



AEROSPACE RECOMMENDED PRACTICE

ARP1827™**REV. D**Issued 1987-06
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Superseding ARP1827C

(R) Measuring Aircraft Gas Turbine Engine Fine Fuel Filter Element Performance

RATIONALE

The proper performance of the engine fuel filter element is important in protecting engine fuel system components from particulate contamination that could lead to accelerated component wear, fuel system malfunction, and premature component failure. This SAE Aerospace Recommended Practice (ARP) provides a standard test method for determining the filtration efficiency and dirt capacity of engine main fuel filter elements. This will allow both manufacturer and customer a common means to evaluate the performance of engine main fuel filter elements.

The standard has been revised to: (1) clarify the scope in terms of the applicability of the procedure to fuel filter elements rated at 25 $\mu\text{m(c)}$ or finer, (2) include an update on the current status of the standard reference material (SRM) used for calibration of automatic particle counters per ISO 11171, (3) update the dirt capacity test setup validation procedure for clarity and to include the option of using a suitable validation filter element, (4) specify periodic determination of the water content in the jet fuel during the dirt capacity test, and (5) include editorial changes for clarity.

1. SCOPE

This SAE Aerospace Recommended Practice (ARP) delineates two complementary filter element performance parameters: (1) dirt capacity, and (2) filtration efficiency, and corresponding test procedures. It is intended for non-cleanable (disposable), fine fuel filter elements, rated at 25 $\mu\text{m(c)}$ or finer, used in aviation gas turbine engine fuel systems.

1.1 Purpose

Variation in fuel filter element testing methods and requirements make comparison of performance results difficult. In order to minimize these problems, this document describes standard filtration ratings and test procedures. Both manufacturer and customer will have a common means to evaluate fuel filter elements.

1.2 Filter Element Performance Ratings

1.2.1 Filter Element Dirt Capacity

The mass of test contaminant added to the filter element test system, under the test conditions specified herein, to produce a prescribed terminal filter element differential pressure. The dirt capacity is determined in a specified test fluid.

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1.2.2 Filter Element Efficiency

Filter element efficiency is the ability of a filter element to remove (and retain) contaminant particles from the fluid stream. This procedure determines the particle removal efficiency of the filter element as a function of particle size. The particle removal efficiencies for the various particle size ranges ("x") are expressed as filtration ratios, termed beta ratios (β_x). The filtration ratio at a specified particle size is the ratio of the number of particles larger than the specified size entering the filter element (U_x) to the number of particles larger than the same size leaving the filter element (D_x).

$$\text{Filtration ratio at particle size "x"} = \beta_x = U_x/D_x \quad (\text{Eq. 1})$$

The techniques specified in this document allow measurement of filtration ratios up to 1000 (99.9% particle removal efficiency) for the particle size range 4 to 25 $\mu\text{m(c)}$, as defined in ISO 11171.

1.3 Test Contaminant and Particle Counter Calibration

1.3.1 Dirt Capacity

Historically, AC Test Dusts (AC Fine Test Dust and AC Coarse Test Dust) were specified, either as a component of the test contaminant for the Dirt Capacity test or, in some applications, as the principal test contaminant.

Replacement test dusts for the AC Test Dusts, no longer available, were specified by ISO (ISO 12103-1) in the late 1990s. The corresponding ISO Test Dust for AC Fine Test Dust is ISO Fine Test Dust (designated ISO 12103-A2) and the corresponding ISO Test Dust for AC Coarse Test Dust is ISO Coarse Test Dust (designated ISO 12103-A4).

The change to ISO Test Dusts can result in dirt capacity test results that may differ from test results obtained with the corresponding AC Test Dusts. It is necessary for users to take this into account when comparing historic dirt capacity test data generated per ARP1827 with data generated per subsequent revisions, and when comparing dirt capacity test results to historic specification requirements for dirt capacity. Additional information may be found in AIR5455.

1.3.2 Filtration Efficiency

Historically, AC Fine Test Dust was the test contaminant specified for the filtration efficiency test, and the calibration of automatic particle counters was in accordance with ISO 4402 (1991). As stated in 1.3.1, ISO Fine Test Dust (ISO 12103-A2) was selected as the replacement test dust for AC Fine Test Dust. In addition, ISO also specified a calibration procedure, ISO 11171, for automatic particle counters to replace the ISO 4402 (1991) calibration procedure which utilized AC Fine Test Dust. The ISO 11171 calibration procedure uses a batch of ISO Medium Test Dust (ISO 12103-A3), certified by the National Institute of Standards and Technology (NIST), as the standard reference material (SRM) instead of AC Fine Test Dust; the original NIST certified batches were designated SRM 2806 and SRM 2806a.

