SAE Aerospace
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AEROSPACE STANDARD

SAE AS1701 | REV. C

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Superseding AS1701B

Lubricant, Solid Film

RATIONALE

AS1701C has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE:

This document covers the performance requirements for solid dry film lubricants, air dried, or heat cured for use in aerospace applications. These lubricants are intended to prevent galling, and may be capable of remaining effective for extended periods of time after exposure to extreme environmental conditions.

1.1 Field of Application:

The solid film lubricants covered by this document are intended for aerospace applications exposed to extreme environments. Some may be suitable for use in a vacuum at temperatures ranging from -365 to +1400 °F (-221 to 760 °C).

1.2 Product Classification:

In this document is defined the various classes of solid film lubricants, their temperature limitations, and compatibility usage (see Table 1).

1.3 Safety - Hazardous Materials:

While the materials, methods, applications, and processes described or referenced in this document may involve the use of hazardous materials, this document does not address the hazards which may be involved in such use. The product vendor shall prepare materials safety data sheets (MSDS) in accordance with AMS 2825 and abide by MSDS requirements to ensure familiarity with the safe and proper handling of hazardous materials used and take necessary precautionary measures to ensure the health and safety of all personnel involved.

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TABLE 1 - Classes of Solid Film Lubricants

Class	Temperature Limits Min	Temperature Limits Max	Usage	Primary Lubricant	Binder	Cure	Thermal Stability ±15 ° (±8 °C)	Corrosion Resistance
Class I	-65 °F (-54 °C)	+450 °F (+232 °C)	General Purpose: Titanium, Aluminum, Low/High Alloy Steels	MoS_2	Organic	Heat Cure	450 °F (232 °C)	Pass
Class II	-65 °F (-54 °C)	+450 °F (+232 °C)	General Purpose: Titanium, Aluminum, Low/High Alloy Steels	MoS_2	Organic	Air Dry	450 °F (232 °C)	Pass
Class III	-65 °F (-54 °C)	+750 °F (+399 °C)	Corrosion Resistant Steels, Heat-Corrosion Resistant Steels, Titanium Alloys	MoS_2	Organic	Heat Cure	750 °F (399 °C)	Pass
Class IV	-65 °F (-54 °C)	+1400 °F (+760 °C)	Corrosion Resistant Steels, Heat-Corrosion Resistant Steels Waspalloy	Inorganic Pigments	Inorganic	Heat Cure	1400 °F (760 °C)	Pass
Class V	-65 °F (-54 °C)	+850 °F (+454 °C)	Corrosion Resistant Steels, Heat-Corrosion Resistant Steels	MoS_2	Inorganic	Air Dry	850 °F (454 °C)	Pass
Class VI	-365 °F (-221 °C)	+850 °F (+454 °C)	Corrosion-Resistant Steels Heat-Corrosion Resistant Steels, Nickel Based Alloys, Titanium Alloys for Use with Fuels, Oxidizers such as hydrazine, LOX, Nitrogen Tetroxide UDM11	MoS_2	Inorganic	Heat Cure	850 °F (454 °C)	Pass

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this specification and references cited herein, the text of this specification takes precedence. Nothing in this specification, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2488 Anodic Treatment, Titanium and Titanium Alloys
AMS 2825 Material Safety Data Sheets
AS7108 National Aerospace and Defense Contractors Accreditation Program Requirements for Chemical Processing

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM B 117	Test Method for Salt Spray (Fog) Testing
ASTM E 595	Test Method for Total Mass Loss and Collected Volatile Condensable Materials From Outgassing in a Vacuum Environment
ASTM D 1141	Substitute Ocean Water
ASTM D 1186	Test Method for Non-Destructive Measurement of Dry Film Thickness of Non-Magnetic Coatings Applied to a Ferrous Base
ASTM D 1193	Reagent Water
ASTM D 1400	Test Method for Non-Destructive Measurement of Dry Film Thickness of Non-Conductive Coatings Applied to a Non-Ferrous Metal Base
ASTM D 2510	Test Method for Adhesion of Solid Film Lubricants
ASTM D 2512	Compatibility of Materials With Liquid Oxygen (Impact Sensitivity Threshold and Pass-Fail Techniques), Test Method for
ASTM D 2625	Test Method for Endurance (Wear) Life and Load-Carrying Capacity of Solid Film Lubricants (Falex Pin and Vee Method)
ASTM D 2714	Test Method for Calibration and Operation of the Falex Block-On-Ring Friction and Wear Testing Machine
ASTM D 3359	Test Method for Measuring Adhesion by Tape Test

