesel engines in high speed, high output duty requiring highly effective control of wear and deposits.Oils designed for this service were introduced in 1955, and provide protection from bearing corrosion and from high temperature deposits when using fuels of a wide quality range.	Oil meeting the performance requirements in the following diesel and gasoline engine tests: The 1G2 diesel engine test has been correlated indirect injection engines used in heavy-duty operation,particularly with regard to piston and ring groove deposits. The L-38 gasoline test is used to measure copper-lead bearing weight loss and piston varnish under high-temperature operating conditions.
CD-II	Severe Duty Two-Stroke Cycle Diesel Engine Service. Typical of two-stroke cycle diesel engines requiring highly effective control over wear and deposits. Oils designed for this service also meet all performance requirements of API Service Category CD.	Oil meeting the performance requirements measured in the following diesel and gasoline engine tests: The 1G2 diesel engine test has been correlated with indirect injection used in heavy-duty operation, particularly with regard to piston and ring groove deposits. The 6V-53T diesel engine test has been correlated with vehicles equipped with two-stroke cycle diesel engines in high-speed operation prior to 1985, particularly with regard to ring and liner distress.The L-38 gasoline engine test is used to measure copper-lead bearing weight loss and piston varnish under high-temperature operating conditions.

TABLE XIV. Description of commercial performance classifications.(cont'd)

Letter Designation	API Engine Service Description	ASTM Engine Oil Description
CE	Severe Duty Diesel Engine Service II- Service Typical of certain turbocharged heavy duty diesel engines manufactured since 1983 and operated under both low-speed, high-load and high-speed, high-load conditions. Oils designed for this service may also be used when API Engine Service Category CD is recommended for diesel engines.	Oil meeting the performance requirements of the following diesel and gasoline tests: The 1G2 diesel engine test has been correlated with indirect injection engines used in heavy-duty service, particularly with regard to piston and ring groove deposits. The T-6, T-7 and NTC-400 are direct injection diesel engine tests. The T-6 has been correlated with vehicles equipped with engines used in high-speed operation prior to 1980, particularly with regard to deposits, oil comsumption and ring wear. The T-7 test has been correlated with vehicles equipped with engines used in lugging operation prior to 1984, particularly with regard to oil thickening. The NTC-400 diesel engine test has been correlated with vehicles equipped with engines in highway operation prior to 1983, particularly with regard to oil comsumption control, deposits and wear. The L-38 gasoline engine test is used to measure copper-lead bearing weight loss.

Current API Engine Service Classification	Previous API Engine Service Classification
Service Station Engine Service	
SA	ML
SB	MM
SC	MS (1964)
SD	MS (1968)
SE	None
SF	None
SG	None
Commercial and Fleet Engine Services	
CA	DG
CB	DM
CC	DM
CD	DS
CD-II	None
CE	None

TABLE XV. Commercial Classification Criteria.

Test Procedures	Item Rated	SG	CD-II	CE
L-38	Bearing Weight Loss, mg, max	40	50	50
	Piston Skirt Varnish, min	9.0	9.0	NR[1/]
Seq II-D	Avg engine rust rating, min	8.5	NR	NR
	Number stuck lifters	None	NR	NR
Seq III-E	Viscosity increase at 40 °C(64 test h)	375	NR	NR
	Avg sludge rating min	9.2	NR	NR
	Avg piston skirt varnish rating, min	8.9	NR	NR
	Avg oil ring land deposit rating, min	3.5	NR	NR
	Lifter sticking	None	NR	NR
	Scuffing and wear			
	Cam and lifter scuffing	None	NR	NR
	Cam plus lifter wear, in x 10-3			
	Average, max	1.2	NR	NR
	Maximum	2.5	NR	NR
Seq VE	Avg engine sludge rating, min	9.0	NR	NR
	Cam cover sludge rating, min	7.0	NR	NR
	Avg piston skirt varnish rating, min	6.5	NR	NR
	Avg engine varnish rating, min	5.0	NR	NR
	Oil ring clogging, % max	15.0	NR	NR
	Oil screen clogging, % max	20.0	NR	NR

TABLE XV. Commercial Classification Criteria. (Cont'd)

Test Procedures	Item Rated	SG	CD-II	CE
	Compression ring sticking (hot stuck)	None	NR	NR
	Cam wear, in x 10-3			
	Average, max	5.0	NR	NR
	Maximum, max	15.0	NR	NR
1H2	Top groove carbon fill, % vol. max	45	NR	NR
	Weighted total demerits, max	140	NR	NR
	Side clearance loss, in x 10^{-3}, max	0.5	NR	NR
1G2	Top groove filling, % max	NR	80	80
	Weighted total demerits, max	NR	300	300
	Side clearance loss, in x 10^{-3}, max	NR	0.5	0.5
6V-53T	Piston Area, demerits, avg, max			
	Weighted total demerits	NR	400	NR
	Hot stock rings	NR	None	NR
	Face distress,Nos 2&3 rings	NR	13.0	NR
	Liner and head area			
	Liner distress,avg, % area, max	NR	12.0	NR
	Valve distress	NR	None	NR
T-6	Merit rating, min	NR	NR	90
T-7	Avg. rate viscosity increase during last 50 hrs, cSt @100 ^{O}C/h , max	NR	NR	0.040
NTC-400	Camshaft roller follower, in 10^{-3} pin wear, avg, max	NR	NR	2.0
	Crownland (top land) deposits, area covered with heavy carbon, % , avg., max.	NR	NR	25
	Pistons deposits, third ring land, total CRC demerits for all 6 pistons, max.	NR	NR	40
	Oil Consumption	NR	NR	2/

1/ NR - NOT REQUIRED.
2/ Candidate oil consumption second-order-regression-curve must fall completely below the published mean plus one standard deviation curve for the applicable reference oil.

30. PERFORMANCE DEFINITION OF MILITARY SPECIFICATION ENGINE OILS

30.1 As with the commercial engine oils, military specifications use full scale engine tests to define lubricant performance. In fact, the same test procedures are used in both cases, and the military requirements are tailored to provide oils to meet the needs of the military combat, tactical, and administrative fleets. The performance criteria for military specification oils is given in table XVI. It should be noted that MIL-L-2104 and MIL-L-21260 lubricants meet the commercial CD-II classification. MIL-L-46167 meets the commercial classification CD, however, it includes the 6V-53T test but not at the level required for CD-II classification. MIL-L-46152 oils meet the SG and CC criteria.

30.2 In addition, the MIL-L-46167, MIL-L-21260, and MIL-L-2104 specifications have included power transmission tests as performance criteria. These requirements are shown in table XVII.

TABLE XVI. Military engine oil performance requirements.

Test Procedure	Item Rated	Specification MIL-L 2104	21260	46152	46167
L-38	Bearing Weight Loss, mg, max	50	50	40	50
	Piston Skirt Varnish, min	NR[1/]	NR	NR	NR
Seq II-D	Avg engine rust rating, min	8.1	8.1	8.5	8.5
	Number stuck lifters	NR	NR	None	NR
Seq III-E	Viscosity increase at 40 oC(@64 h)	NR	NR	375	NR
	Avg sludge rating min	NR	NR	9.2	NR
	Avg piston skirt varnish rating, min	NR	NR	8.9	NR
	Avg oil ring land deposit rating,min	NR	NR	3.5	NR
	Ring sticking	NR	NR	None	NR
	Lifter sticking	NR	NR	None	NR
	Scuffing and wear				
	Cam or lifter scuffing	None	None	None	None
	Cam plus lifter wear,μm				
	Average, max	64	64	30	64
	Maximum, max	178	178	64	178

TABLE XVI. Military engine oil performance requirements(cont'd).

