Turbine engine oil specifications: HTS and HPC oils: MIL-PRF-23699 (HTS) and SAE AS5780 (HPC)

Background

Traditionally, turbine engine oils (TEO) used in commercial aircraft engines, including in general aviation, have been defined by the US military specification MIL-PRF-23699 (formerly MIL-L-23699). Approval to this specification has been the first essential step in the process of gaining engine equipment manufacturer approval in different engine, engine accessories and auxiliary power unit types. This specification covers four categories of oil:

- STD – Standard, e.g., AeroShell Turbine Oil 500, Mobil Jet 2, Eastman 2380 and TURBONYCOIL 600
- HTS – High Thermal Stability, e.g., AeroShell Turbine Oil 560, Mobil Jet Oil 254 and Eastman 2197
- C/I – Corrosion Inhibited (this grade is for military use only), e.g., AeroShell Turbine Oil 531, Eastman Aero-D, TURBONYCOIL 601 and Castrol AeroJet 5
- EE – Enhanced Ester. No oils listed on QPD (qualified products document as of June 2016).

(**Note:** high load-carrying oils such as AeroShell Turbine Oil *555* are not covered by MIL-PRF-23699 or the new SAE specification; ASTO *555* is covered by DOD-PRF-8573 and DEF STAN 91-100.)

Although primarily a military specification, MIL-PRF-23699 has served the commercial aviation sector since the 1960s. More recently, it has been industry practice to replace military specifications with commercial SAE (Society of Automotive Engineers) specifications, as, in many cases, the test methods for defining the specification are no longer supported. As an example, the range of AeroShell piston engine oils was originally defined by US (MIL) and UK (DERD) specifications but these have now been superseded by SAE J-1966 and J-1899 specifications. Both US and UK governments encourage their militaries to adopt civil standards wherever possible, essentially to save the cost of maintaining military specifications. MIL-PRF-23699 continues to be supported and has recently been updated to introduce a new category called Enhanced Ester (EE).

Society of Automotive Engineers (SAE) AS5780 specification

The SAE E-34 Propulsion Lubricants Committee was established to develop a core TEO specification appropriate to commercial aviation; it was led by Pratt and Whitney and Rolls-Royce. It was recognised that hotter running engines with extended times between overhauls meant that the military MIL-PRF-23699 (HTS) specification was no longer adequate to define the type of oil needed in modern commercial engines. In addition, there were some engine problems associated with product control deficiencies in certain MIL-PRF-23699 “approved” oils. This prompted the equipment manufacturers to question the performance requirements of the oil and the control of quality, the management of change in oil formulations and the oil approval process itself. Such was the seriousness of these problems, that pressure was brought to bear by the airworthiness authorities for tighter controls on TEOs used in commercial aviation. It is fair to say that SAE Qualified Products List (QPL) TEOs are probably the most regulated consumable in the aircraft.

In 2005, SAE AS5780 rev A was ratified and issued. SAE AS5780A defines two grades of oil:

a. SPC – Standard Performance Capability, e.g., AeroShell Turbine Oil 500, Mobil Jet 2 and Eastman 2380. AeroShell Turbine Oil 560 is also listed as SPC but is higher performing compared with other SPC oils.
b. HPC – High Performance Capability, e.g., AeroShell Ascender, Eastman 2197 and Mobil Jet Oil 254.

The SPC grade is almost identical to STD except for additional reporting items included in the SAE spe

The technical differences between SAE AS5780A (HPC) and MIL-PRF-23699F (HTS) grades are detailed in the tables in Appendix 1.

In summary, HPC oils will have

- very low coking propensity in both liquid and vapour/oil mist phase
- higher oxidative stability
- higher thermal stability
- improved compatibility with a wide range of elastomers
- better defined load-carrying capacity.

The AS 5780 specification, as well as listing all the technical requirements for its two grades of oil, also defines the procedure to gain qualification approval. This approval activity is managed by the Qualified Products Group (QPG), a section of the Performance Review Institute, the stand-alone division of SAE that is responsible for product qualifications to SAE specifications and the QPL. The QPG associated with AS5780 comprises only equipment manufacturers and specification authorities; oil suppliers cannot be members. This activity is supported by all the major equipment manufacturers. Approval to AS5780 has become the essential first step to obtaining equipment manufacturers approval. Individual engine approvals remain necessary to ensure the continuing safe and reliable operation of today's modern gas turbine engines.