The definition of particle sizes per the calibration procedure ISO 11171 differs very significantly from the particle sizes defined in the historic calibration procedure ISO 4402 (1991). In order to distinguish the particle sizes defined in ISO 11171, they were designated as $\mu\text{m(c)}$ or micrometer(c) for the original reference batches SRM 2806 and SRM 2806a.

The change in test contaminant and the automatic particle counter calibration procedure has resulted in filter element efficiency test results that are significantly different from test results obtained previously with AC Fine Test Dust and ISO 4402 calibration. It is necessary for users to take this into account when comparing historic filter element efficiency test data generated per ARP1827, Rev. None, with data generated per subsequent revisions, and when comparing filter element efficiency test results to historic specification requirements for filter element efficiency. AIR5455 discusses the impact of the change in test dusts and automatic particle counter calibration on laboratory filter performance and filter ratings.

Around 2016, NIST certified a new reference batch of ISO Medium Test Dust, SRM 2806b, for particle counter calibration since the original reference batches, SRM 2806 and SRM 2806a, were depleted. The size distribution of SRM 2806b determined by NIST differed from the original reference batches of ISO Medium Test Dust (SRM 2806 and SRM 2806a) resulting in a redefinition of particle sizes. Industry designated the particle sizes as $\mu\text{m}(\text{b})$ to coincide with the reference batch SRM 2806b. However, there is consensus in the industry that redefining particle sizes with each certified reference batch of ISO Medium Test Dust leads to confusion in the industry in setting specification requirements and complicates comparison of data determined with particle counters calibrated with different reference batches. In order to alleviate this, going forward, all particle sizes will be expressed in terms of the original particle sizes $\mu\text{m}(\text{c})$ defined for SRM 2806 and SRM 2806a. At the time of this publication, NIST was completing certification of a new batch of ISO Medium Test Dust as the new standard reference material (SRM 2806d) due to the depletion of SRM 2806b.

1.4 Test Fluids (Dirt Capacity)

Historically, test fluids have included MIL-PRF-7024 calibration fluid and petroleum based jet fuels. For commercial applications, fuels such as ASTM D1655 Grades Jet A and Jet A-1 have been used and, more recently, fuels complying to Russian and Chinese national standards and semi and fully synthetic fuels. For military applications, fuels such as MIL-DTL-5624, Grades JP-4 and JP-5, and MIL-DTL-83133, Grade JP-8, have been used. Fuels containing synthetic hydrocarbons, i.e., hydrocarbons derived from non-petroleum based feedstocks, are also being approved. For example, fuels produced per ASTM D7566 are permitted to be re-certified as ASTM D1655 or UK Defence Standard 91-91 fuels in the proper admixture with petroleum based jet fuels. Once re-certified, the fuels are indistinguishable from fuels produced solely from petroleum based feedstocks. Other national standards allow synthetic hydrocarbons complying with one or more of the annexes of approved synthesized paraffinic kerosene within ASTM D7566 to be blended with petroleum based jet fuels up to 50% by volume as long as the final blend meets the requirements of the national standard.

The dirt capacity is dependent on test fluid properties (such as viscosity), the dispersion of solid contamination and the solubility and dispersion of water in the fluid phase, which are dependent on the chemical composition (including additives) and chemical/physical properties of the test fluid. The above should be kept in mind when comparing dirt capacities of filter elements in different test fluids.

1.5 Filter Element Conditioning

Filter element performance ratings can be adversely affected by harsh operating environments. Filter elements should, therefore, be subjected to procedures simulating these harsh operating conditions prior to performance testing. Conditioning is the term covering these procedures. This document does not cover conditioning requirements. They should be determined by the user and reported by the testing agency. AIR1666 discusses recommended filter element conditioning methods for gas turbine engine lubrication filter elements. The methods discussed in AIR1666 can also be applied to filter elements utilized in other aerospace fluid systems.

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.