Test Procedure	Item Rated	Specification MIL-L 2104	21260	46152	46167
Seq V-E	Avg engine sludge rating, min	8.5	8.5	9.0	8.5
	Avg rocker cover sludge rating, min	6.5	6.5	7.0	6.5
	Avg piston skirt varnish rating, min	6.0	6.0	6.5	6.0
	Avg engine varnish rating, min	4.2	4.2	5.0	4.2
	Oil ring clogging, % max	15	15	15	15
	Oil screen clogging, % max	23	23	20	23
	Compression ring sticking (hot stock)	None	None	None	None
	Cam wear, µm				
	Average, max	203	203	127	203
	Maximum, max	457	457	381	457
1H2 2/	Top groove filling, %, max	NR	NR	45	NR
	Weighted total demerits, max	NR	NR	140	NR
1G2	Top groove filling, %, max	80	80	NR	80
	Weighted total demerits, max	300	300	NR	300
6V-53T 3/	Piston area				
(FIM 354)	Average total deposits (max)	400	400	NR	400
	Hot stuck rings	None	None	NR	None
	Average ring face distress,% area				
	Fire ring, max	Report	Report	NR	Report
	Nos. 2 and 3 compression	13	13	NR	35
	Linear and head area, max				
	Average liner distress, % area	12	12	NR	45
	Valve distress	None	None	NR	None
	Port plugging, %	Report	Report	NR	Report

1/ NR - Not required
2/ Passing 1G2 test results will be accepted in place of 1H2 test results.
3/ Not required for Grade 10 oil. May be waived for Grade 30, 40 and 15W-40 oil formulated using previously approved additive technologies Use FIM 354 for MIL-L-46167.

TABLE XVII. Transmission Test Requirements for MIL-L-2104, MIL-L-21260, and MIL-L-46167.

Test technique	Item rated	2104/ 21260*	46167
C-3 (Seal)1/	Total Immersion (Buna N)		
	Volume changes, %	0 to 5	0 to 5
	Hardness changes, points	0 5	0 + 5
	Dip cycle (Polyacrylate)		
	Volume changes, %	0 to 10	0 to 10
	Hardness change, points	0 to 5	0 to 5
	Tip cycle (Silicone)		
	Volume changes, %	0 to 5	0 to 5
	Hardness changes, points	0 to -10	0 to -10
C-3(Time-Torque)	Slip time at 5500 cycles, s (max.)	0.85	0.85
	Torque, N.m		
	at 0.2s slip time (min)	101.7	101.7
	△ between 1500 & 5500 cycles (max)	40.7	40.7
C-3 (Anti-Wear)	Degrees of remaining grinding pattern	NR	360
	Scuffing, scoring or chatter wear marks	NR	None
TO-2	Stopping time increase % (max)	152/	20
	Average total wear, μm (max)	350	350

1/ Nominal values; to be adjusted for individual elastomer batches.
2/ Stopping time increase is 20% (max.) for Grade 10 oils.

* In addition, the corrosion protection (humidity cabinet) test of FED-STD-791, method 5329 and a salt water immersion test are required.

APPENDIX C

VISCOSITY MEASUREMENT AND CLASSIFICATION OF GEAR LUBRICANTS

10. VISCOSITY AND HOW IT IS MEASURED

10.1 The viscosity of a lubricant is a measure of its resistance to flow. When comparing two oils, the higher viscosity oil will be thicker and flow at a slower rate than the lower viscosity oil, i.e., the higher viscosity oil has more resistance to flow. Since flow is of such vital importance, viscosity is one of the most commonly measured properties of an engine oil. Many instruments and techniques have been developed to measure viscosity. For this purpose military specifications require the use of two standard procedures developed by the American Society for Testing and Materials (ASTM). The following is a brief description of the ASTM procedures:

10.2 ASTM D 445 - This method determines viscosity by measuring the time for a volume of oil to flow by gravity through a small diameter tube (glass capillary viscometer). Viscosities determined by this method are called kinematic viscosities and are reported in units known as centistokes (cSt).

10.3 ASTM D 2983 - This method determines the apparent viscosity of gear oils at low temperature. An electric motor drives a spindle which is immersed in oil. When the spindle is turned with a constant force, its speed is a function of the oil viscosity. The viscosity of the oil under test is determined by comparing the spindle speed to previously determined spindle speeds for reference oils of known viscosity. Viscosities determined by this method are reported in units known as centipoise (cP).

20. VISCOSITY CLASSIFICATION OF GEAR OILS

20.1 Since viscosity is such a frequently measured property, it is used to classify or grade oils into viscosity groups. The most widely used classification system is the one established by the Society of Automotive Engineers (SAE) and shown by table XVIII. The SAE system specifies groups by a range of viscosities at a high temperature, also a maximum 150,000 cP limit is established at specific low temperatures for three of the grades. The classification of an oil is determined by measuring its viscosities at the two temperatures. For example, an oil with a -26 ^{o}C apparent viscosity below 150,000 cP and a 100 ^{o}C viscosity of 15.5 cSt would meet the requirements for SAE Grade 80W and Grade 90 classifications. This would be a multi-viscosity Grade 80W/90 oil.

20.2 Military specification MIL-L-2105 classifies or grades oils based on the SAE system as shown in table XIX. In the case of both the SAE and military classifications, the Viscosity Grade refers only to the viscosity-temperature characteristics of an oil.

TABLE XVIII. SAE viscosity classifications.

Grade	75W	80W	85W	90	140	250
Viscosity, kinematic, cSt at 100 °C						
minimum	4.1	7.0	11.0	13.5	24.0	41.0
maximum	NR	NR	NR	24.	41.0	NR
Maximum temperature for viscosity of 150,000 cP, °C	-40	-26	-12	N	NR	NR

NR - Not required

TABLE XIX. MIL-L-2105 Viscosity grades.

Grade	75W	80W/90	85W/140
Viscosity, kinematic, cSt at 100 °C			
minimum	4.1	13.5	24.0
maximum	NR	24.0	41.0
Maximum temperature for viscosity of 150,000 cP, °C	-40	-26	-12

NR - Not required

APPENDIX D

PERFORMANCE MEASUREMENT AND CLASSIFICATION OF GEAR OILS

10. GEAR OIL PERFORMANCE AND HOW IT IS MEASURED

10.1 Gear oil performance defines a lubricant's ability to resist degradation, control deposits, and prevent corrosion and wear during its service life. Since oil performance is so greatly influenced by the gear loading and service, a series of laboratory axle and bench tests have been developed to evaluate and define its performance. The following (see Table XX) provides a brief summary of the current test procedures used to evaluate lubricant performance:

TABLE XX. Summary of gear oil test procedures.

