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AEROSPACE INFORMATION REPORT

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PERFORMANCE TESTING OF GAS TURBINE LUBE OIL FILTER ELEMENTS

1. SCOPE:

This SAE Aerospace Information Report (AIR) reviews performance testing parameters for noncleanable, often referred to as disposable, aircraft gas turbine engine lubricant filter elements.

1.1 Purpose:

Performance testing is necessary to assure that filter elements retain their functional characteristics under operating conditions. This document highlights recommended tests and the appropriate test sequence. The methodology discussed should be incorporated in filter element specifications.

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.

2.1 SAE Publications:

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

AIR887 Liquid Filter Ratings, Parameters and Tests
ARP901 Bubble Point Test Method
ARP1827 Measuring Aircraft Gas Turbine Engine Fine Fuel Filter Element Performance
AIR4023 Aircraft Turbine Fuel Contamination History and Endurance Test Requirements

2.2 Military Publications:

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

MIL-F-8815D Filter and Filter Elements, Fluid Pressure, Hydraulic Line, 15 Micron Absolute and 5 Micron Absolute, Type II Systems General Specification for

2.3 NFPA Publications:

Available from the Publications Department of NFPA, 3333 North Mayfair Road, Milwaukee, WI 53222-3219.

T3.10.8.5 Hydraulic Filter Element Collapse Burst Test

3. FILTER ELEMENT INTEGRITY AND PERFORMANCE EVALUATION:

Filter element integrity and performance are evaluated by a variety of tests using controlled and reproducible procedures. The more prominent tests currently in use are listed in Table 1.

TABLE 1 - Filter Element Function Tests

Parameters	Test Method	Paragraph
Filter Element Integrity	Bubble Point	5.1
Hardware Integrity	End Cap Pull/Bubble Point	5.2/5.1
Clean Pressure Drop	Flow vs. Differential Pressure	
Dirt Capacity	Pressure Build-up vs. Contaminant Added	7.1
Filter Element Efficiency	Filtration Ratio	7.2.1
	Gravimetric Efficiency	7.2.2
Filter Element Rating	Maximum Spherical Particle Passed (Absolute Rating)	7.2.3.1
Collapse Rating	Extreme Differential Pressure	7.3

In addition, a number of laboratory procedures have been developed which expose filter elements to harsh conditions simulating those encountered during service (Table 2). The generic term for these procedures is Conditioning. Conditioning of filter elements prior to testing is necessary in order to determine if filter element performance will degrade during actual service.

TABLE 2 - Filter Element Conditioning Methods

Extreme Environment	Method	Paragraph
Fluid Compatibility	Heat Soak	6.1
Exposure to Cold	Cold Soak	6.2
Cold Start-Up	Cold Start	6.2
Pump Ripple (Hydraulic Applications)	Flow Fatigue	6.3

4. QUALIFICATION TEST SEQUENCE:

Figure 1 depicts a qualification test sequence. Criteria for acceptance or rejection should be defined in the filter element specification. For filter elements utilized in engine hydraulic circuits, flow fatigue testing should be incorporated as discussed in 6.3.

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 seals, and damage from handling. This procedure is nondestructive.

The bubble point test is performed by fully wetting and then immersing the filter element horizontally in a bath of appropriate fluid. The filter element is positioned so that the upper edge of the filter element medium is 1/2 inch below the fluid surface. The inside of the filter element is then pressured with air. After every pressure increase of 1/2 inch of water column, the filter element is rotated by 360° about the horizontal axis. The pressure at which the first stream of bubbles issuing from the filter element is observed is 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 filter element medium can have a lower bubble point than a less efficient filter element constructed from a different type of filter element medium. The bubble point test is, however, an excellent integrity check method, useful for quality control as well as for qualification testing. For details, refer to ARP901.

5.2 End Cap Pull Test:

The end caps shall be capable of withstanding a pull of 50 lb (or otherwise specified force) to ensure the integrity of the bond between end caps and filter element pack.

