INTERNATIONAL STANDARD

ISO 14085-3

First edition
2015-03-01

Aerospace series — Hydraulic filter elements — Test methods —

Part 3:
Filtration efficiency and retention capacity

Série aérospatiale — Eléments filtrants hydrauliques — Méthode d'essais —

Partie 3: Efficacité de filtration et capacité de rétention

Reference number
ISO 14085-3:2015(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 10, *Aerospace fluid systems and components*.

ISO 14085 consists of the following parts, under the general title *Aerospace series — Hydraulic filter elements — Test methods*:

- *Part 1: Test sequence*
- *Part 2: Conditioning*
- *Part 3: Filtration efficiency and retention capacity*
- *Part 4: Verification of collapse/burst pressure rating*
- *Part 5: Resistance to flow fatigue*
- *Part 6: Initial cleanliness level*

Introduction

In aerospace hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure. The liquid is both a lubricant and power-transmitting medium. The presence of solid contaminant particles in the liquid interferes with the ability of the hydraulic fluid to lubricate, and causes wear and malfunction of the components. The extent of contamination in the fluid has a direct bearing on the performance, reliability, and safety of the system, and needs to be controlled to levels that are considered appropriate for the system concerned.

Different principles are used to control the contamination level of the fluid by removing solid contaminant particles; one of them uses a filter element enclosed in a filter housing. The filter element is the porous device that performs the actual process of filtration. The complete assembly is designated as a filter.

The performance characteristics of a filter are a function of the element (its medium and geometry) and the housing (its general configuration and seal design). For a given filter, the actual performance is a function of the characteristics of the liquid (viscosity, temperature, conductivity, etc.), the particles in suspension (size, shape, hardness, etc.), and the flow conditions.

A standard multi-pass method for evaluating the performance of hydraulic fluid filter elements under steady state conditions has been developed and used for several years, and is referred to in several aircraft hydraulic systems specifications.

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. To enable the relative performance of hydraulic filters to be reliably compared so that the most appropriate filter can be selected, it is necessary to perform testing with the same standard operating conditions.

This part of ISO 14085 describes two test methods and the equipment required to measure hydraulic filter element performance with multi-pass flow in both steady and cyclic conditions.

The influence of other stressful operating conditions, such as heat, cold, and vibration, are not measured with this procedure alone. The influence of such conditions is determined with pre-conditioning being performed on the test filter element prior to efficiency testing (refer to ISO 14085-1 for descriptions of such tests and when they are applied).

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 and reliability levels.

The measurements are made with precise control over the operating conditions in particular the test fluid and test contaminant, to ensure repeatability and reproducibility. However, because the test parameters and test contaminant do not exactly replicate actual operating conditions which significantly differ from one system to another, the measurements cannot be expected to duplicate actual performance in an operating system.

Aerospace series — Hydraulic filter elements — Test methods —

Part 3:
Filtration efficiency and retention capacity

1 Scope

This part of ISO 14085 describes two methods to measure in repeatable conditions the filtration efficiency of filter elements used in aviation and aerospace hydraulic fluid systems. It can be applied when evaluating the overall characteristics of a filter element per ISO 14085-1, or separately.

Since the filtration efficiency of a filter element can change during its service life as it is clogging, this test method specifies its continuous measurement by using on-line particle counters with continuous injection of test contaminant and recirculation of particles not retained by the test filter element until the differential pressure across the element reaches a given final or “terminal” value.

This part of ISO 14085 allows the efficiency to be measured under both steady or cyclic flow conditions. It also is applied to measure the stabilized contamination levels that are produced by the filter element while testing with cyclic flow.

This part of ISO 14085 is not intended to qualify a filter element under replicate conditions of service; this can only be done by a specific test protocol developed for the purpose, including actual conditions of use, for example the operating fluid or contamination.