Test	Method Description
Storage Stability*	This method was designed to evaluate the storage stability of the lubricant. A sample of the lubricant is heated to 120 ^{o}C, cooled at room temperature, and stored for 30 days after which it is inspected for separated material.
Compatibility*	This test evaluates the oils compatibility with other qualified lubricants. A sample is mixed individually with six reference oils. The mixtures are heated to 120 ^{o}C, cooled at room temperature, and stored for 30 days after which each mixture is inspected for separated material.
L-60*	This test is designed to evaluate the deterioration of a lubricant under condition of severe oxidation. Using a special designed bench scale gear rig, the lubricant is subjected, in the presence of a catalys and air sparge, to 50 hours testing at 163 ^{o}C.
L-33*	This test is designed to determine the corrosion preventive properties of gear oil, in environments where moisture condenses, on metal parts during cyclic ambient temperatures. After a short period of operation, the lubricant is stored in the presence of moisture for seven days.
L-42*	This test evaluates the load-carrying performance of a lubricant under conditions of high-speed and shock-loading. This test uses full scale axle unit.
L-37*	This test evaluates the load-carrying performance of a lubricant under conditions of high-speed, low-torque followed by low-speed, high-torque. This test uses a full scale axle unit.

*ASTM Special Publication STP 512

20. COMMERCIAL GEAR OIL PERFORMANCE CLASSIFICATIONS

20.1 Because of the extreme importance of a gear lubricant's load-carrying capacity, a service classification system has been developed based on this characteristic. The following (see Table XXI) table provides a description of the service and lubricant requirements for each classification.

TABLE XXI. Description of commercial performance characteristics.

API Letter Designation	Service Description	Oil Description
GL-1 *	Designates the type of service characteristic of automotive spiral-bevel and worm-gear axles and some manually operated transmissons operating under such mild conditions of low unit pressures and sliding velocities, that straight mineral oil can be used satisfactorily. Oxidation and rust inhibitors, defoamers, and pour depressants may be utilized to improve the characteristics of lubricants for this service. Frictional modifiers and extreme pressure agents shall not be utilized.	Lubricants suitable for this type of service are therefore,considered to be "straight mineral gear oils." In antiscoring protection, these lubricants are comparable to CRC RGO-100. Due to speeds and loads involved, straight mineral oil is not a satisfactory lubricant for most 4-speed and some 3-speed passenger car manual transmissions. For some truck and tractor manual transmissions, straight mineral oil is suitable.
GL-2 *	Designates the type of service characteristic of automotive type worm-gear axles operating under such conditions of load, temperature, and sliding velocities, that lubricants satisfactory for API-GL-1 service, will not suffice.	Products suited for this type of service contain anti-wear or very mild extreme pressure agents which provide protection for worm gears. There are relatively very few differentials in use that are equipped with worm gears. The GL-2 designation is included in this list for those worm gears used in a service that has been found to require a lubricant other than straight mineral oil.

TABLE XXI. Description of commercial performance characteristics (ct'd).

API Letter Designation	Service Description	Oil Description
GL-3 *	Designates the type of service characteristic of manual transmissions and spiral-bevel axles operating under moderately severe conditions of speed and load. These service conditions require a lubricant having load carrying capacities greater than those which will satisfy API-GL-1 service, but below the requirements of lubricants satisfying API-GL-4 service.	Lubricants designated for this service typically contain additives which react with tooth surfaces at the temperature resulting from high speed or load. Due to the rate of reactivity or the relatively low concentration of the additives, products designated for GL-3 are not formulated to provide adequate protection for hypoid gears. The scoring resistance of such oils is comparable to that provide by CRC reference gear oils below RGO-104.
GL-4 *	This classification is still used commercially to describe lubricants, but the equipment required for the antiscoring test procedures to verify lubricant performance is no longer available. Designates the type of service characteristic of gears, particularly hypoid in passenger cars and other automotive type equipment operated under high-speed low-torque, and low-speed, high-torque conditions.	Lubricants suitable for this service are those which provide antiscore protection equal or better than define by CRC Reference Gear Oil RGO-105 and have been subjected to the test procedures and provide the performance levels described in ASTM STP-512, dated April 1972.
GL-5	Designates the type of service characteristic of gears, particularly hypoid, in passenger cars and other automotive equipment operated under high-speed, shock-load; high-speed, low-torque;and low-speed, high-torque conditions.	Lubricants suitable for this service are those which provide antiscore protection equal to or better than defined by CRC Reference Gear Oil RGO-110 and have been subjected to the test procedures and provide the performance levels described in ASTM STP-512, dated April 1972.

TABLE XXI. Description of commercial performance characteristics (ct'd).

API Letter Designation	Service Description	Oil Description
GL-6 *	This is an obsolete classification. The equipment required for the test procedure to verify lubricant performance is no longer available. The type of service designated by API-GL-6 is characteristic of gears, specifically high offset hypoid gears (above 2 in offset and approaching 25% of ring gear diameter) in passenger cars and other automotive equipment operated under high-speed high-performance conditions.	Lubricants suitable for this service are those which provide antiscore protection equal to or greater than Reference Gear Oil L-100 and have been subjected to the test procedures and provide the performance levels described in ASTM STP-512, dated April 1972.

* Obsolete classifications

30. PERFORMANCE DEFINITION OF MILITARY SPECIFICATION GEAR OILS

30.1 As with the commercial gear oils, Military Specification MIL-L-2105 uses a series of bench and full scale axle tests to define lubricant performance. These requirements are shown in Table XXII. It should be noted that MIL-L-2105 lubricants meet the commercial API classification GL-5.

TABLE XXII. Performance requirements for MIL-L-2105 gear oil.

Test	Requirements
Storage Stability	The gear oil shall demonstrate the following characteristics for separated solid/liquid material. Solid Material-When the separated material is solid, the average increase in the weight of each centrifuge tube and residue over the initial weight of the clean tube shall not exceed 0.25 mass percent of the additive material originally contained in the Liquid Material - When the separated material is liquid, it shall not exceed 0.50 volume percent of the additive material originally contained in the sample.

TABLE XXII. Performance requirements for MIL-L-2105 gear oil (cont'd).

Test	Requirements
Compatibility	The oil shall be compatible with other gear lubricants, previously qualified under this specification, when tested against selected reference oils.
L-33*	When tested for seven days under the prescribed conditions, satisfactory performance shall be demonstrated if rust is observed on no more than 1 percent of the area of the cover plate and no rust is observed on gear teeth, bearings, the differential case, or any functional area.
L-60*	When tested for 50 hours, satisfactory performance shall be demonstrated if the lubricant viscosity increase is no more than 100 percent; n-pentane insolubles are no more than 3 percent by mass; and benzene insolubles are no more than 2 percent by mass.
L-42*	The oil shall satisfactorily prevent gear tooth scoring or other distress when tested in duplicate.
L-37*	The oil shall satisfactorily prevent gear tooth ridging, rippling, pitting, welding, excessive wear or other surface distress or the formation of objectionable deposits and shall not produce excessive wear, pitting or corrosion of bearing rollers, races, or thrust washers when tested using noncoated and phosphate-coated gear assemblies.

*ASTM Special Technical Publication STP 512

APPENDIX E

PREPARATION PROCEDURE FOR SPECIFICATIONS MIL-L-8937, MIL-L-23398, and MIL-L-46010

10. Vapor degrease with aliphatic naphtha meeting requirements of TT-N-95, Type 2.

20. Sandblast the surface with 120 mesh sand.

30. Treat the surface with the treatment listed below:

    Aluminum - MIL-STD-171, Finish No. 7.2.1.

    Copper - MIL-F-495.

    Magnesium - MIL-M-45202, Type 1, Class A, B, or C.

    Steel - DoD-P-16232, Type M, Class 3 or Type Z, Class 3.

    Stainless Steel - QQ-P-35, Types I, II, or III as applicable.

    Titanium - Alkaline Anodize.