Filter Element #1 Lowest Bubble Point		Filter Element #2 Highest Bubble Point		Filter Element #3* Second Highest Bubble Point		Filter Element #4** Third Highest Bubble Point		Paragraph
				1. Pretest Integrity				
1.1.1	Examination of Product (Dimensions and Weight)	2.1.1	Examination of Product (Dimensions and Weight)	3.1.1	Examination of Product (Dimensions and Weight)	4.1.1	Examination of Product (Dimensions and Weight)	
1.1.2	End Cap Pull	2.1.2	End Cap Pull	3.1.2	End Cap Pull	4.1.2	End Cap Pull	5.2
1.1.3	Bubble Point	2.1.3	Bubble Point	3.1.3	Bubble Point	4.1.3	Bubble Point	5.1
				2. Conditioning				
1.2.1	Heat Soak	2.2.1	Heat Soak	3.2.1	Heat Soak	4.2.1	Heat Soak	6.1
1.2.2	Cold Soak	2.2.2	Cold Soak	3.2.2	Cold Soak	4.2.2	Cold Soak	6.2
1.2.3	Cold Start	2.2.3	Cold Start	3.2.3	Cold Start	4.2.3	Cold Start	6.2
						4.2.4	Flow Fatigue	6.3
				3. Postconditioning Integrity				
1.3.1	Bubble Point	2.3.1	Bubble Point	3.3.1	Bubble Point	4.3.1	Bubble Point	5.1
				4. Performance Tests				
1.4.1	Clean Element Pressure Drop	2.4.1	Clean Element Pressure Drop	3.4.1	Clean Element Pressure Drop			
1.4.2	Filtration Efficiency: Filtration Ratio							7.2.1
		2.4.2	Dirt Capacity					7.1
				3.4.2	Maximum Spherical Particle Passed			7.2.3.1
						4.4.1	Post Flow Fatigue Filtration Efficiency: Filtration Ratio	7.2.1.1
1.4.3	Collapse Rating: Extreme Differential Pressure	2.4.3	Collapse Rating: Extreme Differential Pressure					7.3
				5. Posttest Integrity				
1.5.1	End Cap Pull	2.5.1	End Cap Pull	3.5.1	End Cap Pull	4.5.1	End Cap Pull	5.2
1.5.2	Bubble Point	2.5.2	Bubble Point	3.5.2	Bubble Point	4.5.2	Bubble Point	5.1

* To be incorporated only if the absolute rating of the filter element is required (see 7.2.3.1).

** To be incorporated only if high cyclic flow is encountered in service; see 6.3.

FIGURE 1 - Qualification Test Sequence

6. CONDITIONING:

6.1 Heat Soak:

A primary requirement is that the filter element medium, seals, and bonding material be compatible with the operating fluid(s) of the system. Incompatibility between component materials and the operating fluid(s) is accelerated by high temperatures. Because of the large surface area of filter element medium exposed to the fluid(s), a compatibility requirement is of major importance. Problems that may occur when operating at high fluid temperature include degradation of the filter element medium and the bonding material used to attach the medium to the support hardware.

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

6.2 Cold Soak and Cold Start:

Since lubricating fluids have high viscosities at low temperatures, forcing cold fluid through a filter element can produce potentially damaging differential pressures. This occurs during system cold starts. In addition, cold temperature embrittlement can amplify any tendency toward damaging the filter element.

In order to evaluate the effects of low temperature on filter elements, cold soak and cold start tests are employed. Cold soak is performed by immersing a test filter element in the operating fluid. The fluid is then chilled to the required temperature, usually between 0 and -65 °F. This temperature is held for 72 h. A cold start test is then performed. This consists of a predetermined number of flow cycles of cold fluid, at the required temperature, or viscosity, through the filter element. The flow cycles are adjusted so that the filter element is subjected to the maximum required differential pressure for a specified duration at the peak of each cycle.

6.3 Flow Fatigue:

While cyclic flow is not a common phenomenon in typical lubrication circuits, it is in turbine engine hydraulic systems using lubricating oil as the service fluid. Cyclic flow across a filter element may cause the medium to flex. This movement can result in filter element medium failure. Often, filter element fatigue failures go unnoticed. If the filter element application is for a lube hydraulic system, a flow fatigue test should be considered. For the flow fatigue test procedure, refer to MIL-F-8815D.

7. FILTER ELEMENT PERFORMANCE TESTS:

7.1 Dirt Capacity Test:

There are several versions of this test. All tests are performed utilizing predetermined test parameters such as test temperature and flow rate. In addition, all methods add a standardized test contaminant, often Air Cleaner (AC) Fine Test Dust or AC Coarse Test Dust conforming to the specification in AIR4023, upstream of the filter element until a predefined differential pressure across the filter element is reached. The contaminant may be added continuously throughout the test (slurry loading), or in discreet amounts separated by intervals of several minutes (slug loading). Depending on the test protocol employed, contaminant may be recirculated through the test circuit (multipass) or, alternatively, collected by a high efficiency cleanup filter downstream of the test filter element (single-pass). The results are reported as the total weight, in grams, of contaminant added to the test system until a predefined differential pressure across the filter element is reached.

