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(R) Gas Turbine Engine Lubricant Specifications:
Current Technical Review and Future Direction

RATIONALE

This SAE Aerospace Information Report (AIR) summarizes and captures the motivation for test procedures that are embodied within AS5780, along with a discussion of new test methods under consideration within the E-34 Committee. This AIR also describes the current scientific and engineering principles of gas turbine lubricant performance testing per AS5780 and identifies gaps in understanding of the technology to help the continuous improvement of this specification. A revision was completed to update changes in test methods that have occurred in the last 10 years and to capture new technology developments within SAE E-34 regarding future directions of specific lubricant test methods.

FOREWORD

Background: During the decade beginning in 2000, there were significant events and milestones that shaped the means by which synthetic turbine oils are approved for engine and other aircraft component use. There were high visibility in-service events that focused both the Civil Aviation Authority's and Original Equipment Manufacturers' (OEMs') attention on improving the processes used to approve synthetic turbine oils. An SAE E-34 Propulsion Lubricants meeting with representatives of the global Airworthiness Authorities was held on September 11 of 2003 to discuss Turbine Oil Approval and Control. Coincident to this scrutiny, and after a decade-long effort, AS5780 was released in November 2004. AS5780 consolidates the majority of OEM chemical, physical, and rig performance requirements short of model specific engine tests. AS5780 also drove the formation of a Qualified Products Group made up of OEM representation that maintains the AS5780 Qualified Products List and oversees change management of the listed products. While these milestones set a framework for OEMs to mutually specify and control oil formulations, in-service events pointed to several gaps in AS5780 that require further development.

Regulations: To understand the role of specifications in the aviation industry, an examination of engine OEM responsibility for certifying engines is necessary. Industry guidance on approving lubricants (and fuels) for certificated aircraft engines is provided by the U.S. Federal Aviation Administration in the form of an Advisory Circular No. 20-24D (refer to AC 20-24D):

- Engine operating limitations are established during the certification of an engine. One such operating limitation is the lubricants which are declared and substantiated during the certification of the engine model.
- Approved lubricants are listed (or referenced) on the engine model's Type Certificate Data Sheet (TCDS).
- Each engine model or engine model series requires separate approval.
- The approved lubricant must be identified and defined by a specification which adequately details its physical properties and associated limits and controls its composition.

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- If qualification to a specification alone is not sufficient to approve the synthetic lubricants used in gas turbine engines, then they may be individually approved by formulation and brand name.
- The Process (refer to AC 20-24D) by which new oils are approved involves:
 - a. The oil manufacturer providing analysis and performing component, rig, or engine testing necessary to comply with the applicable airworthiness standards such to show the new oil will not result in harmful buildup of carbon deposit. In the U.S., these standards are 14 CFR Part 33 for engines, Parts 23 and 25 for airplanes, and Parts 27 and 29 for rotorcraft accomplished by any combination of engine test, rig test, and analysis based on prior service, experience, or testing.
 - b. The FAA accepting data that was generated during the AS5780 qualification process to document that the lubricant has undergone sufficient testing to demonstrate that it will be compatible with the applicable engine. This data will typically address chemical, physical, compatibility, and rig performance testing. OEMs have the responsibility to bridge testing gaps to show that, under the conditions in which the lubricant will be used in the aircraft, it is compatible with the applicable engine and engine materials, if these are not tested during qualification to AS5780.
 - c. The engine test facility documenting the test conditions, oil consumption, analysis of oil before and after engine test, evidence of wear, deposits, or attack/deterioration/change of metal or non-metal components.
 - d. Responsible parties identifying and controlling the lubricant by the specific oil brand name unless the engine OEM has substantiated that any oil qualified to AS5780 is acceptable for use on the subject engine (refer to U.S. Department of Transportation, Federal Aviation Administration, 2006).
- New oil formulations seeking approval to a certificated engine model are approved by Engineering Changes to that model which in turn amends its existing Type Certificate.
- European airworthiness regulations applicable to turbine engine oil are specified in EASA CS-E 570 (g).

