

AEROSPACE INFORMATION REPORT

AIR6985™

Issued

2021-06

Performance Evaluation of Fuel Filter Elements Utilized in Aircraft Gas Turbine Engine and APU Main Fuel Systems

RATIONALE

The proper specification of filtration in gas turbine engine and APU main fuel systems is important in protecting fuel system components from particulate contamination that could lead to accelerated component wear, system malfunction and premature component failure. This AIR provides information about standard test procedures developed for the evaluation of the performance of fuel filter elements utilized in gas turbine engine and APU main fuel systems. This will allow both manufacturer and customer a common means to specify, control, and evaluate fuel filter elements to ensure that the filter elements retain their functional characteristics under operating conditions.

1. SCOPE

This SAE Aerospace Information Report (AIR) reviews performance testing parameters for fuel filter elements utilized in gas turbine engine and APU main fuel systems. The scope is limited to main fuel filter elements rated at 35 $\mu\text{m(c)}$, or finer, which constitute the majority of contemporary engine main fuel system filtration. This document does not address icing tests specific to fuel filter elements since they are only required for certain engine designs and are custom test procedures. General information on icing tests for aircraft fuel system components can be found in ARP1401. This document also does not address fuel filter elements utilized in fuel hydraulic systems since it is outside the scope of this document,

This document is confined to laboratory testing of filter element performance to qualify the filtration medium and filter element construction as opposed to qualification of the complete fuel filter assembly. The testing discussed here is usually followed by laboratory and on-engine testing of the entire fuel filter assembly (including filter element, housing, valving, etc.) which is outside the scope of this AIR.

1.1 Purpose

Performance testing is necessary to assure that filter elements retain their functional characteristics under operating conditions. Variations in filter element testing methods and requirements make comparison of performance test results difficult. In order to minimize these issues, this AIR describes standard filter element performance test procedures, allowing both manufacturer and customer a common means to specify, control, and evaluate fuel filter elements. This document highlights recommended tests and the appropriate test sequence. The methodology discussed should be incorporated in fuel filter element specifications.

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.

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Documents

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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.

AIR887	Liquid Filter Ratings, Parameters and Tests
AIR4023	Aircraft Turbine Fuel Contamination History and Endurance Test Requirements
AIR4246	Contaminants for Aircraft Turbine Engine Fuel System Component Testing
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
ARP901	Bubble-Point Test Method
ARP1401	Aircraft Fuel System and Component Icing Test
ARP1827	Measuring Aircraft Gas Turbine Engine Fine Fuel Filter Element Performance
MAP749	Aircraft Turbine Engine Fuel System Component Endurance Test Procedure (Room Temperature Contaminated Fuel)

2.2 U.S. Government Publications

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

MIL-F-8815	Filter and Filter Elements, Fluid Pressure, Hydraulic Line, 15 Micron Absolute and 5 Micron Absolute, Type II Systems General Specification for
MIL-E-5007 ¹	Engines, Aircraft, Turbojet and Turbofan, General Specification for

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 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 12103-1	Road Vehicles - Test Dust for Filter Evaluation; Part 1: Arizona Test Dust

3. FILTER ELEMENT INTEGRITY AND PERFORMANCE EVALUATION

The evaluation of filter element integrity and performance may be divided, broadly, into three categories:

1. Assurance that the filter element has been properly manufactured: dimensions, weight, materials of construction, and overall integrity of the filter element *via* the Bubble Point and End Load tests.

¹ MIL-E-5007 is inactive for new design as of January, 1997.

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

2. Conditioning: A number of laboratory procedures have been developed, listed in Table 1, which expose filter elements to harsh conditions simulating extreme conditions encountered during service. The generic term for these procedures is conditioning. Conditioning of filter elements, prior to performance testing, is necessary in order to determine if filter element performance will degrade during actual service.

Table 1 - Fuel filter element conditioning methods

Extreme Environment	Associated Issues	Test Method	Paragraph
Fluid Compatibility	Chemical incompatibility, especially at higher temperatures	Heat Soak in fuel(s) at highest service temperature	6.1
Exposure to High Temperature	Thermal incompatibility of materials, Differential coefficient of expansion	Heat Soak (part of fluid compatibility)	6.1
Exposure to Low Temperature	Embrittlement, Differential coefficient of expansion	Cold Soak	6.2

3. Filter element performance: The key performance characteristics of the filter element are evaluated by a variety of tests using controlled and reproducible test procedures accepted by the industry. The more prominent tests, currently in use, are listed in Table 2.