40. Apply coating.

50. Cure for the specified time. NOTE: Timing begins when the coated part reaches the specified temperature.

60. The cured coating shall be 0.0005 cm (0.0002") to 0.00125 cm (0.0005") thick.

APPENDIX F

NATIONAL STOCK NUMBER FOR PRODUCTS IN CHAPTER II

Specification	Grade/type	NSN	Size
Lubricating engine & gear oils			
MIL-L-2104	10W	9150-01-177-3988	1 qt
		9150-00-183-7807	Bulk
		9150-00-186-6668	5 gal
		9150-00-191-2772	55 gal
	30	9150-01-178-4726	1 qt
		9150-00-188-9858	5 gal
		9150-00-189-6729	55 gal
		9150-00-183-7808	Bulk
	40	9150-00-189-6730	1 qt
		9150-00-188-9860	5 gal
		9150-00-188-9862	55 gal
		9150-00-405-2987	bulk
	15W/40	9150-01-178-4725	1 qt
		9150-01-152-4118	5 gal
		9150-01-152-4119	55 gal
MIL-L-2105	75W	9150-01-035-5390	1 qt
		9150-01-035-5391	5 gal
		9150-01-048-4593	1 gal
	80W/90	9150-01-035-5392	1 qt
		9150-01-035-5393	5 gal
	*Limited slip	*9150-00-001-9395	5 gal
		9150-01-035-5394	55 gal
	85W/140	9150-01-048-4591	1 qt
		9150-01-035-5395	5 gal
		9150-01-035-5396	55 gal
MIL-L-6082	1065	9150-00-231-6669	55 gal
MIL-L-7808		9150-00-108-5359	8 oz
		9150-00-782-2627	1 qt
		9150-00-270-4057	1 gal
		9150-00-782-2679	55 gal
MIL-L-7870		9150-00-263-3490	1 qt
		9150-00-281-9438	55 gal
		9150-00-542-1430	4 oz
MIL-L-9000	9250	9150-00-181-8229	5 gal
		9150-00-181-8097	55 gal
		9150-00-181-8232	bulk

APPENDIX F

NATIONAL STOCK NUMBER FOR PRODUCTS IN CHAPTER II (cont'd)

Specification	Grade/type	NSN	Size
MIL-L-21260	10W	9150-00-111-3199	5 gal
		9150-00-111-0208	55 gal
# NSN for other size containers can be obtained from DGSC.	30	9150-00-111-0201	1 Pt
		9150-00-153-0207	1 qt
		9150-00-111-0209	5 gal
		9150-00-111-0210	55 gal
	#40	9150-01-293-2773	5 gal
	#15W/40	9150-01-293-2772	1 qt
MIL-L-23699		9150-00-180-6266	8 oz
		9150-00-985-7099	1 qt
		9150-01-144-3808	1 qt
		9150-00-681-5999	55 gal
MIL-L-46152	10W	9150-00-186-6682	1 qt
		9150-00-186-6683	5 gal
		9150-00-186-6685	55 gal
	30	9150-00-186-6689	1 qt
		9150-00-186-6691	5 gal
		9150-00-186-6696	55 gal
	5W30	9150-01-278-1357	1 qt
		9150-01-275-8404	55 gal
	10W/30	9150-01-177-2762	1 qt
		9150-01-104-0956	1 gal
		9150-00-256-6411	5 gal
		9150-00-186-6703	55 gal
		9150-00-451-6947	bulk
	15W/40	9150-01-177-2763	1 qt
		9150-00-186-6706	5 gal
		9150-00-186-6709	55 gal
MIL-L-46167		9150-00-402-4478	1 qt
		9150-00-402-2372	5 gal
		9150-00-491-7197	55 gal
VV-L-765	140	9150-00-270-0067	5 gal
	250	9150-00-292-0097	1 gal
		9150-00-664-4972	16 gal

NATIONAL STOCK NUMBER FOR PRODUCTS IN CHAPTER II (cont'd)

Specification	Grade/type	NSN	Size
Power transmission/hydraulic fluids			
MIL-H-5606		9150-00-252-6383	1 qt
		9150-00-223-4134	1 gal
		9150-00-082-7524	10 gal
		9150-00-265-9408	55 gal
MIL-H-6083		9150-00-935-9807	1 qt
		9150-00-159-4472	16 oz
		9150-00-935-9808	1 gal
		9150-00-935-9809	5 gal
		9150-00-935-9810	55 gal
MIL-H-46001	1	9150-00-966-8830	5 gal
		9150-00-966-8831	55 gal
	2	9150-00-966-8833	5 gal
		9150-00-966-8834	55 gal
	3	9150-00-966-8832	5 gal
		9150-00-966-8835	55 gal
	4	9150-00-966-8837	55 gal
MIL-H-46170	I	9150-00-111-6256	1 qt
		9150-00-111-6254	1 gal
		9150-01-158-0462	55 gal
	II	9150-01-119-8149	55 gal
MIL-B-46176		9150-01-102-9455	1 gal
		9150-01-059-2586	1 gal
		9150-01-123-3152	5 gal
		9150-01-072-8379	55 gal
MIL-H-83282		9150-00-149-7431	1 qt
		9150-00-149-7432	1 gal
		9150-00-180-6290	55 gal
VV-B-680		9150-00-190-0932	1 pt
		9150-00-231-9071	1 gal
DOD-L-85734		9150-01-209-2684	1 qt
		9150-01-210-1938	1 gal
		9150-01-209-3399	55 gal

NATIONAL STOCK NUMBER FOR PRODUCTS IN CHAPTER II (cont'd)

Specification	Grade/type	NSN	Size
Automatic Transmission Fluids			
	Dexron II	9150-00-657-4959	5 gal
		9150-00-698-2382	1 qt
	Type F (Ford ESN-M2C33-F)	9150-00-843-1636	1 gal
		9150-01-092-9755	1 qt
Lubricating greases			
VV-G-632	2	9150-00-753-4649	8 oz
		9150-00-273-2374	35 lb
VV-G-671	1	9150-00-257-5370	1.75 lb
		9150-00-235-5568	7.5 lb
		9150-00-272-7652	35 lb
	2	9150-00-190-0918	1.75 lb
		9150-00-190-0919	7.5 lb
	3	9150-00-190-0917	1.75 lb
VV-G-679		no NSN's	
MIL-G-4343		9150-00-119-9291	2 oz
		9150-00-269-8255	1.75 lb
MIL-G-6032	I	9150-00-190-0926	8 oz
		9150-00-257-5360	1.75 lb
	II, CLA	9150-00-261-8278	box
	II, CLB	9150-00-261-8289	box
	II, CLC	9150-00-261-8290	box
	II, CLD	9150-00-261-8291	box
	II, CLG	9150-00-261-8292	box
MIL-G-10924		9150-00-065-0029	2.25 oz
		9150-00-935-1017	14 oz
		9150-00-190-0904	1.75 lb
		9150-00-190-0905	6.5 lb
		9150-00-530-7369	120 lb
MIL-G-18458		9150-00-530-6814	35 lb
MIL-G-21164		9150-00-754-2595	1.75 lb
		9150-00-223-4004	6.5 lb
		9150-00-965-2003	35 lb

NATIONAL STOCK NUMBER FOR PRODUCTS IN CHAPTER II (cont'd)