Motivation: An engine experiencing an uncontained turbine blade release related to the use of a novel engine/oil combination has focused much attention on the adequacy of aviation industry specifications and OEM engine/oil approval processes. Following an investigation of this incident, the U.S. NTSB issued a Safety Recommendation (refer to National Transportation Safety Board, 2006) to revise AC 20-24B to include guidance that ensures new engine/oil combinations are inspected where there is an identified risk for (porous) carbon formation and subsequent hazardous engine behavior. The FAA issued AC 20-24C in response to the NTSB recommendation and has committed to work with E-34 to develop and incorporate enhanced qualification test methods into AS5780 to assess the long-term thermal stability of oil and, in particular, the longer-term coking of turbine engine lubricants (refer to Presentation to SAE E-34 Propulsion Lubricants Committee, 2008).

E-34 Strategy: The E-34 Committee determined that it was valuable to produce this AIR as a vehicle toward improving the current specification by:

- Documenting the AS5780 specification requirements in terms of each test's purpose, history, applicability, and future direction.
- Critically examining the specification requirements contained in AS5780 in light of current engine designs, operating conditions, and maintenance programs for adequacy in maximizing safety and reliability.
- Developing plans for future revisions of AS5780 to bridge performance gaps:
 - a. First priority: Carbon formation per the NTSB Safety Recommendation.
 - b. Second priority: Rationalize and refine current requirements where there are multiple methods and OEMs are coping with emerging issues (e.g., elastomer compatibility and oil oxidation).

Additionally, it is hoped this document serves as a useful reference to educate in this specialized technical field of synthetic turbine oils.

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1. SCOPE

This AIR describes the current scientific and engineering principles of gas turbine lubricant performance testing per AS5780 and identifies gaps in our understanding of the technology to help the continuous improvement of this specification. Test methodologies under development will also be described for consideration during future revisions of AS5780.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document 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 document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS3217/4	Test Slabs, Fluoroelastomer (FKM) 65 - 75
AIR4978	Temporary Methods for Assessing the Load Carry Capacity of Aircraft Propulsion System Lubricating Oils
AIR5433	Lubricating Characteristics and Typical Properties of Lubricants Used in Aviation Propulsion and Drive Systems
AIR6989	Micropitting of Bearings and Gears in Aviation
ARP5088	Test Method for the Determination of Total Acidity in Polyol Ester and Diester Gas Turbine Lubricants by Automatic Potentiometric Titration
ARP5921	Evaluation of Coking Propensity of Aviation Lubricants in an Air-Oil Mist Environment using the Vapor Phase Coke
ARP5996	Evaluation of Coking Propensity of Aviation Lubricants Using the Single Phase Flow Technique
ARP6156	WAM High Speed Load Capacity Test Method
ARP6157	Pressure-Viscosity Coefficient Measurement
ARP6179	Evaluation of Gas Turbine Engine Lubricant Compatibility with Elastomer O-Rings
ARP6223	Oil Carbon Particulate Test
ARP6243	Traction Coefficient Measurement
ARP6255	Aviation Lubricant Tribology Evaluator (ALTE) Method to Determine the Lubricating Capability of Gas Turbine Lubricants
ARP6299	Procedure of Thermal Aging Test for Polyol Ester Gas Turbine Engine Lubricants
ARP6917	Evaluation of Gas Turbine Engine Lubricant Compatibility with Elastomer Slabs - Long Duration Test
ARP6991	MPR Micropitting Test Method
ARP6992	Evaluation of Thermal Stability and Corrosivity of Aviation Lubricants

ARP7120	Compatibility of Turbine Lubricating Oils
ARP7355	Assessment of Elastomer Volume Swelling Behavior in Aero-Derived Gas Turbine Engine Lubricants - Short Duration Test
ARP8462	Evaluation of Fouling Propensity of Aviation Lubricants Using the Mixed-Phase Flow Technique (High-Temperature Deposition Test)
AS5780	Specification for Aero and Aero-Derived Gas Turbine Engine Lubricants