AIR1666	Performance Testing of Lubricant Filter Elements Utilized in Aircraft Power and Propulsion Lubrication Systems
AIR5455	Impact of Changes in Test Dust Contaminants and Particle Counter Calibration on Laboratory Filter Element Performance and Fluid Cleanliness Classes
ARP24	Determination of Hydraulic Pressure Drop

ARP785	Procedure for the Determination of Particulate Contamination in Hydraulic Fluids by the Control Filter Gravimetric Procedure
AS4059	Aerospace Fluid Power - Contamination Classification for Hydraulic Fluids
MAP749	Aircraft Turbine Engine Fuel System Component Endurance Test Procedure (Room Temperature Contaminated Fuel)

2.2 Military Specifications

2.2.1 U.S. Military Specifications

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

MIL-DTL-5624	Turbine Fuel, Aviation, Grades JP-4 and JP-5
MIL-DTL-83133	Turbine Fuels, Aviation, Kerosene Type, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-27)
MIL-E-5007 ¹	Engines, Aircraft, Turbojet and Turbofan, General Specification for
MIL-PRF-56061	Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance
MIL-PRF-7024	Performance Specification, Calibrating Fluids, Aircraft Fuel System Components
MIL-PRF-81836	Filter and Disposable Element, Fluid Pressure, Hydraulic, 3 Micron Absolute

2.2.2 UK Military Specifications

Available from Defence Equipment and Support, UK Defence Standardization, Kentigern House, 65 Brown Street, Glasgow G2 8EX, United Kingdom, Tel: +0141 224 2531/2, Fax: +0141 224 2503, <http://www.dstan.mod.uk>.

Defence Standard 91-91 Turbine Fuel, Aviation Kerosene Type, Jet A-1, NATO Code: F-35, Joint Service Designation: AVTUR

2.3 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO 4021	Hydraulic Fluid Power - Particulate Contamination Analysis - Extraction of Fluid Samples from Lines of an Operating System
ISO 4402 ²	Hydraulic Fluid Power - Calibration of Automatic-Count Instruments for Particles Suspended in Liquids - Method Using Classified AC Fine Test Dust Contaminant
ISO 11171	Hydraulic Fluid Power - Calibration of Automatic Particle Counters for Liquids
ISO 11943	Hydraulic Fluid Power - On-Line Automatic Particle-Counting Systems for Liquids - Methods of Calibration and Validation

¹ MIL-E-5007 is inactive for new design as of January 1997. MIL-PRF-5606 is inactive for new design as of March 1996.

² ISO 4402 has been withdrawn as of December 9, 1999.

ISO 12103-1	Road Vehicles - Test Dust for Filter Evaluation - Part I: Arizona Test Dust
ISO 16889	Hydraulic Fluid Power Filters - Multi-Pass Method for Evaluating Filtration Performance of a Filter Element

2.4 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 D445	Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
ASTM D971	Standard Test Method for Interfacial Tension of Oil against Water by the Ring Method
ASTM D1298	Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D3240	Standard Test Method for Undissolved Water in Aviation Turbine Fuels
ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

2.5 NIST Publications

Available from NIST, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070, Tel: 301-975-6478, www.nist.gov.

NIST SRM 2806	National Institute of Standards and Technology - Standard Reference Material 2806 - Medium Test Dust (MTD) in Hydraulic Fluid, (1997)
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3. GLOSSARY

3.1 Terms

β	the filtration ratio obtained using ISO Fine Test Dust (ISO 12103-A2) under multi-pass test conditions
C	the percent of accountable contaminant obtained in the dirt capacity test validation
Q_T	the total flow rate (liters/minute) through the test filter element for the dirt capacity test
Q_R	the recirculated flow rate (liters/minute) for the dirt capacity test
Q_V	the flow rate (liters/minute) for validation of the dirt capacity test setup; this is the lowest flow rate that the test setup is rated for.
Q_1	the required flow rate (liters/minute) through the test filter element for the filter element efficiency test
Q_2	the required flow rate (liters/minute) of injection flow from the contaminant injection system to the filter element test system for the filter element efficiency test
Q_{2A}	the calculated average rate of injection flow from the contaminant injection system to the filter element test system in the filter element efficiency test
G_1	the required base upstream gravimetric level (milligrams/liter) of contaminant in the filter element test system for the filter element efficiency test
G_{1A}	the actual, average base upstream gravimetric level (milligrams/liter) of contaminant in the filter element test system in the filter element efficiency test

