



AEROSPACE RECOMMENDED PRACTICE

ARP4205™

REV. A

Issued 2005-12
Revised 2026-06

Superseding ARP4205

(R) Hydraulic Filter Elements - Method for Evaluating Dynamic Efficiency with Cyclic Flow

RATIONALE

This revision was made to correct the table of particle counts for the ISO Fine Test Dust (FTD) that is used in the test stand validation procedure, as well as incorporate technical and editorial changes suggested by users of the document since its initial publication.

FOREWORD

This standard test method evaluates filter performance under cyclic flow conditions representative of the unsteady flow typically encountered in aircraft hydraulic systems. Unlike traditional steady-flow tests, this approach captures the impact of flow variation on filter efficiency. The stabilized contamination level observed during cyclic flow testing reflects the average contamination maintained in dynamic operation, which is critical for assessing system wear rates. While this method does not account for additional stressors such as temperature extremes or vibration, these factors may be incorporated as needed.

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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 levels while testing with cyclic flow.

NOTE: Appendix A provides background information and lessons learned for this document.

2. REFERENCES

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 Applicable Documents

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 1-877-606-7323 (U.S. and Canada only) or 1-724-776-4970 (outside U.S. and Canada), 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

AS4059 Contamination Classification for Hydraulic Fluids

2.1.2 ISO Publications

Copies of these documents are available online at www.iso.org/store.

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

ISO 12103-1 Road vehicles - Test dust for filter evaluation - Part I: Arizona test dust

ISO 14085-2 Aerospace series - Test methods for hydraulic filter elements - Part 2: Conditioning

ISO 16889 Hydraulic fluid power filters - Multi-pass method for evaluating filtration performance of a filter element

2.1.3 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

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

2.2 Definitions

TARGET BASE UPSTREAM GRAVIMETRIC LEVEL: This is the desired test contaminant mass per unit fluid volume ingressed into the filter element test system, upstream of the test filter element.

2.3 Abbreviations

NOTE: The specification uses metric units consistent with the industry test method

APC = Automatic Particle Counter

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 the contaminant in the contaminant injection fluid.

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_E = The estimated mass (grams) of contaminant required for the test filter element to reach the terminal filter element differential pressure.

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 = The differential pressure (kPa) of housing and free flow dummy element at rated flow, Q_F .

ΔP_F = The differential pressure (kPa) of housing and clean test filter element at rated flow, Q_F .

ΔP_{CE} = The clean filter element differential pressure (kPa) at rated flow, Q_F .

ΔP_T = The terminal filter element differential pressure (kPa) 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.

ΔP_N = The net element differential pressure (kPa) equals ΔP_T minus ΔP_{CE} .

$\Delta P_{2.5A}$ = The assembly differential pressure (kPa) at an increase of 2.5% of net element differential pressure.

ΔP_{80A} = The assembly differential pressure (kPa) at an increase of 80% of net element differential pressure.

$\Delta P_{2.5E}$ = The filter element differential pressure (kPa) at an increase of 2.5% of net element differential pressure.

ΔP_{80E} = The filter element differential pressure (kPa) at an increase of 80% of net element differential pressure.

Q_A = The 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 = The 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 (L/min) 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_{sf} = The filter element test system fluid volume after the test (L).

V_{si} = The filter element test system fluid volume before the test (L).

V_{ii} = The contaminant injection system fluid volume before the test (L).

V_{if} = The contaminant injection system fluid volume (L) after the test.

X = The contaminant particle size, $\mu m(c)$, per ISO 11171 calibration.

σ = The filtration ratio, Sigma, obtained using Fine Test Dust (refer to ISO 12103-1, A.2) 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).

3. TEST EQUIPMENT AND CONDITIONS

3.1 Instrument Accuracy and Test Conditions

The instrument accuracy and test conditions should be 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 mm²/s = 1 centistoke (cSt).

⁽³⁾ Or as required to guarantee the viscosity tolerance.

3.2 Test Fluids

The test fluid should conform to MIL-PRF-5606, MIL-PRF-83282 or MIL-PRF-87257. However, if none of these are to be used, then the test fluid should be specified by the procuring agency.

3.3 Test Fluid Temperature

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

3.4 Test Contaminant

3.4.1 Test Contaminant Type

The test contaminant used should be Fine Test Dust per ISO 12103-1, A.2.

3.4.2 Test Contaminant Concentration

The target base upstream gravimetric level is recommended to be between 3 and 10 mg/L 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 should be selected as either 3 mg/L, 5 mg/L, or 10 mg/L to obtain (if possible) a test time of 30 to 120 minutes, excluding the total stabilization time (see 5.1.3.8). 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_B , selected, and the average test element flow rate, Q_A , per the following equation:

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

3.5 Test Circuit

The filter performance test circuit should comprise a "Filter Test System" and a "Contaminant Injection System." A schematic diagram of a typical cyclic flow filter performance test system is shown in Figure 1. A multi-pass test circuit per the guidelines in ISO 16889 can be modified for use with this procedure by the addition of valves for creating flow cycles.