Specification	Grade/type	NSN	Size
MIL-G-23549		9150-00-985-7316	1.75 lb
		9150-00-235-5555	7.5 lb
		9150-00-823-8047	35 lb
MIL-G-23827		9150-00-985-7244	4 oz
		9150-00-985-7245	8 oz
		9150-00-985-4017	14 oz
		9150-00-985-7243	1 oz
		9150-00-985-7246	1.75 lb
		9150-00-985-7247	6.5 lb
		9150-00-985-7248	35 lb
MIL-G-24139		9150-00-180-6381	1.75 lb
		9150-00-180-6382	6.5 lb
DOD-G-24508		9150-00-149-1593	1 lb
		9150-01-117-2928	5 lb
MIL-G-46003		9150-00-754-0063	1 lb
		9150-00-057-8976	5 lb
MIL-G-46178		None given.	
MIL-G-46886	I	9150-00-145-0161	8 oz
	II	9150-00-584-4299	8 oz
MIL-G-81322		9150-00-181-7724	8 oz
		9150-00-944-8953	1 lb
		9150-00-145-0268	5 lb
		9150-00-935-5851	35 lb
MIL-G-81937		No NSN w/Army Int.	
Corrosion preventatives and specialty compounds			
O-I-490		6850-00-753-4967	6 oz
		6850-00-598-7311	12 oz
P-D-680	I	6850-00-281-3061	4 oz
		6850-00-264-9038	5 gal
		6850-00-285-8012	55 gal
		6850-00-264-9039	bulk
		6850-00-281-1985	1 gal
	II	6850-00-110-4498	1 pt
		6850-00-664-5685	1 qt
		6850-00-274-5421	5 gal
		6850-00-285-8011	55 gal
		6850-00-637-6135	bulk

APPENDIX F

NATIONAL STOCK NUMBER FOR PRODUCTS IN CHAPTER II (cont'd)

Specification	Grade/type	NSN	Size
VV-L-800		9150-00-273-2389	4 oz
		9150-00-458-0075	16 oz
		9150-00-231-6689	1 qt
		9150-00-231-9062	5 gal
		9150-00-281-2060	55 gal
VV-P-216	I	9150-00-261-7899	1 pt
		9150-00-223-4119	1 gal
	II	9150-00-529-7518	16 oz
MIL-C-372		6850-00-224-6656	2 oz
		6850-00-224-6657	8 oz
		6850-00-224-6658	1 qt
		6850-00-224-6663	1 gal
		6850-00-249-8029	5 gal
		6850-00-753-4806	55 gal
MIL-L-3150		9150-00-231-2361	1 qt
		9150-00-231-2356	5 gal
MIL-C-10597		6850-00-598-7328	1 qt
MIL-C-11090		6850-00-584-4077	1 gal
		6850-00-224-6665	5 gal
		6850-00-224-6666	55 gal
MIL-L-11734		No NSN w/Army interest	
MIL-A-11755		6850-00-174-1806	55 gal
MIL-L-14107		9150-00-292-9689	1 qt
		9150-00-292-9687	5 gal
MIL-C-16173	1	8030-00-062-6950	1 qt
		8030-00-231-2345	1 gal
		8030-00-244-1299	5 gal
		8030-00-244-1300	55 gal
	2	8030-00-244-1297	1 gal
		8030-00-244-1298	5 gal
		8030-00-244-1295	55 gal
	3	8030-00-837-6557	1 pt
		8030-00-244-1296	1 gal
		8030-00-244-1293	5 gal
		8030-00-244-1294	55 gal

NATIONAL STOCK NUMBER FOR PRODUCTS IN CHAPTER II (cont'd)

Specification	Grade/type	NSN	Size
MIL-C-16173	4	8030-00-903-0931	1 pt
		8030-00-062-5866	1 gal
		8030-00-526-1605	5 gal
		8030-00-526-1604	55 gal
	5	8030-00-223-3193	1 gal
		8030-00-137-1671	5 gal
MIL-L-46000		9150-00-935-6597	2 oz
		9150-00-889-3522	4 oz
		9150-00-687-4241	1 qt
		9150-00-753-4686	1 gal
MIL-L-46150		9150-00-949-0323	8 oz
		9150-01-109-7793	10 lb
MIL-L-63460		9150-01-102-1473	0.5 oz
		9150-01-079-6124	4 oz
		9150-01-054-6453	1 pt
		9150-01-053-6688	1 gal
MIL-D-46002	1	9150-00-889-3523	1 qt
		9150-00-985-7293	5 gal
		9150-00-407-0973	55 gal
MIL-A-46153		6850-00-181-7929	1 gal
		6850-00-181-7933	5 gal
		6850-00-181-7940	55 gal
MIL-C-51047		6850-00-849-4035	1.5 oz
VV-L-751	1	9150-00-234-5197	5 lb
		9150-00-261-7891	35 lb
		9150-00-530-7293	120 lb
	2	9150-00-234-5199	5 lb
		9150-00-246-3276	35 lb
		9150-00-530-7371	120 lb
	3	9150-00-234-5200	5 lb
		9150-00-264-2918	35 lb

APPENDIX F

NATIONAL STOCK NUMBER FOR PRODUCTS IN CHAPTER II (cont'd)

Specification	Grade/type	NSN	Size
Solid film lubricants			
MIL-A-53009		6850-01-160-3868	1 qt
MIL-L-8937		9150-00-834-5608	1 pt
		9150-00-985-7255	1 gal
MIL-L-23398	I	9150-00-954-7422	1 qt
	II	9150-00-754-0064	12 oz
MIL-L-46010		9150-00-948-6912	1 qt
		9150-00-948-7025	1 gal

APPENDIX G

LOW OR NON DETERGENT OILS

Property	MIL-L-6082D[1]			
	1065[2]		1100[3]	
	Min.	Max.	Min.	Max.
Viscosity @210 °F, cSt	10.78*	12.42*	18.86*	21.05*
VI	100	---	95	---
Flash Pt, °F(°C)	420(216)	---	470(243)	---
Pour Pt., °F(°C)	---	0(-18)	---	10 (-12)
Con Carbon, %M	---	0.6	---	1.2
TAN (TBN)	---	0.10(--)	---	0.10(--)
Ash, %M	---	0.0025	---	0.0025
S, %M	---	0.5	---	0.5
Saponification No.	---	0.5	---	0.5
Cu Corrosion	---	1	---	1

*Viscosity without pour depressant added.
1/ MIL-L-6082D Lubricating Oil, Aircraft Reciprocating Engine (Piston)
2/ 1065 ≈ Grade 30
3/ 1100 ≈ Grade 50

All of the above oils can only contain pour depressents, i.e., they contain no antioxidants or wear inhibitors.

Property	MIL-L-7870A Lubricating Oil General Purpose Low Temperature
Viscosity @38 °C	10 cSt
Pour Point	-57 °C
Flash Point	130 °C

The products under this specification require the use of oxidation and corrosion inhibitors. Some of these additives could have detergent characteristics.