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D92	Flash and Fire Point by Cleveland Open Cup Tester
ASTM D97	Pour Point of Petroleum Products
ASTM D341	Viscosity-Temperature Equations and Charts for Liquid Petroleum or Hydrocarbon Products
ASTM D445	Kinematic Viscosity of Transparent and Opaque Liquids
ASTM D892	Foaming Characteristics of Lubricating Oils
ASTM D972	Evaporation Loss of Lubricating Greases and Oils
ASTM 1298	Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
ASTM D2270	Standard Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 and 100 °C
ASTM D2532	Viscosity and Viscosity Change after Standing at Low Temperature of Aircraft Turbine Lubricants
ASTM D2603	Sonic Shear Stability of Polymer-Containing Oils
ASTM D2624	Electrical Conductivity of Aviation and Distillate Fuels
ASTM D2717	Thermal Conductivity of Liquids
ASTM D4052	Density, Relative Density and API Gravity of Liquids by Digital Density Meter
ASTM D4636	Standard Test Method for Corrosiveness and Oxidation Stability of Hydraulic Oils, Aircraft Turbine Engine Lubricants, and Other Highly Refined Oils
ASTM D5001	Standard Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)
ASTM D5185	Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
ASTM D5950	Standard Test Method for Pour Point of Petroleum Products (Automatic Tilt Method)

- ASTM D6595 Standard Test Method for Determination of Wear Metals and Contaminants in Used Lubricating Oils or Used Hydraulic Fluids by Rotating Disc Electrode Atomic Emission Spectrometry
- ASTM D7042 Standard Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
- ASTM D7896 Standard Test Method for Thermal Conductivity, Thermal Diffusivity, and Volumetric Heat Capacity of Engine Coolants and Related Fluids by Transient Hot Wire Liquid Thermal Conductivity Method
- ASTM E1269 Determining Specific Heat Capacity by Differential Scanning Calorimetry

2.3 Code of Federal Regulations (CFR) Publications

Copies of these documents are available online at <https://www.ecfr.gov>.

- 14 CFR Part 23 Airworthiness Standards: Normal Category Airplanes
- 14 CFR Part 25 Airworthiness Standards: Transport Category Airplanes
- 14 CFR Part 27 Airworthiness Standards: Normal Category Rotorcraft
- 14 CFR Part 29 Airworthiness Standards: Transport Category Rotorcraft
- 14 CFR Part 33 Airworthiness Standards: Aircraft Engines

2.4 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu.

CS-E 570 Oil System

2.5 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

AC 20-24D Approval of Propulsion Fuels, Additives, and Lubricating Oils

U.S. Department of Transportation, Federal Aviation Administration. (2006, March 29). Memorandum, *ACTION: FAA Certification Policy for Turbine Engine Lubricating Oils Qualified to AS5780 - [ANE-2006-33.7-3]*.

2.6 IP Publications

Available from Energy Institute, 61 New Cavendish Street, London, W1G 7AR, UK, Tel: +44 (0) 20 7467 7100, www.energyinst.org.

- IP 15 Petroleum and related products from natural or synthetic sources - Determination of pour point
- IP 36 Determination of flash and fire points - Cleveland open cup method
- IP 71 Petroleum products - Transparent and opaque liquids - Determination of kinematic viscosity and calculation of dynamic viscosity

IP 146	Determination of foaming characteristics of lubricating oils
IP 226	Petroleum products - Calculation of viscosity index from kinematic viscosity
IP 274	Determination of electrical conductivity of aviation and distillate fuels

2.7 United Kingdom Ministry of Defence - (UK MOD) Publications

Available from Ministry of Defence - UK, UK Defence Standardization, Kentigern House, Room 1138, 65 Brown Street, Glasgow G2 8EX, UK, <https://sts.defencegateway.mod.uk>.