A. M. Dobbins

Global Technical Manager, Aviation Lubricants

Shell International Petroleum Company

Appendix 1

Differences between SAE AS5780A and MIL-PRF-23699F specifications

Note: Shaded rows indicate where the requirements of MIL-PRF-23699F and SAE AS5780A are identical

TABLE 1: Physical properties

Property	Test method	MIL-PRF-23699F	SAE AS5780A	MIL-PRF-23699F	SAE AS5780A
		HTS	HPC	STD	SPC
Kinematic viscosity @ 100°C, mm^2/s (cSt) Kinematic viscosity @ 40°C, mm^2/s (cSt) Kinematic viscosity @ –40°C, mm^2/s (cSt)	ASTM D445 or IP71	4.9 to 5.4 23.0 min. 13,000 max.	4.9 to 5.4 23.0 min. 13,000 max.	4.9 to 5.4 23.0 min. 13,000 max.	4.9 to 5.4 23.0 min. 13,000 max.
Viscosity stability, 72 h @ -40°C, % change	ASTM D2532	6 max.	6 max.	6 max.	6 max.
Pour point, °C	ASTM D97/IP15	–54 max.	–54 max.	–54 max.	–54 max.
Flash point, °C	ASTM D92/IP36	246 min.	246 min.	246 min.	246 min.
Evaporation, 6.5 h @ 204 °C, %m	ASTM D972	10 max.	10 max.	10 max.	10 max.
Foaming tendency, Sequence I, II, III, ml	ASTM D892/IP146	25/0 max. (1)	25/0 max. (1)	25/0 max. (1)	25/0 max. (1)
Shear stability, viscosity change @ 40°C, %	ASTM D2603	4 max.	4 max.	4 max.	4 max.
Note: (1) Volume after aeration/volume after 1 minute settling					

TABLE 2: Chemical properties

Property	Test method	MIL-PRF-23699F	SAE AS5780A	MIL-PRF-23699F	SAE AS5780A
		HTS	HPC	STD	SPC
Total acid number (TAN), mg KOH/g	SAE ARP5088	1.0 max.	1.0 max.	1.0 max.	1.0 max.
Sediment, mg/L Ash, mg/L Undissolved water	FED-STD-791, Method 3010	10 max. 1 max. (1) None	10 max. 1 max. (1) None	10 max. 1 max. (1) None	10 max. 1 max. (1) None
Lubricant compatibility Sediment, mg/L Turbidity	FED STD 791, Method 3403 (Mod)/DEF STAN 05-50 (Part 61) Method 24	10 max. None	10 max. None	10 max. None	10 max. None
Elastomer compatibility: Rubber swell, % SAE-AMS3217/1 (nitrile), 72 h @ 70°C SAE-AMS3217/4 (fluorocarbon), 72 h @ 204°C Standard silicone rubber, 96 h @ 121°C Tensile strength loss, %	FED-STD-791, methods 3604 and 3433	 5 min., 25 max. 5 min., 25 max. 5 min., 25 max. 30 max	 NR 5 min., 25 max. NR NR	 5 min., 25 max. 5 min., 25 max. 5 min., 25 max. 30 max.	 NR 5 min., 25 max. NR NR
Elastomer compatibility: Mass change after 24/120 h, % Fluorocarbon LCS fluorocarbon Nitrile Silicone Perfluorocarbon	DEF STAN 05-50 (Part 61) Method 22	NR	 11/15 max. 12/20 max. Report Report Report	NR	 10/15 max. 10/20 max. Report Report NR
Note: If the total sediment does not exceed 1 mg/L, the ash content requirement shall be waived.					

TABLE 2: Chemical properties cont.

Property	Metal	MIL-PRF-23699F	SAE AS5780A	MIL-PRF-23699F	SAE AS5780A
		HTS	HPC	STD	SPC
Trace metals, ppm	Aluminium, Al	2 max.	2 max.	2 max.	2 max.
	Iron, Fe	2 max.	2 max.	2 max.	2 max.
	Chromium, Cr	2 max.	2 max.	2 max.	2 max.
	Silver, Ag	1 max.	1 max.	1 max.	1 max.
	Copper, Cu	1 max.	1 max.	1 max.	1 max.
	Tin, Sn	4 max.	4 max.	4 max.	4 max.
	Magnesium, mg	2 max.	2 max.	2 max.	2 max.
	Nickel, Ni	2 max.	2 max.	2 max.	2 max.
	Titanium, Ti	2 max.	2 max.	2 max.	2 max.
	Silicon, Si	10 max.	10 max.	10 max.	10 max.
	Lead, Pb	2 max.	2 max.	2 max.	2 max.
	Molybdenum, Mo	3 max.	3 max.	3 max.	3 max.
	Zinc, Zn	2 max.	2 max.	2 max.	2 max.