2.3 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

DOD-P-16232	Phosphate Coatings, Heavy, Manganese or Zinc Base (For Ferrous Metals)
MIL-C-5541	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-DTL-5624	Turbine Fuel, Aviation, Grades JP-4, JP-5, and JP-5/JP-8 ST
MIL-PRF-7808	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, Nato Code Number 0-148
MIL-A-8243	Anti-Icing and Deicing-Defrosting Fluids
MIL-A-8625	Anodic Coatings for Aluminum and Aluminum Alloys
MIL-PRF-23699	Lubricating Oil, Aircraft Turbine Engine, Nato Code Number 0-156
MIL-PRF-83282	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft, Metric, Nato Code Number H-537
O-M-232	Methanol (Methyl Alcohol)
AMS-QQ-P-35	Passivation Treatments for Corrosion-Resistant Steel
VV-D-1078	Damping Fluid, Silicone Base (Dimethyl Polysiloxane)

3. TECHNICAL REQUIREMENTS:

3.1 General:

The solid dry film lubricants shall NOT contain silver or its compounds, lead or halogenated solvents as part of their formulations. The lubricants shall consist essentially of lubricating solids, dispersed in a suitable binder and be capable of being applied by either brushing, spraying, or dipping. The user should know which lubricants cause detrimental effects for the applications in which they are used.

3.1.1 Physical Properties: The application of the solid film lubricants to the product or component, including curing, shall have no adverse effect on the physical or mechanical properties of the product.

3.1.2 Process Application: Process application shall be in accordance with the requirements of AS7108.

3.2 Lubricant Composition:

The composition of the solid film lubricant shall be such to produce cured film coatings capable of meeting the requirements of this document.

3.3 Bonding Capability:

The solid film lubricants shall be capable of being applied as a coating to specified surface(s), completely cured, and ready for use. For testing requirements in 3.4 through 3.12, the lubricant shall be completely cured and bonded to panels, specimens, or actual parts.

3.3.1 Surface Treatment of Parts: To obtain maximum adhesion and to minimize the possibility of surface contamination, surfaces of parts shall be treated per Table 2 prior to the coating application unless otherwise specified in the purchase order or applicable drawing.

3.4 Coating Thickness:

Unless otherwise specified, the coating thickness on external surfaces requiring coating shall on external surface requiring coating shall be 0.0002 to 0.0005 in thick (0.0051 to 0.0127 mm thick) when determined in accordance with 4.2.1. Unless otherwise specified, internal surfaces requiring coating shall show complete coverage with no restrictions on thickness when determined visually with no magnification. Surfaces defined as coating optional, external or internal shall not be inspected for coverage or thickness.

3.5 Film Adhesion:

The lubricant film when tested in accordance with 4.2.2 shall not be lifted from the test panel or part such that the substrate is exposed. The coatings may have a uniform deposit of powdery material clinging to the tape.

3.5.1 Fluid Resistance: The lubricant film shall not flake, crack, peel, or be removed when tested according to 4.2.2.1.

TABLE 2 - Surface Treatment Prior to Coating

Material	Surface Treatment Prior to Coating Application
Carbon and Low Alloy Steels	(a) Degrease with alkaline cleaner or vapor degrease (b) Unplated parts only: Dry grit blast with 120-400 mesh aluminum oxide at a blasting pressure of 40 psi ± 10 psi (2.758 $(10)^5$ Pa ± 6.894 $(10)^4$ Pa), or equivalent. (c) Phosphate per DOD-P-16232 type M or Z Class 3.
Precipitation Hardened, 300 Series and 400 Series Stainless Steel, Other Corrosion Resistant Steels, Nickel Base Alloys, and Super Alloys	(a) Degrease with alkaline cleaner or vapor degrease (b) Unplated parts only: Dry grit blast with 120-400 mesh aluminum oxide at a blasting pressure of 40 psi ± 10 psi (2.758 $(10)^5$ Pa ± 6.894 $(10)^4$ Pa), or equivalent. (c) Passivate, AMS-QQ-P-35
Aluminum Alloys	(a) Degrease with alkaline cleaner or vapor degrease (b) Unplated parts only: Dry grit blast with 120-400 mesh aluminum oxide, or equivalent to an optimum surface roughness of about 32 RHR. (c) Chromate per MIL-C-5541 or anodize per MIL-A-8625.
Titanium Alloys	(a) Degrease with alkaline cleaner (b) Unplated parts only: Dry grit blast with 120-240 mesh aluminum oxide, or equivalent, or alkaline anodize per AMS 2488.