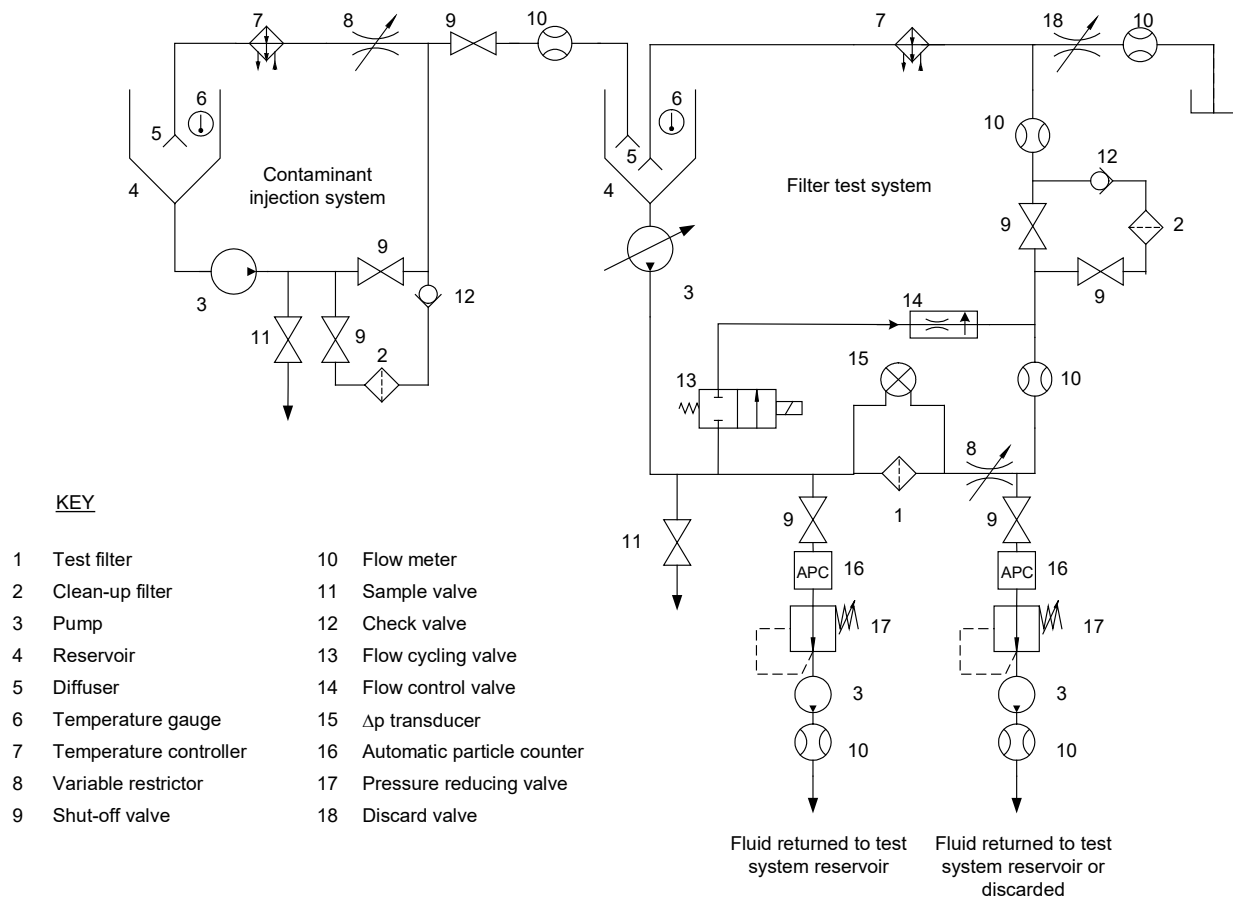


Figure 1 - Schematic of typical test setup for cyclic flow filter performance test

3.6 General Considerations

3.6.1 General

The following should be considered in the design of the test circuit:

- 3.6.1.1 Conduits, reservoirs, and fittings should be selected with smooth contours, and no pockets, and should be properly oriented to prevent contaminant entrapment.
- 3.6.1.2 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, should be the criteria for the suitability of the test stand.
- 3.6.1.3 Reservoirs should be constructed with smooth conical bottoms that have an included angle of not more than 90 degrees. The reservoir outlet should be located at the bottom of the cone.
- 3.6.1.4 Fluids entering the reservoir should be diffused. Diffusion should take place below the reservoir fluid surface to eliminate the formation of air bubbles. These air bubbles could adversely affect automatic particle counter readings. Reservoir diffusion will also aid contaminant dispersion.

3.6.2 Pressure Measurements

Pressure measurements should be performed using the guidelines of ARP24.