DEF STAN 05-05 (Part 61) Method 6	Hydrolytic Stability
DEF-STAN 05-50 (Part 61) Method 9	Resistance to Oxidation and Thermal Decomposition
DEF-STAN 05-50 (Part 61) Method 22	Assessment of the Compatibility of Gas Turbine Lubricants with Elastomers - Gravimetric Method
DEF-STAN 05-50 (Part 61) Method 24	Assessment of the Compatibility of Mixtures of Gas Turbine Lubricating Oils
DEF-STAN 91-094	Lubricating Oil, Gas Turbine Engine, Synthetic Grade 3 cSt Joint Service Designation: OX-7
DEF-STAN 91-098	Lubricating Oil, Gas Turbine Engine, Synthetic Grade 7.5 cSt NATO Code: 0-149 Joint Service Designation: OX-38

2.8 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

DOD-PRF-85734	Lubricating Oil, Helicopter Transmission System, Synthetic Base
FED-STD-791, Method 3010	Solid Particle Contamination in Aircraft Turbine Engine Lubricants (Gravimetric Procedure)
FED-STD-791, Method 3410	High Temperature Deposit and Oil Degradation Characteristics of Aviation Turbine Oils
FED-STD-701, Method 3411	Thermal Stability and Corrosivity of Aircraft Turbine Engine Lubricants
FED-STD-701, Method 3604	Swelling of Synthetic Rubber by Aircraft Turbine Lubricants
FED-STD-701, Method 5308	Corrosiveness and Oxidation Stability of Light Oils (Metal Squares)
FED-STD-791, Method 6508	Load Carrying Capacity of Lubricating Oils (U.S. Navy RYDER Gear Machine)
MIL-PRF-7808	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base
MIL-PRF-23699	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, NATO Code Numbers: O-152, O-154, O-156, and O-167

2.9 Other Publications

National Transportation Safety Board. (2006, December 14). *Safety Recommendation, Reference A-06-85 through A-06-87*.

Presentation to SAE E-34 Propulsion Lubricants Committee. (2008, September 23). Edelweiss Engine Event (NTSB Recommendations, FAA Proposed Responses).

3. HISTORY OF AVIATION GAS TURBINE ENGINE LUBRICANTS

The development of aviation gas turbine engine lubricants has progressed in parallel with the development of aviation gas turbine engines. The engine and lubricant development have relied on a successful partnership between oil companies, military organizations, and engine builders/designers. Modern gas turbine engines could not exist without the lubricants that were developed to meet the increases in engine power and severity that have occurred since the first gas turbine engine.

During the late 1930s, several military establishments were sponsoring the mechanical and engineering research related to development of the gas turbine engines. Frank Whittle, a member of the Royal Air Force, is generally credited with leading the construction of the first, experimental gas turbine engine in 1937. Parallel developments were also taking place in Germany and other countries. The individual engineering developments were sponsored by the country's military so results from one laboratory were not known by the other laboratories.

Natural oils, such as castor oil, and moderately refined mineral oils were used to lubricate the low-powered aviation piston engines of the time. These oils lacked the thermal and oxidative stability necessary to lubricate high-temperature mechanical systems, forming gums and lacquers on hot metal surfaces. The natural oils and moderately refined mineral oils also had poor physical properties, particularly at low temperatures where they tended to gel. Independent, parallel research programs at the U.S. Naval Research Laboratory and the I.G. Farben Industrie began to examine the chemical and physical properties of different classes of organic compounds with an eye towards identifying materials with improved thermal-oxidative stability and desirable physical properties. Both laboratories identified diesters of eight to ten carbon diacids as potential candidates for synthetic lubricant base stocks.

The results of the U.S. Naval Research Laboratory and the I.G. Farben Industrie chemical research began to be published in the open literature after 1945. The U.S. and European militaries needed improved lubricants at this time as increasing numbers of aviation gas turbine engine powered aircraft began to enter their fleets. The U.S. Air Force needed a lubricant which would allow turbojet engine starts at -65 °F, while the UK Royal Air Force was looking for a heavier viscosity lubricant for the reduction gears in their turboprop aircraft. Both organizations specified mineral-oil-based lubricants suitable to their individual requirements. The engines operating with these lubricants required frequent oil drains, but this did not seem too burdensome with a 50-hour duty cycle.