The tests data resulting from application of this part of ISO 14085 can be used to compare the performance of aerospace hydraulic filter elements.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1219-1, *Fluid power systems and components — Graphical symbols and circuit diagrams — Part 1: Graphical symbols for conventional use and data-processing applications*

ISO 2942, *Hydraulic fluid power — Filter elements — Verification of fabrication integrity and determination of the first bubble point*

ISO 3968, *Hydraulic fluid power — Filters — Evaluation of differential pressure versus flow characteristics*

ISO 4021, *Hydraulic fluid power — Particulate contamination analysis — Extraction of fluid samples from lines of an operating system*

ISO 4405, *Hydraulic fluid power — Fluid contamination — Determination of particulate contamination by the gravimetric method*

ISO 5598, *Fluid power systems and components — Vocabulary*

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 12103-1:1997, *Road vehicles — Test dust for filter evaluation — Part 1: Arizona test dust*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598 and the following apply.

3.1
contaminant mass injected
mass of specific particulate contaminant injected into the test circuit to obtain the terminal differential pressure

3.2
cyclic flow
change of flow from the specified rated flow rate to 25 % of rated flow rate at a specified frequency and waveform

3.3
differential pressure
Δp
difference between the inlet and outlet pressures of the component under test, as measured under specified conditions

Note 1 to entry: See Figure 1 and Figure 2 for graphical depiction of *differential pressure* (3.3) terms.

3.3.1
clean assembly differential pressure
difference between the tested component inlet and outlet pressure as measured with a clean filter housing containing a clean filter element

3.3.2
clean element differential pressure
differential pressure (3.3) of the clean element calculated as the difference between the *clean assembly differential pressure* (3.3.1) and the *housing differential pressure* (3.3.4)

3.3.3
final assembly differential pressure
assembly differential pressure at end of test equal to sum of housing plus *terminal element differential pressures* (3.3.5)

3.3.4
housing differential pressure
differential pressure of the filter housing without an element

3.3.5
terminal element differential pressure
maximum differential pressure across the filter element as designated by the manufacturer or specification to limit useful performance

3.4
filtration ratio
ratio of the number of particles larger than a specified size per unit volume in the influent fluid to the number of particles larger than the same size per unit volume in the effluent fluid

Note 1 to entry: For steady flow testing, the *filtration ratios* (3.4) are designated with the Greek letter beta, *ß*.

Note 2 to entry: For *cyclic flow* (3.2) testing, the *filtration ratios* (3.4) are designated with the Greek letter sigma, σ.

3.5
free-flow dummy element
duplicate test filter element with its media layers removed to replicate the flow pattern in the housing generated by the test filter element

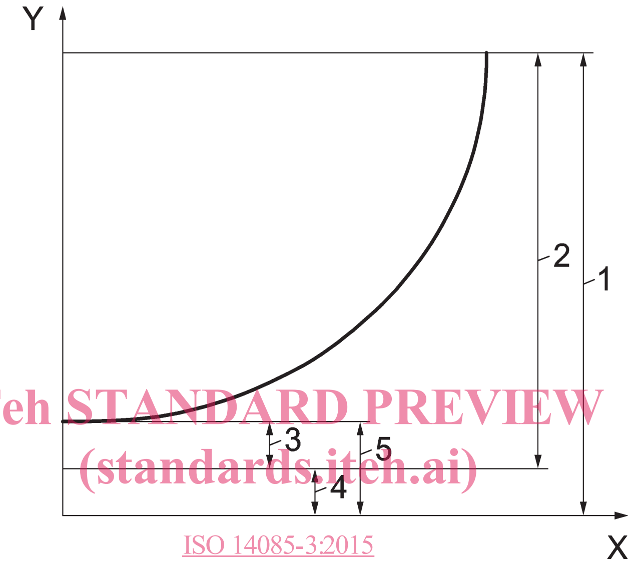
3.6
rest conductivity

electrical conductivity at the initial instant of current measurement after a dc voltage is impressed between electrodes

Note 1 to entry: It is the reciprocal of the resistance of uncharged fluid in the absence of ionic depletion or polarization.