Table 2 - Fuel filter element performance tests

Parameter	Test Method	Paragraph
Clean pressure drop	Flow versus differential pressure	7.1
Dirt capacity	Filter element differential pressure build-up versus contaminant added	7.2
Filtration efficiency	Filtration ratios from multi-pass or single-pass filter element performance test	7.3.2
Collapse rating	Extreme differential pressure	7.4

4. QUALIFICATION TEST SEQUENCE

Table 3 depicts a model qualification test sequence. Success criteria should be defined in the filter element specification.

Table 3 - Model qualification test sequence

Filter Element #1	Filter Element #2	Procedure Paragraph
Examination of Product (Dimensions and Weight)	Examination of Product (Dimensions and Weight)	
Bubble Point	Bubble Point	5.1
End Load Test	End Load Test	5.2
Bubble Point	Bubble Point	5.1
Heat Soak	Heat Soak	6.1
Cold Soak	Cold Soak	6.2
Bubble Point	Bubble Point	5.1
Filter Element with Lowest Bubble Point	Filter Element with Highest Bubble Point	
	Clean Pressure Drop	7.1
Filtration Efficiency: Filtration Ratios		7.3.2
	Dirt Capacity	7.2
Collapse Rating: Extreme Differential Pressure		7.4

A minimum of two filter elements are subjected to the sequence of tests as indicated in Table 3. Additional filter elements may be required for the sequence of tests associated with the dirt capacity depending on customer requirements (7.2).

5. INTEGRITY TESTS

5.1 Bubble Point Test

In order to ensure that the filter element has been properly manufactured and handled, an integrity check is performed. The Bubble Point test is an excellent method for detecting punctures and/or tears in the medium, defective sealing, and damage from handling. This procedure is non-destructive.

The Bubble Point test is performed by immersing the filter element horizontally in a bath of appropriate test fluid (usually an alcohol) and allowing the fluid to fully wet the filter element. The filter element is positioned so that the upper edge of the filter element is 1/2 inch below the fluid surface. The inside of the filter element is then slowly pressured with air. After every pressure increase of 1/2 inch of water column, the filter element is rotated by 360 degrees about its horizontal axis and positioned to ensure that any originating air bubbles are from the top surface of the filter element. The pressure at which the first, steady stream of bubbles issues from the top surface of the filter element is defined as the Bubble Point.

The Bubble Point test procedure does not measure the filter element efficiency. A high efficiency filter element constructed with one type of filtration medium can have a lower Bubble Point than a less efficient filter element constructed from a different type of filtration medium. However, the Bubble Point test is an excellent method to check filter element integrity, useful for quality control as well as for qualification testing. A detailed discussion of the theory and procedure is given in ARP901.

5.2 End Load Test

The End Load test is used to verify the bonding of the end caps to the filtration medium pack. Typically, a tensile load (in some cases a compressive load) of 50 pounds (or otherwise specified force) is applied to the end caps, along the axis of the filter element. The Bubble Point of the filter element is then determined to ensure that the integrity of the bond between end caps and filter element pack is retained.

Usually, the filter element end caps experience compressive stresses. If there are applications where the filter element end caps may experience significant tensile stresses, the End Load test and subsequent Bubble Point test in Table 3 may be performed after Cold Soak conditioning and the subsequent Bubble Point test since conditioning would amplify any deficiencies in the bonding of the end caps.

6. CONDITIONING

6.1 Heat Soak

A primary requirement is that the filter element medium pack, end caps, core, seals, and bonding materials be compatible with the maximum temperature experienced by the filter element in the system, and with the operating fluid(s) of the system at this maximum temperature; incompatibility between filter element materials and the operating fluid(s) is accelerated by high temperatures. Because of the large surface area of the filter element medium pack exposed to the fluid(s), a compatibility requirement is of major importance. Issues that may occur when operating at high fluid temperature include degradation of the filter element medium pack and the bonding materials used to attach the filter element medium pack to the support hardware. In addition, thermal incompatibility of the support hardware, including different thermal expansion coefficients of the different materials, can result in degradation of the filter element and hence, reduced filtration efficiency.

Heat soak is performed by immersing the test filter element in the type(s) of fuel(s) to be used in service, at the highest temperature(s) anticipated in service, typically for a period of 72 hours.

6.2 Cold Soak

Cold temperature embrittlement and differences in coefficients of thermal expansion between the materials in the filter element can amplify any tendency toward filter element damage. In order to evaluate the effects of low temperature on filter elements, cold soak conditioning is employed.