APPENDIX H

RECOMMENDED TEMPERATURE AND GRADE USAGE OF SELECTED MILITARY LUBRICANTS ON VEHICLE COMPONENTS AND LUBRICANT OPERATING TEMPERATURE LIMITS

10. General

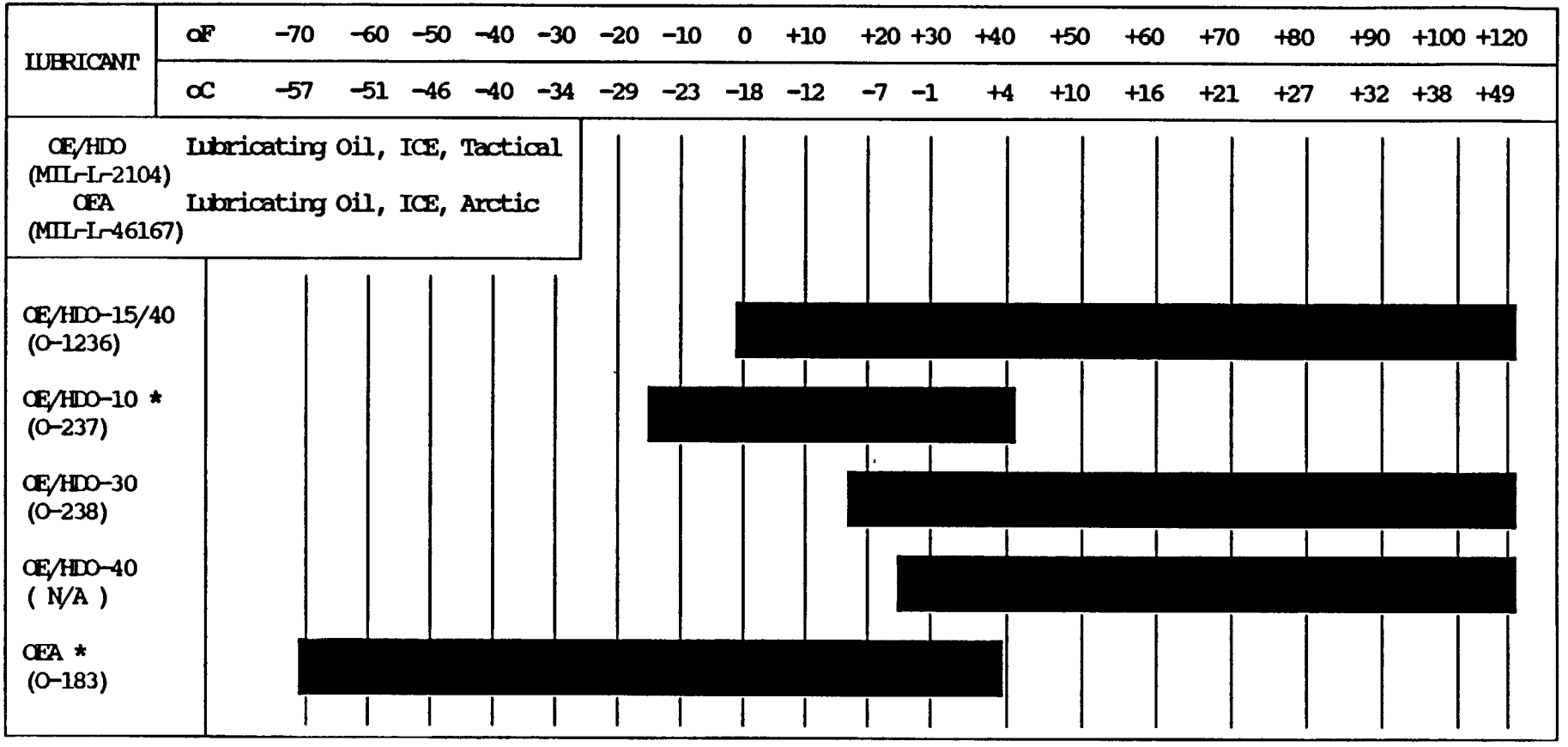
10.1 The operating temperature range of a lubricant is dependent on the grade and the component where it is being used. To facilitate the answer to "What lubricants to use?" this appendix provides operating temperature charts of major vehicle components.

10.2 The charts only address typically used lubricants and most major components. More charts will be included as they become available.

10.3 Chart G provides the recommended maximum operating temperature limits of selected lubricants covered by this handbook.

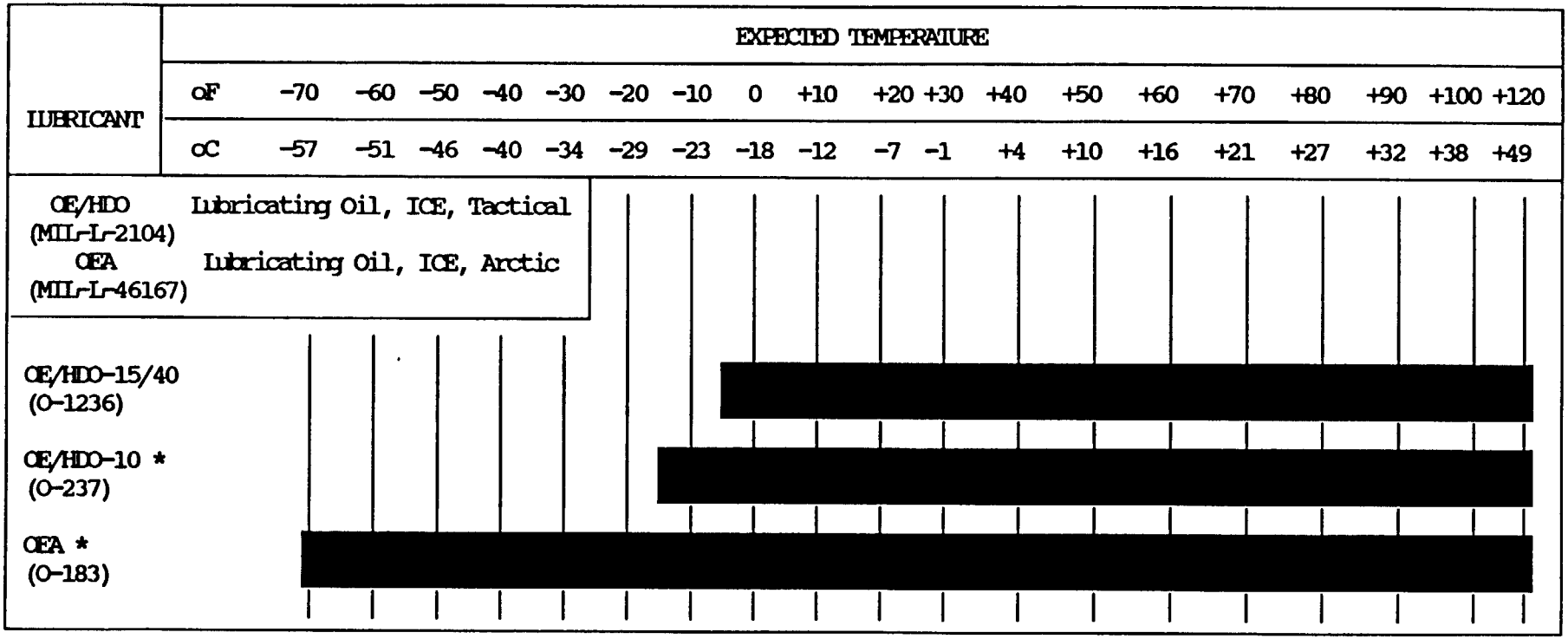
CHART A LUBRICANTS FOR ENGINE APPLICATIONS

EXPECTED TEMPERATURE



* If OEA lubricant is required to meet the low expected-temperature range, OEA lubricant is to be used in lieu of OE/HDO-10 lubricant for all expected temperatures where OE/HDO-10 is specified.