TABLE 3: Stability properties

Property	Test method	MIL-PRF-23699F	SAE AS5780A	MIL-PRF-23699F	SAE AS5780A
		HTS	HPC	STD	SPC
Oxidation and corrosion stability, 72 h @ 175°C:	FED-STD-791, Method 5308 (mod.)				
Viscosity change, %		0 to +10	0 to +10	–5 to +15	–5 to +15
TAN change, mg KOH/gm		1.0 max.	1.0 max.	2.0 max.	2.0 max.
Sediment, mg/100 ml		25 max.	25 max.	50 max.	50 max.
Metal weight change, mg/cm^2:					
Steel		±0.2	±0.2	±0.2	±0.2
Silver		±0.2	±0.2	±0.2	±0.2
Aluminium		±0.2	±0.2	±0.2	±0.2
Magnesium		±0.2	±0.2	±0.2	±0.2
Copper		±0.4	±0.4	±0.4	±0.4
Oxidation and corrosion stability, 72 h @ 204°C:	FED-STD-791, Method 5308 (mod.)				
Viscosity change, %		0 to +22.5	0 to +22.5	–5 to +25	–5 to +25
TAN change, mg KOH/gm		2.0 max.	2.0 max	3.0 max	3.0 max
Sediment, mg/100 ml		25 max.	25 max.	50 max.	50 max.
Metal weight change, mg/cm^2:					
Steel		±0.2	±0.2	±0.2	±0.2
Silver		±0.2	±0.2	±0.2	±0.2
Aluminium		±0.2	±0.2	±0.2	±0.2
Magnesium		±0.2	±0.2	±0.2	±0.2
Copper		±0.4	±0.4	±0.4	±0.4
Oxidation and corrosion stability, 72 h @ 218°C:	FED-STD-791, Method 5308 (mod)				
Viscosity change, %		Report	Report	Report	Report
TAN change, mg KOH/gm		Report	Report	Report	Report
Sediment, mg/100 ml		25 max.	25 max.	50 max.	50 max.
Metal weight change, mg/cm^2:					
Steel		±0.2	±0.2	±0.2	±0.2
Silver		±0.2	±0.2	±0.2	±0.2
Aluminium		±0.2	±0.2	±0.2	±0.2
Titanium		±0.2	±0.2	±0.2	±0.2

TABLE 3: Stability properties cont.

Property	Test method	MIL-PRF-23699F	SAE AS5780A	MIL-PRF-23699F	SAE AS5780A
		HTS	HPC	STD	SPC
Thermal stability and corrosivity, 96 h @ 274°C: Viscosity change, % TAN change, mg KOH/g Metal weight change, mg/cm^2	FED-STD-791, Method 3411	 ±5.0 max. 6.0 max. ±4.0 max.	 ±5.0 max. 6.0 max. ±4.0 max.	 ±5.0 max. 6.0 max. ±4.0 max.	 ±5.0 max. 6.0 max ±4.0 max.
Oxidative stability (19 2 h): E temperature (volume loss = 15%), °C A temperature (TAN incr. =1.0 mg KOH/g), °C V temperature (kinematic visc., incr. = 15%), °C B temperature (insolubles incr = 0.05%), °C Z temperature (solidification), °C Effective life @ 200°C: Volatilisation loss, h TAN increase, h Viscosity increase, h Insolubles increase, h Effective life @ 250°C: Volatilisation loss, h TAN increase, h Viscosity increase, h Insolubles increase, h	DEF STAN 05-50 Part 61, Method 9	NR	Report 190 min. 190 min. 190 min. 205 min. 210 min. N/A N/A N/A N/A 4.9 min. 1.4 min. 1.9 min. 22 min.	NR	Report 185 min. 190 min. 185 min. Report Report 90 min. 100 min. 60 min. 225 mi.n 3 min. 0.5 min. 1.0 min. 20 min

TABLE 4: Deposition properties

Property	Test method	MIL-PRF-23699F	SAE AS5780A	MIL-PRF-23699F	SAE AS5780A
		HTS	HPC	STD	SPC
ERDCO high temperature bearing rig test (USN): Demerits Deposits, g Oil consumption, ml Viscosity increase, % TAN increase, mg KOH/g	FED-STD-791 Method 3410, severity 1½	100-h test: 20 max. 1.5 max. 2,000 max. 20 max. 1.5 max.	200-h test 40 max. 1.5 max. 4,000 max. 0 to +35 2.0 max.	100-h test 80 max. 3.0 max. 2,000 max. −5 to +30 2.0 max.	100-h test 80 max. 3.0 max. 2,000 max. −5 to +30 2.0 max.
HLPS dynamic coking @ 375°C, mg @ 20 h @ 40 h	SAE ARP5996	 NR NR	 0.4 max. 0.6 max.	 NR NR	 Report NR