3.6 Thermal Stability:

The lubricant film shall not flake, crack, or peel and shall meet the requirements of 3.5 and 3.10 when tested in accordance with 4.2.3.

3.7 Vacuum Stability:

The lubricant film shall show a total mass loss of less than or equal to 1.0% and collected volatile condensable material measurement less than or equal to 0.1%, when tested in accordance with 4.2.4.

NOTE: This requirement pertains to Class VI lubricants only.

3.8 Shock Sensitivity to Liquid Oxygen:

The lubricant film, shall show no adverse reaction to liquid oxygen when tested in accordance with 4.2.5.

NOTE: This requirement pertains to Class VI lubricants only.

3.9 Film Appearance:

The lubricant film shall appear free from cracks, scratches, blisters, foreign matter or other surface imperfections when examined in accordance with 4.2.6.

3.10 Corrosion Resistance:

Class I and II lubricant films shall show no signs of substrate corrosion greater than 1/16 inch in diameter when tested in 4.2.7, exposure times shall be 100 hours for Class I and 72 hours for Class II.

NOTE: All other classes are designed for corrosion resistant alloys and materials.

3.11 Coefficient of Friction:

The lubricant film shall have a static coefficient of friction of 0.03 to 0.13 when tested in accordance with 4.2.8 and the test shall be performed in an oscillatory mode if static coefficient is to be determined.

3.12 Wear Requirements:

3.12.1 Class I Lubricants:

3.12.1.1 Endurance Life: The lubricant film shall have an average Falex endurance life of 450 minutes at 1000 lbf (4450 N) load, 750 lbf (3336 N) load on the direct reading gauge. No single test shall be less than 390 minutes when tested in accordance to 4.2.9.

3.12.1.2 Load Carrying Capacity: The lubricant film shall have an average Falex load carrying capacity of not less than 2500 lbf (11120 N) gauge. No single test shall be less than 2250 lbf (10010 N) when tested in accordance with 4.2.9.

3.12.2 Class II Lubricants:

3.12.2.1 Endurance Life: The lubricant film shall have an average Falex endurance life of 90 minutes at 1000 lbf (4450 N) load. No single test shall be less than 75 minutes when tested in accordance with 4.2.9.

3.12.2.2 Load Carrying Capacity: The lubricant film shall have an average Falex load carrying capacity of not less than 2500 lbf (11120 N) gauge. No single test shall be less than 2000 lbf (8896 N) when tested in accordance to 4.2.9.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Qualification Tests/Inspection:

The product manufacturer is responsible for the qualification tests and inspection requirements as specified in 4.1.1 and 4.1.2. The coating vendor is responsible for the inspection requirements as specified in 4.1.3.

4.1.1 Qualification Tests: Solid film lubricant products that are supplied in compliance with this document shall be products that have passed all the requirements specified in Section 3 as applicable to each class.

4.1.2 Quality Conformance Tests for Product: Each batch/lot of solid dry film lubricant product shall pass the tests (as applicable to the product class) for coating thickness (3.4), film adhesion (3.5), film appearance (3.9), and wear life requirements (3.12).

4.1.3 Quality Conformance Tests for Processed/Coated Parts: Each lot of processed/coated parts shall pass the tests for coating thickness (3.4), film adhesion (3.5), and film appearance (3.9).

4.2 Classification of Tests:

4.2.1 Coating Thickness Measurement:

4.2.1.1 Nonferrous Material: Coating thickness shall be determined in accordance with ASTM D 1400.

4.2.1.2 Ferrous Material: Coating thickness shall be determined in accordance with ASTM D 1186.

4.2.2 Film Adhesion: Film adhesion shall be determined in accordance with ASTM D 3359 Test Method B.

4.2.2.1 Fluid Resistance: Test the coated panels in accordance with ASTM D 2510 procedure C, in the liquids specified below:

a. ASTM D 1141 Vol. 31
b. MIL-A-8243
c. VV-D-1078
d. MIL-PRF-83282
e. MIL-PRF-23699
f. MIL-PRF-7808
g. MIL-DTL-5624
h. Methanol (O-M-232) 44 parts by volume and Reagent water (D1193) 56 parts by volume

The lubricant film shall not demonstrate softening, blistering, discoloration, undercutting, or loss of adhesion.