Unfortunately the label given to this class of tests is a misnomer. The amount of contaminant retained by a filter element is not determined. What is measured is the amount of contaminant added to the test circuit. By capturing only a small portion of the test contaminant, a coarse filter element may show a higher dirt capacity than a finer filter element which captures most of the test contaminant. Operating with cleaner oil significantly reduces the amount of wear debris generated by operating systems. With fewer particles to capture, a high efficiency filter element can have longer service life than a coarse filter. For these reasons dirt capacity test results should only be compared for filter elements having similar efficiencies.

7.2 Filtration Efficiency Tests:

Filtration efficiency is a measure of the ability of a filter element to remove particles from a fluid stream. Most methods for determination of filtration efficiency involve challenging the filter element with standardized particulate contaminant, under controlled test conditions to ensure repeatable and reproducible results, and measuring the amount of contaminant emerging from the test filter element. The particles may be counted individually, utilizing light microscopes or automatic particle counters, or collectively (e.g., gravimetric analysis or turbidity measurement). Typically, the test contaminants have particle sizes ranging over selected size intervals.

Several laboratory tests incorporating particle challenges have been developed for measuring filter element efficiency. These tests have generated uniform scales, or ratings, of filter element efficiency. These ratings are convenient yardsticks for comparing the performance of different filter elements. For additional details, refer to AIR887. The preferred method for measuring filter element efficiency is the filtration ratio test.

7.2.1 Filter Element Efficiency by the Filtration Ratio Test: The filtration ratio test measures the ability of filter elements to capture particles in specific size ranges. The number of particles challenging the filter element and the number of particles emerging from the filter element are counted. Filter element efficiency is reported as filtration ratios. The filtration ratio at a specific size is obtained by dividing the number of particles upstream, greater than the specified particle size, by the number of particles downstream greater than the same particle size:

$$\text{Filtration Ratio}_x = \frac{\text{No. of Particles Upstream} > x\ \mu m}{\text{No. of Particles Downstream} > x\ \mu m} \qquad \text{(Eq.1)}$$

The particle removal efficiency, expressed as a percentage, is given by the following equation:

$$\text{Particle Removal Efficiency at } x\ \mu m = (1 - 1/\text{Filtration Ratio}_x) \times 100 \qquad \text{(Eq.2)}$$

The particle removal efficiencies for several filtration ratios are listed in Table 3.

TABLE 3

Filtration Ratio	Particle Removal Efficiency %
1	0
2	50
10	90
20	95
50	98
100	99
200	99.5
1000	99.9
5000	99.98

7.2.1 (Continued):

The filtration ratio test is performed at rated flow. A slurry of contaminant (often AC Fine Test Dust) is continuously injected into the test filter element circuit until the required differential pressure, often referred to as terminal differential pressure, is reached. Using on-line sampling techniques, representative portions of upstream and downstream fluid are passed through automatic particle counters throughout the test. Particle counts, corresponding to the size ranges for which filtration ratios are required, are monitored throughout the test. The applicable procedure for the filter element efficiency test is described in ARP1827.

Obtaining filter element efficiency by the filtration ratio test has several important advantages:

a. Irregularly shaped test contaminant is employed which is similar to contaminant in operating systems.

b. Efficiencies are measured over a spectrum of particle sizes.

c. Filter efficiency results are averages of filter element performance from the initial clean differential pressure to the terminal differential pressure.

7.2.1.1 Post Flow Fatigue Filtration Efficiency: The post flow fatigue filtration efficiency test is designed to demonstrate the ability of the filter element to maintain an adequate level of performance when subjected to the stresses associated with the high cyclic flow(s)/pressure(s) that may be encountered in turbine engine lube oil hydraulic systems.

A modified filtration ratio test is used to determine filter element efficiency. In this test, a reduced flow rate, along with a reduced particulate challenge level, is employed. The reduced flow rate and reduced particulate challenge level allow for an adequate test time to acquire meaningful data since the flow fatigue test requires significantly contaminating the filter element in order to achieve the required filter element differential pressure(s) associated with the flow fatigue test cycles.

7.2.2 Gravimetric Efficiency by the Single-Pass Gravimetric Efficiency Test: The test is performed in a fashion similar to the maximum spherical particle passed test (see 7.2.3.1). A slurry of contaminant, not necessarily composed of spherical particles, is allowed to flow through the filter element. The weight of contaminant challenging the filter element is compared to the weight of contaminant emerging from the filter element. The data is reported as an efficiency value:

$$E(\%) = [(A-B)/A] \times 100 \qquad \text{(Eq.3)}$$