The U.S. Air Force's collaborative testing with the engine builders and oil companies demonstrated the superior performance of lubricating oils based on synthetic diesters. The U.S. Air Force issued the MIL-L-7808 specification in 1950, defining the composition and performance requirements for synthetic, diester-based lubricants. These products with a minimum viscosity of 3 cSt at 100 °C are known as Type I lubricants.

The military and the engine builders continued to improve aviation gas turbine engine output power with a commensurate increase in engine operating temperatures. The diester-based lubricant technology was becoming challenged. The U.S. Navy led the oil companies in a development program during the late 1950s to obtain a higher performance lubricant. Synthetic esters based on trimethylol propane or pentaerythritol emerged as base stocks of choice. These fluids had a very high inherent thermal stability and their strong response to added antioxidants gave them excellent oxidative stability. The U.S. Navy, not being concerned with the U.S. Air Force's requirement for very low temperature operations, was able to direct the oil companies to develop higher viscosity lubricants for improved lubricity and wear protection. The U.S. Navy issued the MIL-L-23699 specification in 1960 defining the composition and performance requirements for synthetic, polyol ester-based lubricants. These products with a minimum viscosity of 5 cSt at 100 °C are known as Type II lubricants.

MIL-L-7808 (now MIL-PRF-7808) eventually evolved to exclude diester technology in favor of polyol ester technology by making thermo-oxidative test requirements more stringent. MIL-PRF-7808 now has two viscosity grades: Grade 3 is the original 3 cSt at 100 °C, while Grade 4 is a 4 cSt oil at 100 °C with even more improved thermo-oxidative stability requirements.

The ready availability of the Type I and Type II lubricant products was a boon to civil aviation as gas turbine engine powered aircraft became more prevalent. The gas turbine engine powered Boeing 707 and Douglas DC-8 were starting to provide passenger service by the end of the 1950s. The Type I and Type II lubricants defined by MIL-L-7808 and MIL-L-23699 were able to provide safe, reliable lubrication for military and civil aviation gas turbine engines for these and successor aircraft for the next four decades.

In the late 1980s, the manufacturers of gas turbine engines for civil applications could see the demands on lubricant performance in a high by-pass turbofan engine were starting to diverge from those used in the military high-performance aircraft. Rolls-Royce organized the SAE E-34 Propulsion Lubricants Committee to develop laboratory lubricant test methods that would lead to a performance specification for lubricants tailored for civil engines. During this time, improvements in antioxidant and synthetic base stock technology led to significant improvements in lubricant performance compared to some of the initial Type I and Type II lubricant products. However, the civil engine builders, with support from the oil companies and military organizations, led the drafting of a new specification, AS5780, defining the composition and performance requirements for modern, civil aviation gas turbine engine lubricants which was released in November 2004.

The AS5780 specification, now in effect for civil aviation, adopted many of the existing requirements for Type II lubricants and increased the focus on the lubricant's deposition resistance and elastomer compatibility. The new specification also formalized the procedures that dealt with the change management of lubricant componentry. A Qualified Products Group, consisting mainly of engine manufacturer representatives, were empaneled under the auspices of the Performance Review Institute as being the responsible party for assessing whether submitted lubricants comply with the relevant standard and to review any proposed changes in the same manner. Aviation authorities such as the FAA and EASA have endorsed AS5780 as applicable preliminary data for approving oil to engine type and has delegated oversight of change process for aviation lubricating oils to the AS5780 QPG.

