



AEROSPACE RECOMMENDED PRACTICE

ARP5454™

REV. C

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Superseding ARP5454B

Multi-Pass Method for Evaluating Filtration Performance of Fine Lube Filter Elements Utilized in Aerospace Power and Propulsion Lubrication Systems

RATIONALE

The proper performance of lubricant filter elements utilized in aerospace power and propulsion systems is important in protecting system components from particulate contamination that could lead to accelerated component wear, system malfunction, and premature component failure. This ARP provides a standard test method for determining the filtration efficiency and dirt capacity of lubricant filter elements utilized in power and propulsion systems. This will allow both manufacturer and customer a common means to evaluate the performance of lubricant filter elements.

The standard has been revised to: (1) include an update on the current status of the standard reference material (SRM) used for calibration of automatic particle counters per ISO 11171, (2) remove the reference to ARP1827 since it is not referred to in the standard, and (3) include editorial changes for clarity.

1. SCOPE

This SAE Aerospace Recommended Practice (ARP) describes the multi-pass method for evaluating the filtration performance of fine lube filter elements, commonly utilized in aerospace power and propulsion lubrication systems: gas turbine engines, auxiliary power units (APUs), helicopter transmissions, constant speed drives (CSDs), and integrated drive generators (IDGs).

1.1 Introduction

Variation in filter element testing methods and requirements make comparison of 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 specify, control, and evaluate filter elements.

1.2 Filter Element Performance Ratings

1.2.1 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 are expressed as filtration ratios, termed Beta ratios. The filtration ratio at a specified particle size "x," designated β_x , 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 $\mu\text{m(c)}$ to 25 $\mu\text{m(c)}$, as defined in ISO 11171.

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1.2.2 Multi-Pass Filter Element Dirt Capacity

The multi-pass filter element dirt capacity is the mass of test contaminant introduced into the filter element test system during the filtration efficiency test to produce the prescribed terminal filter element differential pressure. This value should be used only for comparing filter elements having similar filtration efficiencies.

It should be noted that a commonly specified dirt capacity test for lubricant filter elements utilized in aerospace lubrication systems is the MIL-F-8815 dirt capacity test, MIL-F-8815 (4.7.2.6). In this dirt capacity test, contaminant is added in discrete increments, "slugs," each increment consisting of a constant, predetermined mass of test contaminant, immediately upstream of the test filter, via a "slug" addition valve, at fixed intervals (usually every 4 minutes) during the test. The filter element differential pressure is recorded 2 minutes after each contaminant "slug" addition. The total mass of contaminant added to achieve the prescribed terminal filter element differential pressure is reported as the dirt capacity.

Depending on the customer specification, either dirt capacity test may be specified. Due to the differences in the two dirt capacity tests, the dirt capacities determined from the two tests will be different.

1.3 Test Contaminant and Particle Counter Calibration

Historically, AC Fine Test Dust was the test contaminant specified for the multi-pass filter performance test, and the calibration of automatic particle counters was in accordance with ISO 4402. 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). 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 performance test results that are significantly different from performance 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 performance test data with data generated per ARP5454, and when comparing filter element performance test data per ARP5454 to historic specification requirements. 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 $\mu\text{m(b)}$ 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 $\mu\text{m(c)}$ defined for SRM 2806 and SRM 2806a. At the time of this publication, NIST completed 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 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 lubrication 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 +1 724-77604970 (outside USA), www.sae.org.

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

Available from DLA Document Services, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6396, <http://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-23699	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base
MIL-PRF-81836	Filter and Disposable Element, Fluid Pressure, Hydraulic, 3 Micron Absolute

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 ¹	Hydraulic Fluid Power - Calibration of Automatic-Count Instruments for Particles Suspended in Liquids - Method Using Classified AC Fine Test Dust Contaminant

¹ ISO 4402 has been withdrawn as of 12/09/1999.

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

2.4 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)

3. GLOSSARY OF TERMS

β = the filtration ratio obtained using ISO Fine Test Dust (ISO 12103-A2) under multi-pass test conditions

Q_1 = the required flow rate (liters/minute) through the filter element

Q_2 = the required rate (liters/minute) of injection flow from the contaminant injection system to the filter element test system

Q_{2A} = the calculated average rate of injection flow from the contaminant injection system to the filter element test system

G_1 = the required base upstream gravimetric level (milligrams/liter) of contaminant in the filter element test system

G_{1A} = the actual, average base upstream gravimetric level (milligrams/liter) of contaminant in the filter element test system

G_2 = the required gravimetric level (milligrams/liter) of contaminant in the contaminant injection system fluid

G_{2A} = the calculated average gravimetric level (milligrams/liter) of contaminant in the contaminant injection system fluid

U_x = the total number of particles per unit volume greater than a given particle size "x" upstream of the filter element

D_x = the total number of particles per unit volume greater than a given particle size "x" downstream of the filter element

τ = the predicted test time (minutes) of the test

τ_A = the actual, recorded test time

τ_t = the timer value at the end of the test

V_1 = the filter element test system fluid volume (liters)

