

AEROSPACE RECOMMENDED PRACTICE

SAE ARP4205

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Aerospace Fluid Power - Hydraulic Filter Elements - Method for Evaluating Dynamic Efficiency with Cyclic Flow

RATIONALE

Flow variations that occur in aircraft hydraulic systems are known to have a significant impact on filter performance. Current filter test procedures evaluate filter performance under steady flow conditions, and therefore, do not provide a measure of dynamic filter performance. ARP 4205 was developed to impose dynamic test conditions while measuring filter performance, to more closely simulate how a filter might perform on an operating aircraft.

FOREWORD

It is important for a laboratory test to simulate conditions of actual operation as closely as feasible. Most aircraft hydraulic systems are subjected to unsteady flow with flow cycles caused by such conditions as actuator movement. Such flow variations can have a significant impact on filter performance. Most previous filter efficiency tests utilize steady flow, which does not represent such cyclic flow conditions.

This standard test method measures filter performance under cyclic flow conditions. The influence of other stressful operating conditions, such as heat, cold and vibration, are not measured with this procedure. The stabilized contamination level measured while testing with cyclic flow gives an indication of the average contamination level maintained by the filter in a dynamic operating system. The average system contamination level is important in establishing wear rates.

The measurements are made with precise control over the operating conditions to ensure repeatability and reproducibility, and the results will more closely represent actual performance than previous test methods. However, because the test parameters and test contaminant do not exactly replicate actual operating conditions, the measurements cannot be expected to duplicate actual performance in an operating system.

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1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) describes a method for evaluating the performance of filter elements designed for Aerospace hydraulic systems. The performance is measured and reported in terms of filtration ratios and stabilized contamination level while testing with cyclic flow.

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

ARP24	Determination of Hydraulic Pressure Drop
ARP785	Procedure for the Determination of Particulate Contamination in Hydraulic Fluids by the Control Filter Gravimetric Procedure

2.2 ISO Publications:

Available from International Organization for Standardization, 1, rue de Varembe, Case postale 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	Hydraulic fluid power - Calibration of liquid automatic particle-count instruments - Method using air cleaner fine test dust contaminant (Obsolete)
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

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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

2.3 Military Specifications:

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, <http://assist.daps.dla.mil/quicksearch>

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-PRF-5606 Hydraulic Fluid, Petroleum Base, Aircraft, Missile and Ordnance (Inactive for new design)

MIL-PRF-81836 Filter and Disposable Element, Fluid Pressure, Hydraulic, 3 Micron Absolute

MIL-PRF-83282 Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Metric, NATO Code Number H-537

MIL-PRF-87257 Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile

2.4 NIST Publications: Available from National Institute of Standards and Technology, 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

3. GLOSSARY OF TERMS:

- D_X = the total number of particles per unit volume greater than a given particle size 'x' downstream of the filter element
- G_B = the required base upstream gravimetric level (mg/L) of contaminant in the filter element test system.
- G_{BA} = the actual, average base upstream gravimetric level (mg/L) of contaminant in the filter element test system.
- G_I = the required gravimetric level (mg/L) of contaminant in the contaminant injection system fluid.
- G_{IA} = the calculated average base upstream gravimetric level (mg/L) of contaminant in the contaminant injection fluid.
- M_E = the estimated mass (g) of contaminant required for the test filter element to reach the terminal filter element differential pressure.
- M = the required amount of contaminant (grams) to be added to the contaminant injection system to achieve the desired base upstream gravimetric level, G_B , in the filter element test system.
- M_I = the total mass of contaminant injected at the terminal differential pressure.
- M_V = 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.
- ΔP_H = differential pressure of housing and free flow dummy element at rated flow, Q_F .
- ΔP_F = differential pressure of housing and clean test filter element at rated flow, Q_F .
- ΔP_{CE} = Clean filter element differential pressure at rated flow, Q_F .
- ΔP_T = terminal filter element differential pressure at rated flow, Q_F , for test termination.

NOTE: The terminal filter element differential pressure for test purposes should be set at the maximum differential pressure the element is expected to see in service. This is normally higher than the setting of the filter change indicator.