TABLE 5: Tribological properties

Property	Test method	MIL-PRF-23699F	SAE AS5780A	MIL-PRF-23699F	SAE AS5780A
		HTS	HPC	STD	SPC
Load-carrying capacity (Ryder gear test)	FED-STD-791, Method 6508 (conducted by USN)	>102% of reference oil	>102% of reference oil	>102% of reference oil	>102% of reference oil
Load-carrying capacity, load stage	AIR 4978 Appendix E, WAM Method	NR	15 min.	NR	15 min.

Appendix A – Report items

Report Items are either (a) those properties where no firm specification limits have yet been developed; as data are generated sufficient to define meaningful specification limits, these items will be moved into the main specification tables, or (b) information items for which there are no defined limits but that are useful for engine design purposes.
(*Determinations of percentage swell are conducted periodically throughout the test. The term, "no shrinkage", shall be taken as meaning no reduction in the percentage swell of the test pieces as the test progresses.)

Property	Test method	MIL-PRF-23699F	SAE AS5780A	MIL-PRF-23699F	SAE AS5780A
		HTS	HPC	STD	SPC
Acid assay, mol%	FED-STD-791, Method 3500	Report	Report	Report	Report
Kinematic viscosity @ 200°C, mm^2/s (cSt)	ASTM D341	NR	Report	NR	Report
Viscosity index	ASTM D2270	NR	Report	NR	Report
Pressure–viscosity coefficient @ 38, 65, 93°C	Wedeven Method	NR	Report	NR	Report
Density @ 15°C, kg/m^3	ASTM D4052	NR	Report	NR	Report
Specific heat @ 15, 40, 100, 150, 200°C; J/kg °C	ASTM D2766 or E1269	NR	Report	NR	Report
Thermal conductivity	Holometrix	NR	Report	NR	Report
Electrical conductivity, pS/m	ASTM D2624	NR	Report	NR	Report

Appendix A – Report items (continued)

Property	Test method	MIL-PRF-23699F	SAE AS5780A	MIL-PRF-23699F	SAE AS5780A
		HTS	HPC	STD	SPC
Elastomer compatibility, % swell: Fluorocarbon, 1,800 h @ 100°C 120°Cl 140°C 160°C	Snecma Method	NR	 20 max. 20 max. No shrinkage* No shrinkage*	NR	 20 max. 20 max. No shrinkage* No shrinkage*
Hydrolytic stability @ 90°C	DEF-STAN 05-50 part 61, Method 6	NR	Report	NR	Report
Vapour phase coking @ 371°C, mg of deposits	SAE ARP 5921 (draft)	NR	200 max.	NR	Report
High-temperature deposition, mg deposit	Alcor HTDT	NR	1.0 max.	NR	Report
Severe wear: ball load @ 1.5 mm WSD, kg	AIR 4978 Appendix B, ALTE Severe wear procedure	NR	38 min.	NR	38 min.
Mild wear: WSD @ 20-kg ball load, mm	AIR 4978 Appendix B, ALTE Mild wear procedure	NR	1.30 max.	NR	1.30 max.

Appendix A – Report items (continued)

Property	Test method	MIL-PRF-23699F	SAE AS5780A	MIL-PRF-23699F	SAE AS5780A
		HTS	HPC	STD	SPC
Thermal ageing, 550 h** at 150 and 180°C (**also report results @ 150, 330 and 750 h)	Turbomeca Method	NR		NR	
Antioxidant content, %:					
150°C			50 min.		Report
180°C			15 min.		Report
Density change, %					
150°C			0.5 max.		Report
180°C			1.0 max.		Report
Viscosity change @ 40°C, %					
150°C			5 max.		10 max.
180°C			15 max.		25 max.
Viscosity change @ 100°C, %					
150°C			4 max.		8 max.
180°C			10 max.		15 max.
Acidity change, mg KOH/g					
150°C			2 max.		8 max.
180°C			5 max.		15 max.
Flash point change, °C					
150°C			25 max.		70 max.
180°C			50 max.		85 max.
Sediment, mg/100 ml					
150°C			2 max.		Report
180°C			4 max.		Report
Thermal ageing, 72 h @ 225°C	Turbomeca Method	NR		NR	
Acidity change, mg KOH/g			20 max		NR
Flash point change, °C			100 max		NR
Particulate generation @ 125 psig, 329.5°C, 18 h, mg	P&W pressurised bomb test method	NR	120 max.	NR	120 max.