In 2019 the E-34 Propulsion Lubricants Committee proposed adopting some of the U.S. Military Federal Standards into SAE Standards. Select Federal Standards were rewritten, updated, and turned into SAE Aerospace Recommended Practices (ARPs). Since that time, the following ARPs have been generated from corresponding Federal Standards:

- ARP7355: Assessment of Elastomer Volume Swelling Behavior in Aero-Derived Gas Turbine Engine Lubricants - Short Duration Test (FED-STD-791, Method 3604)
- ARP6992: Evaluation of Thermal Stability and Corrosivity of Aviation Lubricants (FED-STD-791, Method 3411)
- ARP7120: Compatibility of Turbine Lubricating Oils (FED-STD-791, Method 3403)

Since the last revision of AIR6056 in 2014, there have been additional ARP methods that have been developed. These include:

- ARP8462: Evaluation of Fouling Propensity of Aviation Lubricants, Using the Mixed-Phase Flow Technique (High-Temperature Deposition Test)
- ARP6917: Evaluation of Gas Turbine Engine Lubricant Compatibility with Elastomer Slabs - Long Duration Test (Safran Method)
- ARP6299: Procedure for Thermal Aging Test for Polyol Ester Gas Turbine Engine Lubricants
- ARP6223: Oil Carbon Particulate Test

4. SPECIFICATION PROPERTY REVIEWS

The collective of specification testing requirements is classified into six main groups: Physical Properties, Chemical Properties, Compatibility, Stability, Deposition, and Tribology.

4.1 Physical Properties

A physical property of aviation gas turbine engine oils is any measurable property, the value of which describes the physical state of the oil which can be measured without changing the composition of the fluid. There are 12 tests within AS5780 which define the physical properties of aviation gas turbine oils. Four of these properties are also used as batch quality inspection tests to control the fundamental criticalities, such as viscosity, flash point, pour point, and foaming tendency/stability. A description and review of the twelve physical properties will be discussed in the following sections.

4.1.1 Kinematic Viscosity at 40 °C and 100 °C, ASTM D445/IP 71

Viscosity is a measure of the resistance of a fluid which is being deformed by either shear stress or extensional stress.

History: Kinematic viscosity is a fluid property that indicates how resistant the fluid is to gravity-driven flow. ASTM D445 defines this property as momentum diffusivity. For the purposes of this document, kinematic viscosity is considered to be a Physical Property of a lubricant. Historically, scientists such as Newton, Poisseuille, and Gay-Lussac, who developed the fundamental laws governing lubrication, and the formation of lubricating films in gears, bearings, and other liquid lubricated contacts, confirmed viscosity to be a vital property of a lubricant. ASTM Method D445, Method for Kinematic Viscosity of Transparent and Opaque Liquids, was published in 1937, and it was later jointed with the IP Method 71. The methods specify a procedure for measuring the flow of liquids under gravitational forces through a calibrated glass capillary at precise temperatures. Multiplying the kinematic viscosity measurement by the density of the fluid under test gives rise to the dynamic viscosity of the fluid. Standard charts have also been introduced in ASTM Method D341 to plot viscosity temperature characteristics and to provide for interpolation and extrapolation, for temperatures other than the temperatures specified by the individual test procedures.

Aims/Purpose: Viscosity is one of the most important properties of lubricating oil. It controls the formation of lubricating films and the heat generated in fluid film lubricated contacts. Equations used in gear and bearing design rely implicitly upon accurate determination of viscosity and the influence of temperature upon viscosity. Oil system design dictates that the oil maintains a fluid film within the range of loads imposed upon it and at the temperatures of the lubricated contacts. Highly accurate determination of viscometric properties is, therefore, essential to the design process and to the quality control of approved lubricants in service. AS5780 specification requires viscosity to be determined at -40 °C, 40 °C, and 100 °C by ASTM D445 and at 200 °C by ASTM D341.

Applicability: Precise specification of the viscosity of all lubricants approved, or intending to be approved, for each engine application is an imperative. Viscosity measurements are a major quality control tool throughout the manufacture of gas turbine lubricants, from the raw materials to the finished product.