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- ΔP_N = net element differential pressure, equals ΔP_T minus ΔP_{CE} .
- $\Delta P_{2.5A}$ = assembly differential pressure at increase of 2.5% of net element differential pressure.
- ΔP_{80A} = assembly differential pressure at increase of 80% of net element differential pressure.
- Q_A = Average flow rate (L/min) through the filter element, during cyclic flow. For flow cycling from $0.25 Q_F$ to Q_F , $Q_A = 0.63 Q_F$.
- Q_F = Rated filter flow rate (L/min) through the filter element; maximum value during cyclic flow.
- Q_I = the required rate (L/min) of injection flow from the contaminant injection system to the filter element test system.
- Q_{IA} = the calculated average rate of injection flow from the contaminant injection system to the filter element test system.
- U_X = the total number of particles per unit volume greater than a given particle size 'X' upstream of the filter element.
- V_F = the filter element test system fluid volume (L).
- V_I = the contaminant injection system fluid volume (L).
- V_{IF} = the contaminant injection system fluid volume (L) at the conclusion of the test.
- V_{IU} = the unusable fluid volume (L) in the contaminant injection system.
- X = contaminant particle size, $\mu m(c)$, per ISO 11171 calibration.
- σ = the filtration ratio, omega, obtained using ISO Fine Test Dust (ISO 12103-A2) under cyclic flow test conditions.
- T = the predicted test time (minutes) of the cyclic flow portion of the test.
- T_T = the timer value at the end of the test (minutes).

4. TEST EQUIPMENT AND CONDITIONS:

4.1 Utilize and maintain instrument accuracy and test conditions within the limits in Table 1.

TABLE 1 - Instrument Accuracy and Test Condition Variation

Test Parameter	SI Unit	Instrument Accuracy (±) of Reading	Allowed Test Condition Variation (±)
Differential pressure	Pa, kPa or bar	5%	--
Base upstream gravimetric	mg/L	--	10%
Flow:			
Injection flow	mL/min	2%	5%
Test flow	L/min	2%	5%
APC sensor flow	L/min	1.5%	3% (1)
Kinematic viscosity (2)	mm ² /s	2%	1 mm ² /s
Mass	g	0.1 mg	--
Temperature	°C	1 °C	2 °C (3)
Time	s	1 s	--
Volume:			
Injection system	L	2%	--
Filter test system	L	2%	5%
(1) - Sensor flow variation to be included in the overall 10% allowed between sensors			
(2) - 1 mm ² /s = 1 centistoke (cSt)			
(3) - Or as required to guarantee the viscosity tolerance			

4.2 Test Fluids:

The test fluid used shall conform to MIL-PRF-5606 specification, or alternatively to MIL-PRF-83282 or MIL-PRF-87257, or shall be as specified by the procuring agency.

4.3 Test Fluid Temperature:

The temperature of the test fluid, during the test, shall be controlled at a temperature to result in a test fluid viscosity of 15 cSt ± 1 cSt.

4.4 Test Contaminant:

4.4.1 The test contaminant used shall be ISO Fine Test Dust per ISO 12103-A2.

4.4.2 Test Contaminant Concentration: The target base upstream gravimetric level, G_B (mg/L), is defined as the desired test contaminant mass per unit fluid volume ingressed into the filter element test system, upstream of the test filter element. The target base upstream gravimetric level shall not normally be less than 3 mg/L nor more than 10 mg/L in order to achieve a sufficient number of particles challenging the filter while minimizing saturation errors for the automatic particle counters.

The target base upstream gravimetric level shall be selected as either 3 or 10 mg/L to obtain (if possible) a test time of 30 to 120 minutes, excluding the total stabilization time (6.1.3.8). The predicted test time, T , can be calculated from the estimated mass of test contaminant, M_E , required to achieve the terminal filter element differential pressure, the base upstream gravimetric level, G_I , selected, and the average test element flow rate, Q_A , per the following equation:

$$T = (1000 \times M_E) / (G_B \times Q_A) \quad (\text{Eq. 1})$$

4.5 Test Circuit:

- 4.5.1 Use a filter performance test circuit comprised of a "filter test system" and a "contaminant injection system".

NOTE 1: A schematic diagram of the typical cyclic flow filter performance test system is shown in Figure A1, Appendix A.

NOTE 2: A Multi-pass test circuit per the guidelines in ISO 16889 can be modified for use with this procedure by addition of valves for creating flow cycles.