V_2 = the contaminant injection system fluid volume (liters)

V_{2F} = the contaminant injection system fluid volume (liters) at the conclusion of the test

V_{2M} = the unusable fluid volume (liters) in the contaminant injection system

W_1 = the estimated mass (grams) of contaminant required for the test filter element to reach the terminal filter element differential pressure

W_2 = 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

W_3 = 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

W_{DC} = the multi-pass test dirt capacity of the test filter element, defined as the mass of test contaminant introduced into the filter element test system during the filtration efficiency test to produce the terminal filter element differential pressure.

x = contaminant particle size [$\mu\text{m}(c)$] per ISO 11171 calibration

4. CONVERSIONS

(Liters per minute) = $3.785 \times$ (U.S. gallons per minute)

(Milligrams per liter) = $0.2642 \times$ (milligrams per U.S. gallon)

5. TEST SET-UP AND HARDWARE

A schematic diagram of the multi-pass test system is shown in Figure 1.

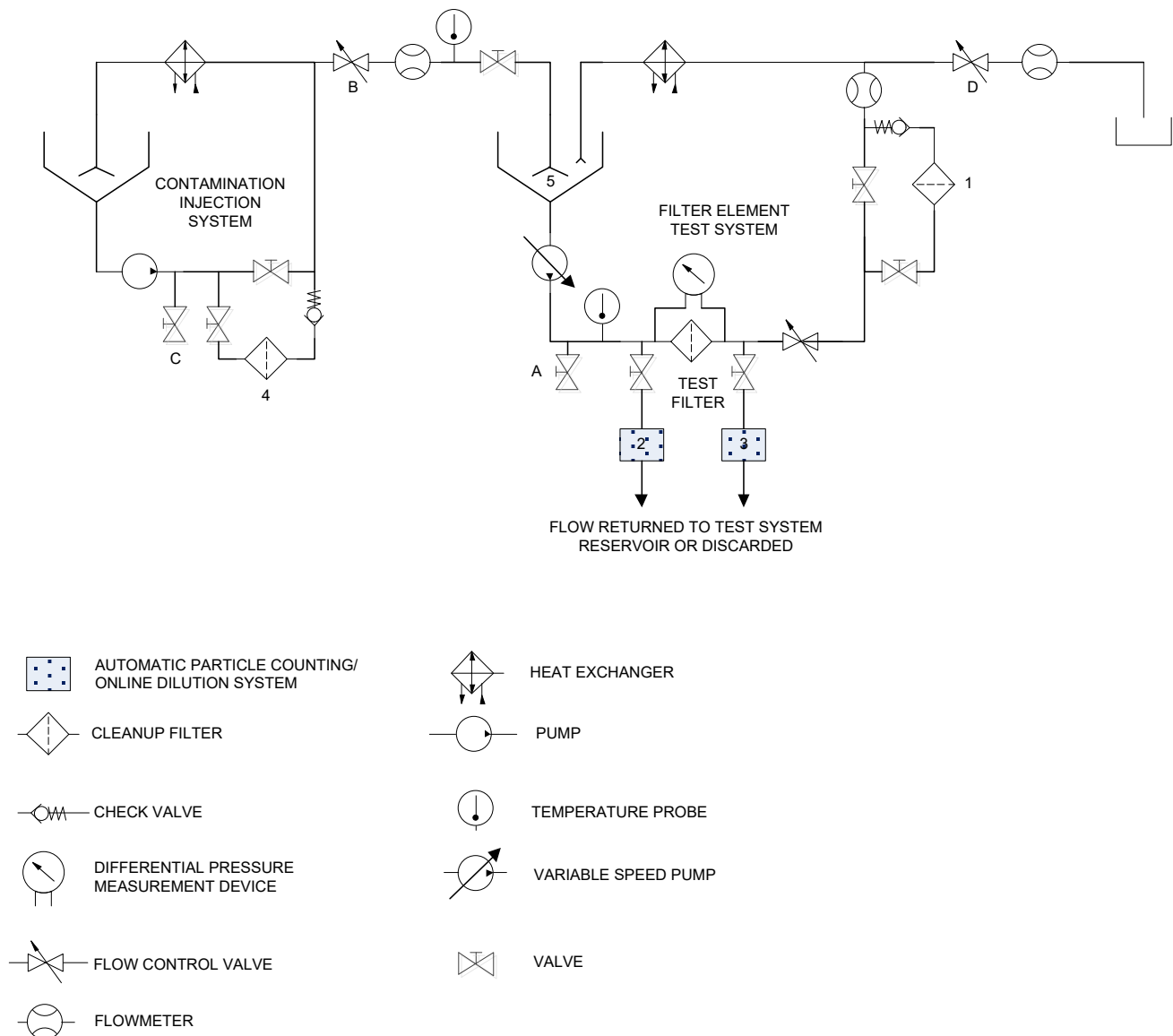


Figure 1 - Schematic of typical test set-up for multi-pass filter performance test