G ₂	the required gravimetric level (milligrams/liter) of contaminant in the contaminant injection system fluid for the filter element efficiency test
G _{2A}	the calculated average gravimetric level (milligrams/liter) of contaminant in the contaminant injection system fluid in the filter element efficiency test
U _x	the total number of particles per unit volume greater than a given particle size “x” upstream of the filter element in the filter element efficiency test
D _x	the total number of particles per unit volume greater than a given particle size “x” downstream of the filter element in the filter element efficiency test
τ	the predicted test time (minutes) of the filter element efficiency test
τ _A	the actual, recorded test time (minutes) of the filter element efficiency test
τ _t	the timer value at the end of the test
V ₁	the filter element test system fluid volume (liters) in the filter element efficiency test
V ₂	the initial contaminant injection system fluid volume (liters) in the filter element efficiency test
V _{2F}	the final contaminant injection system fluid volume (liters) at the conclusion of the filter element efficiency test
V _{2M}	the unusable fluid volume (liters) in the contaminant injection system for the filter element efficiency test
W ₁	the total mass (grams) of contaminant added to the test system in the dirt capacity validation procedure
W ₂	the mass (grams) of contaminant collected on the validation filter element in the dirt capacity validation procedure
W ₃	the mass (grams) of contaminant washed from the validation filter element during degreasing, plus the mass (grams) of contaminant remaining in the validation filter element housing, in the dirt capacity validation procedure
W ₄	the mass (grams) of remaining suspended contaminant in the test fluid in the dirt capacity validation procedure
W ₅	the estimated mass (grams) of contaminant required for the test filter element to reach the terminal filter element differential pressure in the filter element efficiency test
W ₆	the required amount of contaminant (grams) to be added to the contaminant injection system to achieve the desired base upstream gravimetric level (G ₁) in the filter element test system for the filter element efficiency test
W ₇	the required amount of contaminant (grams) to be added to the filter element test system to achieve the target base upstream gravimetric level required to validate the filter element test system in the filter element efficiency test
x	contaminant particle size [μm(c)] per ISO 11171 calibration

3.2 Conversions

(milligrams per liter) = 0.2642 x (milligrams per U.S. gallon)

(liters per minute) = 3.785 x (U.S. gallons per minute)

4. GENERAL TEST CONDITIONS

4.1 Test Fluids

4.1.1 The fuel used for dirt capacity testing shall conform either to ASTM D1655 Jet A or Jet A-1 specification, MIL-PRF-7024 Type II calibration fluid, or to other test fuels specified by the procuring agency (see discussion in 1.4). In order to ensure integrity of the test fluid, the equivalent of a fluid change-out to new fluid should occur once in 24 months (either by topping off with new fluid or by changing out the test fluid) and testing of the fluid for critical properties should occur every 6 months.

4.1.1.1 The interfacial tension (IFT) of the test fluid, determined per ASTM D971, shall be a minimum of 27 dynes/cm if it is Jet A or Jet A-1 fuel, or it shall be as specified by the procuring agency. It is recommended that a Fuller's Earth filter be utilized for achieving the required interfacial surface tension since this has been shown to give reproducible results. The IFT of the fuel shall be recorded prior to and at the end of the test.

4.1.1.2 The kinematic viscosity and density of the test fluid shall be determined. A number of ASTM and other standards are referenced in fuel specifications for determination of viscosity and density. Two standards, ASTM D445 for kinematic viscosity and ASTM D1298 for relative density, are referenced in this ARP. Other standards that are applicable to the test fluid, or as specified by the procuring agency, may be used. The standards used should be indicated.

4.1.1.3 The test fluid shall contain no more than 20 ppm of free water per ASTM D3240.

4.1.2 The fluid used for filter element efficiency testing shall conform to MIL-PRF-5606.

4.2 Test Fluid Temperature

4.2.1 The temperature of the test fluid for the dirt capacity test shall be maintained at $85^{\circ}\text{F} \pm 5^{\circ}\text{F}$ ($29^{\circ}\text{C} \pm 3^{\circ}\text{C}$), unless specified otherwise.

4.2.2 The temperature of the test fluid for the filter element efficiency test shall be maintained at $100^{\circ}\text{F} \pm 2^{\circ}\text{F}$ ($38^{\circ}\text{C} \pm 1^{\circ}\text{C}$), unless specified otherwise.

4.3 Cleanup Filter and Water Removal Coalescer

4.3.1 The efficiency of cleanup filter elements used during testing and for initial cleaning of test fluids shall conform to MIL-PRF-81836 specification, or equivalent. Filter elements meeting this efficiency will control particles in the $4\text{ }\mu\text{m(c)}$ size range which can affect both the particle counts and the filter element dirt capacity. The clean-up filter shall have no by-pass valve, and the filter element shall be sized to ensure that there is adequate dirt capacity for the anticipated test duration.

4.3.2 The efficiency of coalescers for removing free water from the test fuel should be such that the maximum concentration of free water exiting the coalescer does not exceed 20 ppm when tested per ASTM D3240.

NOTE: ASTM D3240 is used with current petroleum based aviation turbine fuels. If other fuel types having differing chemical compositions are used, it should be verified that ASTM D3240 can be used to determine the free water concentration in such fuels.

4.4 Pressure Measurements

Pressure measurements are to be performed in accordance with ARP24.