CHART B LUBRICANTS FOR TRANSMISSION APPLICATIONS



* If OEA lubricant is required to meet the low expected-temperature range, OEA lubricant is to be used in lieu of OE/HDO-10 lubricant for all expected temperatures where OE/HDO-10 is specified.

CHART C LUBRICANTS FOR GEAR APPLICATIONS

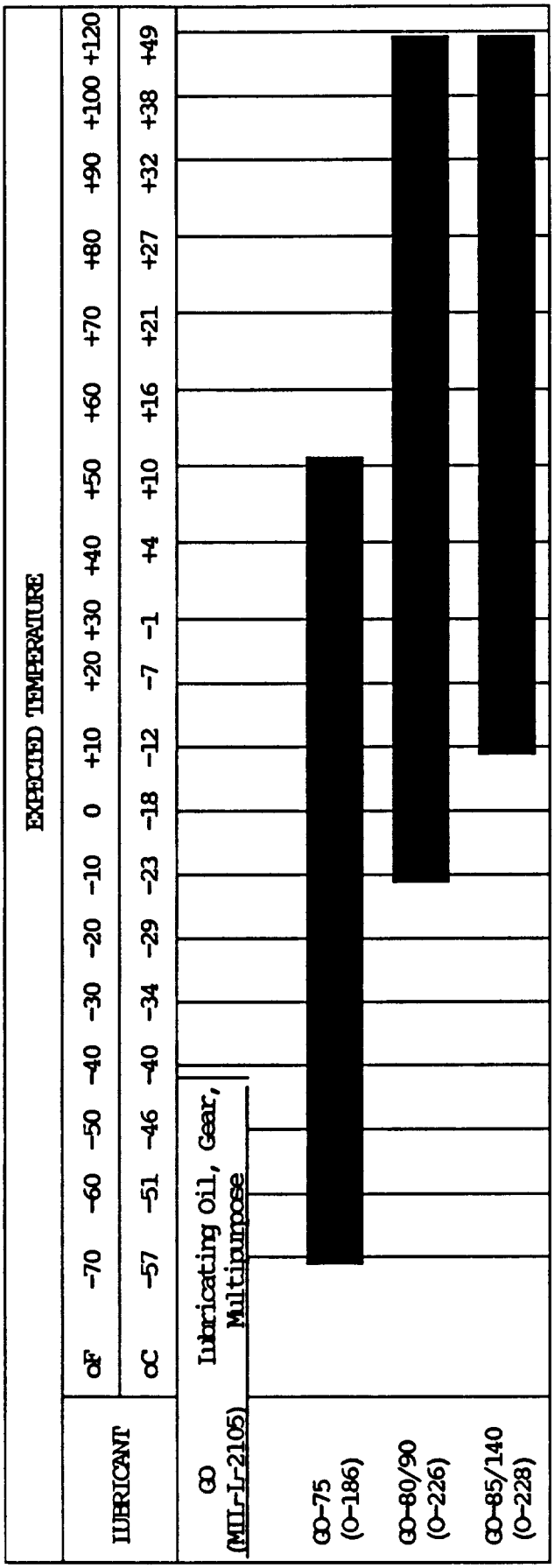


CHART D FLUIDS FOR HYDRAULIC SYSTEM APPLICATIONS

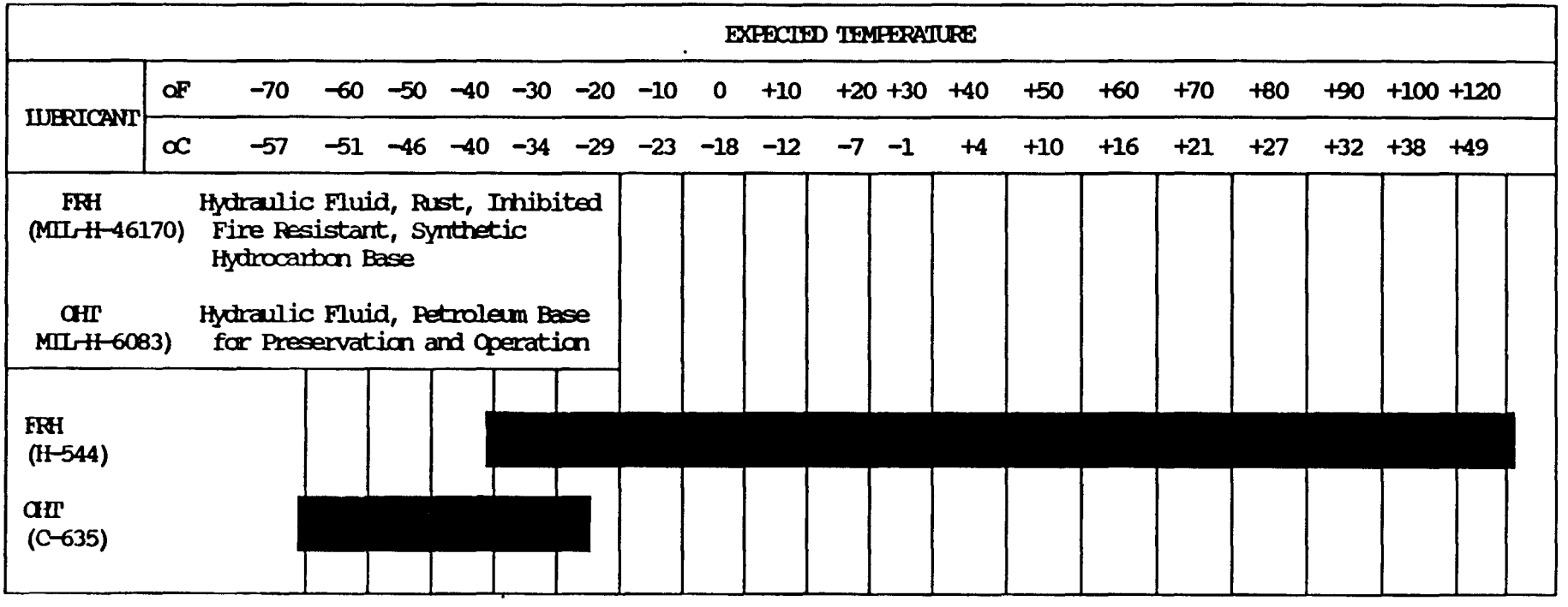


CHART E LUBRICANTS FOR EXPOSED GEAR, CHAIN AND WIRE ROPE APPLICATIONS

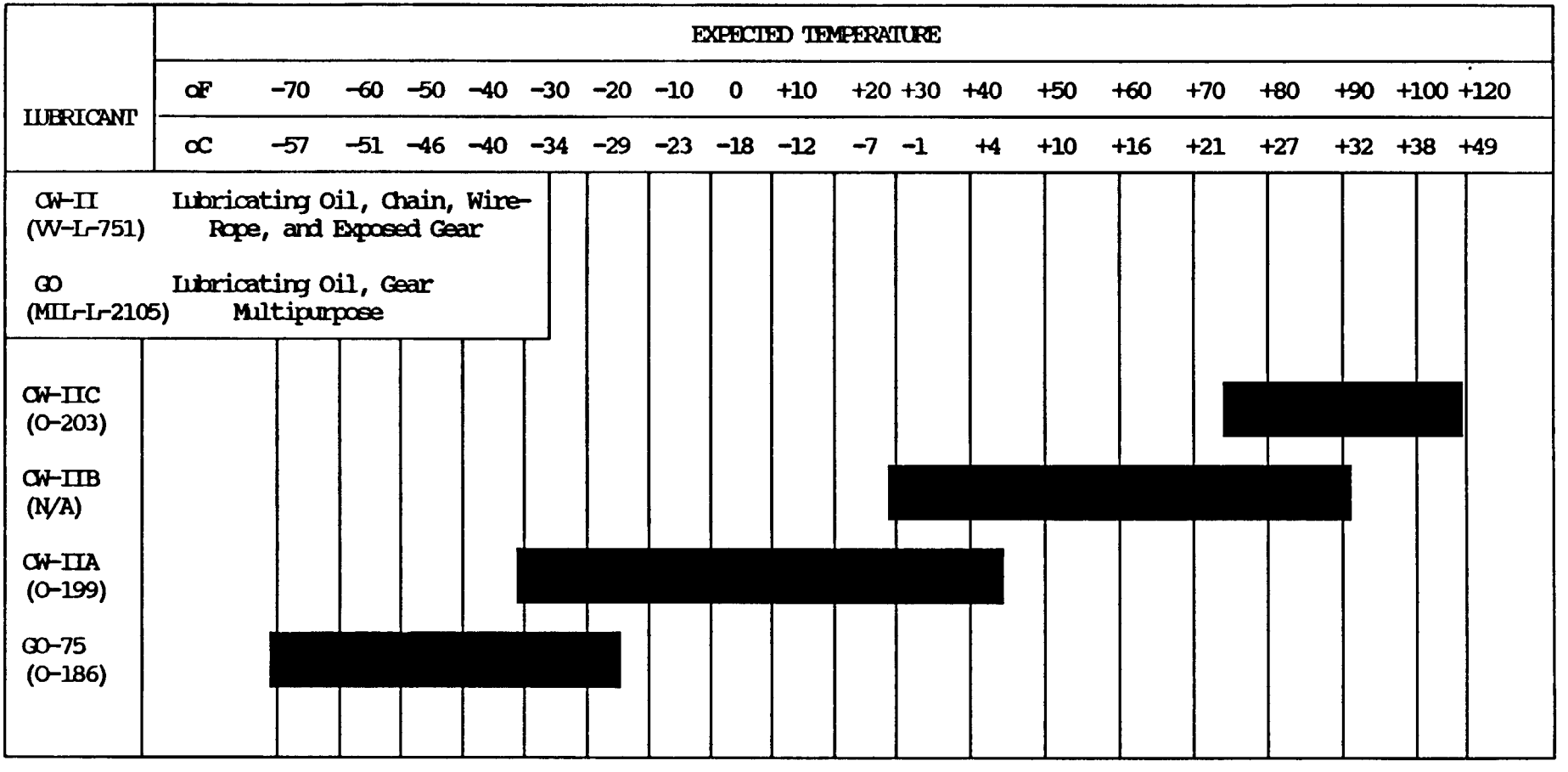
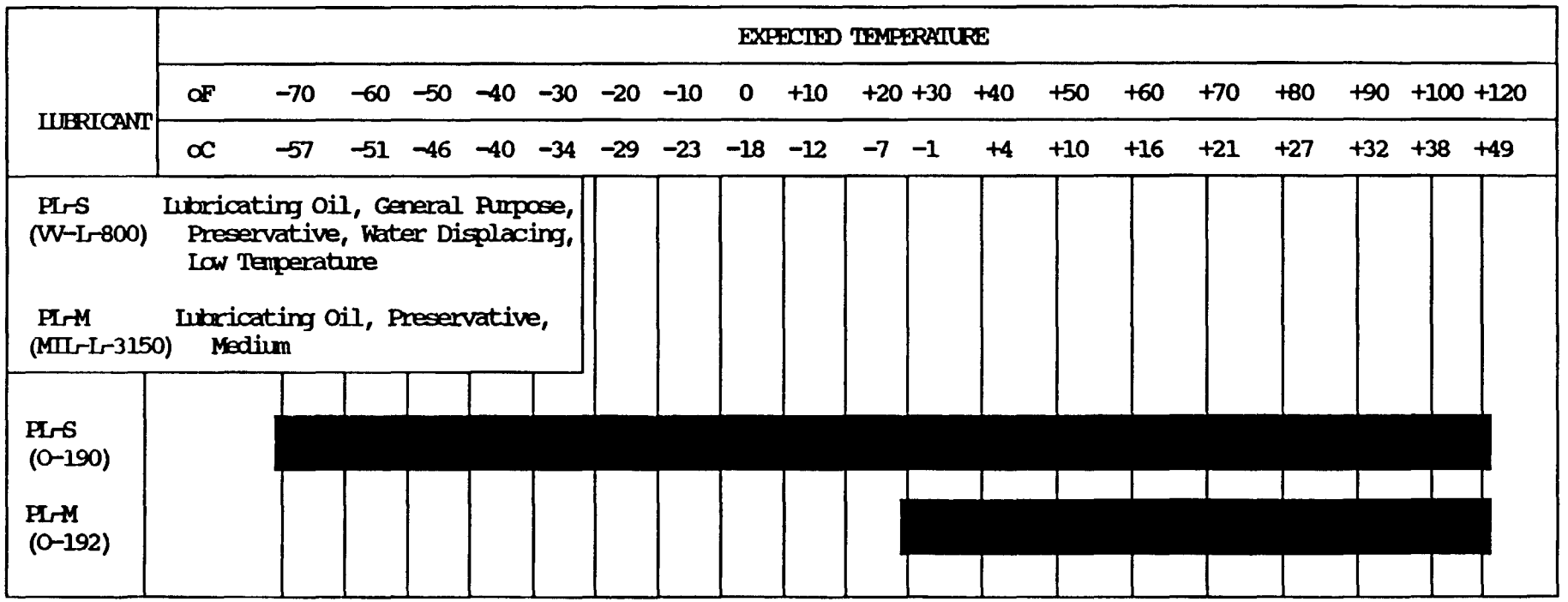


CHART F LUBRICANTS FOR GENERAL PURPOSE APPLICATIONS



RECOMMENDED OPERATION TEMPERATURE LIMITS FOR LUBRICATING OILS AND HYDRAULIC FLUIDS

CHART G

Fluid or Lubricants	Maximum Allowable Temperatures	
	Sustained Operation	Short Period Operation*
Engine Lubricants		
MIL-L-2104 MIL-L-21260 MIL-L-46152 MIL-L-46167	250 °F (120 °C) for engine use 300 °F (150 °C) for automatic transmission or gear box use	275 °F (135 °C) for engine use 300 °F (150 °C) limit should not be exceeded for automatic transmission or gear box use
Brake Fluids		
VV-B-680	265 °F (130 °C)	300 °F (150 °C)
MIL-B-46176	265 °F (130 °C)	400 °F (250 °C)
Hydraulic Fluids		
MIL-H-5606	160 °F (70 °C) open systems 275 °F (150 °C) closed systems	500 °F (260 °C) if system is sealed and inert gas pressurized
MIL-H-6083	160 °F (70 °C) open systems 250 °F (120 °C) closed systems	275 °F (135 °C)
Gear Oil MIL-L-2105	250 °F (120 °C)	300 °F (150 °C)
Transmission Fluid DEXRON II	300 °F (150 °C)	300 °F (150 °C)

* Not to exceed 15 minutes duration

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5. PROBLEM AREAS

a. Paragraph Number and Wording

b. Recommended Wording

c. Reason/Rationale for Recommendation

6 REMARKS

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