4.6 General Considerations:

- 4.6.1 Conduits, reservoirs and fittings shall be selected with smooth contours, no pockets, and shall be properly oriented to prevent contaminant entrapment.
- 4.6.2 All lines should be sized to provide turbulent mixing flow conditions within the line to ensure that the system can be validated at the lowest flow rates. However, validation, not line sizes, shall be the criteria for the suitability of the test stand.
- 4.6.3 Reservoirs shall be constructed with smooth conical bottoms that have an included angle of not more than 90 degrees. Reservoir outlet shall be located at the bottom of the cone.
- 4.6.4 Fluids entering the reservoir shall be diffused. Diffusion should take place below the reservoir fluid surface in order to eliminate the formation of air bubbles. These air bubbles could adversely affect automatic particle counter readings. Reservoir diffusion will also aid contaminant dispersion.
- 4.6.5 Pressure Measurements: Pressure measurements are to be performed in accordance with ARP24.

4.6.6 Cleanup Filter: It is recommended that cleanup filter elements used for cleaning of test fluids meet or exceed the efficiency requirements of MIL-PRF-81836 specification. Filters with a filtration ratio of $\beta_{2(c)} > 200$ should be adequate. Filter elements meeting this efficiency will control particles in the 4 $\mu\text{m(c)}$ size range, which can affect both the particle counts and the dirt loading characteristics of fine aerospace filters.

4.7 Contaminant Injection System:

4.7.1 A turbulent means should be provided for transferring fluid from the contaminant injection system to the filter test system to yield a flow rate, Q_I , in the range of 0.1 to 0.25 L/min.

NOTE 1: The injection flow should be set as low as possible to minimize any influence of contaminant removed by the downstream fluid discarded (see 4.8.2). The injection system must be validated at the minimum flow rate (see 5.1).

NOTE 2: Turbulence may not always be possible or guaranteed by calculation. Long straight lines should not be used. Validation will assure that system is satisfactory.

4.7.2 The total fluid volume, V_I , of the contaminant injection system may be adjusted by varying the level of the fluid in the reservoir and shall be sufficient to contain the fluid volume required by the following equation:

$$V_I \geq (1200 \times Q_I \times M_E)/(G_B \times Q_A) + V_{IU} \quad (\text{Eq. 2})$$

NOTE 1: The volume calculated above will assure a sufficient quantity of contaminated fluid to load the test element plus 20% for adequate circulation throughout the test. The injection fluid volume may be increased as needed by increasing the amount of test dust proportionately. Since during the test, the flow is cycled from 0.25 Q_F to Q_F , the average flow, $Q_A = 0.63 \times Q_F$, is used in the equation.

NOTE 2: The minimum usable volume, V_{IU} , is measured as the minimum volume in the reservoir prior to aeration, loss of pressure or other parameter which might prevent constant injection flow or concentration.

- 4.7.3 Before adding contaminant, the cleanup filter element per 4.6.6 shall clean the contaminant injection system to the extent that particles $>4 \mu\text{m(c)}$ in size do not exceed 200 per mL. Gravimetric analysis of fluid samples taken from the injection system shall be less than 1% of the required gravimetric level, G_I , of the contaminant injection system fluid, defined by the following equation:

$$G_I = (G_B \times Q_A)/Q_I \quad (\text{Eq. 3})$$

4.8 Filter Element Test System:

- 4.8.1 The total fluid volume, V_F , of the filter element test system, including the filter housing, but excluding the cleanup filter system, shall be numerically equal (within $\pm 2\%$) to one-half the volume flowed in 1 minute. This value is numerically equal to one-half the average filter element flow rate (Q_A) per minute value. This volume may be attained by adjusting the reservoir fluid level.
- 4.8.2 The total fluid volume of the filter test system should be maintained to within $\pm 5\%$ of the initial volume, V_F , during the filter element efficiency and stabilization test. This can be accomplished during the injection portions of the test by discarding fluid from the downstream sensor flow and/or from a regulated flow rate via Valve 18 in Figure A1. The total flow rate of fluid discarded should be adjusted to be within $\pm 5\%$ of the contaminant injection flow rate, Q_I , in order to maintain a constant filter element test system volume.
- 4.8.3 The filter element test system shall be sufficiently cleaned, before adding contaminant using a clean-up filter per 4.6.6, so that particles in each size range (refer to Table 2) do not exceed five percent of the expected downstream test values.
- 4.8.4 The flow cycling set-up (see Figure A1) shall be capable of cycling at 0.1 Hz. Each 10 second cycle shall consist of two equal parts, the first including a flow rise period (25 to 100% of the test flow rate, Q_F) and a constant 100% flow period, followed by the second part including a flow decay back to 25% Q_F and a constant 25% flow period. This is accomplished via the solenoid operated shut-off valve and the flow control valve in the by-pass circuit shown in Figure A1. The set-up should be such that the flow cycle falls within the limits set forth in Figure 1.