Current Method: ASTM D445 describes a procedure by which the time is measured for a fixed volume of liquid to flow under gravity through a capillary of a calibrated viscometer at a closely controlled and known temperature. The kinematic viscosity (determined value) is the product of the measured flow time and the calibration constant of the viscometer. ASTM D341 describes the use of kinematic viscosity-temperature charts to plot viscosity data as a straight line provided the viscosity at two temperatures is known. The straight-line charts allow for extrapolation to higher temperatures.

Future Methods: ASTM D445, ASTM D341, and IP 71 are established methods under the jurisdiction and control of ASTM and the Energy Institute, respectively. Those organizations impose rigid control of the methods and review and update them in line with their control policies. No changes, which could impact the application of the methods in specifications, are envisaged.

4.1.2 Viscosity Stability (Low Temperature), ASTM D2532

Viscosity Stability is a measure of an oil's ability to resist changes in viscosity over a period of time.

History: Changes in the viscosity of MIL-L-7808 oils, following low temperature soak, were thought to have an influence on engine starting in rapid deployment situations; the possibility that an increase in viscosity during the soak could influence engine reliability was also considered. The U.S. Air Force, therefore, developed Federal Standard 791 Test Method 307 (FTM 307) and a viscosity change limit was introduced to the specification MIL-L-7808 edition current at the time. The FTM 307 was standardized by ASTM in 1966 as Method D2532, and in 2004, a requirement for testing by the latter method was included in the AS5780 5 cSt oil specification.

Aims/Purpose: Aircraft turbine engines that contain lubricants often stand at low temperatures for prolonged periods of time. These low temperatures cause the turbine lubricant to increase in viscosity. This increase may potentially pose a problem for the starting and safe operation of the engine. This low temperature viscosity test ensures the kinematic viscosity does not exceed the limits for proper operation.

Applicability: Method ASTM D2532 is applicable to aviation gas turbine lubricants meeting the AS5780 specification and also to lubricants meeting the U.S. DoD and UK Defence Standards for 3 cSt and 5 cSt gas turbine oils.

Current Test Method: Test Method ASTM D2532 requires the determination of kinematic viscosity of a sample at -40 °C at time intervals of 3 hours and 72 hours to determine percent change. Presently, for AS5780, only the data generated at 72 hours is required and reported. Precision for the test has been established at -40 °C and -51 °C with guidance provided within ASTM D2532.

Future Development: No work is currently taking place to develop a new method, as the current test is considered adequate for use in specifications and for investigation of service events.

4.1.3 Viscosity Index (VI), ASTM D2270/IP 226

Viscosity Index is an arbitrary scale for lubricating oils that indicates how viscosity varies with respect to temperature over a specific temperature range.

History: E. W. Dean and G. H. B. Davis first proposed the use of a Viscosity Index scale in 1929 using a seven-point scale based upon Pennsylvanian and Gulf Coast crudes. The scale was used for many years before the method was refined and became ASTM D567 in 1965. The more recent method, ASTM D2270, incorporating changes to simplify the scale, was introduced in 1964 and quickly became the industry standard.

Aims/Purpose: The viscosity index is a widely used and accepted measure of the variation in kinematic viscosity due to changes in the temperature of lubricating oil between 40 and 100 °C. A high VI indicates a small decrease in kinematic viscosity with increasing temperature, whereas a low VI signifies a larger change of viscosity with increasing lubricant temperature.

Applicability: The viscosity of a lubricant and how the viscosity changes with variations in temperature are fundamental properties of a lubricant that are required for bearing and gear design and for heat to oil calculations.

Current Test Method: The method for calculating the VI Scale, and the precision attached to it is described in ASTM D2270 (jointed with IP 226): The method details how to calculate the VI of petroleum products and related materials from their kinematic viscosities at 40 °C and 100 °C. The practice does not apply to petroleum products with kinematic viscosities less than 2.0 mm²s⁻¹ at 100 °C.

Future Development: Method ASTM D2270 and IP 226 are established methods under the purview of ASTM and the Energy Institute. The methods are stable, and no significant changes are anticipated in the foreseeable future.