3.7
retention capacity

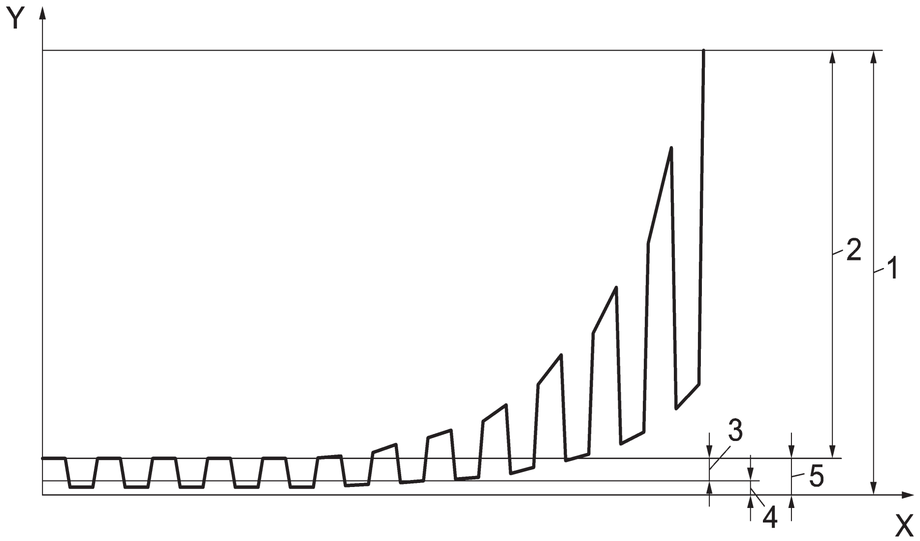
mass of specific particulate contaminant effectively retained by the filter element when terminal element differential pressure is reached



Key

x	test time or mass injected
y	differential pressure
1	final assembly (end of test) differential pressure
2	terminal element differential pressure
3	clean element differential pressure
4	housing differential pressure
5	clean assembly differential pressure

Figure 1 — Differential pressure conventions for multi-pass test with steady flow



Key

x test time or mass injected

Y differential pressure

1 final assembly (end of test) differential pressure

2 terminal element differential pressure at test flow rate (q_f)

3 clean element differential pressure at test flow rate (q_f)

4 housing differential pressure at test flow rate (q_f)

5 clean assembly differential pressure at test flow rate (q_f)

Figure 2 — Differential pressure conventions for multi-pass test with cyclic flow

4 Symbols and abbreviated terms

4.1 Graphic symbols used are in accordance with ISO 1219-1.

4.2 The letter symbols used in this part of ISO 14085 are shown in Table 1.

Table 1 — Letter symbols

Symbol	Unit	Description or explanation
$\overline{A}_{u,x}$	particles/ml	Overall average upstream count greater than size, *x*
$\overline{A}_{d,x}$	particles/ml	Overall average downstream count greater than size, *x*
$\overline{c}_b$	mg/l	Average base upstream gravimetric level
c_b'	mg/l	Desired base upstream gravimetric level
$\overline{c}_i$	mg/l	Average injection gravimetric level
c_i'	mg/l	Desired injection gravimetric level
c_{80}	mg/l	Test reservoir gravimetric level at 80 % assembly Δp
m	G	Mass of contaminant needed for injection
m_e	G	Estimated filter element capacity (mass injected)
m_i	G	Contaminant mass injected
m_p	G	Contaminant mass injected at element differential pressure

Table 1 *(continued)*

Symbol	Unit	Description or explanation
m_{R}	G	Retained capacity
n	None	Number of counts in specific time period
$N_{\mathrm{u},x,j}$	particles/ml	Number of upstream particles greater than size, *x*, at count, *j*
$N_{\mathrm{d},x,j}$	particles/ml	Number of downstream particles greater than size, *x*, at count, *j*
$\overline{N}_{\mathrm{u},x,t}$	particles/ml	Average upstream count greater than size, *x*, at time interval, *t*
$\overline{N}_{\mathrm{d},x,t}$	particles/ml	Average downstream count greater than size, *x*, at time interval, *t*
Δp	Pa or kPa (bar)	Differential pressure
Δp_{f}	Pa or kPa (bar)	Final assembly differential pressure
Δp_{n}	Pa or kPa (bar)	Net assembly differential pressure
$\Delta p_{2,5\,\%}$	Pa or kPa (bar)	Assembly differential pressure after increase of 2,5 % net Δp
$\Delta p_{80\,\%}$	Pa or kPa (bar)	Assembly differential pressure after increase of 80 % net Δp
$\bar{q}_{\mathrm{f}}$	l/min	Average filter test flow rate
q_{d}	l/min	Discarded downstream sample flow rate
q_{f}	l/min	Filter rated flow (maximum flow for cyclic conditions)
q_i'	l/min	Desired injection flow rate
$\bar{q}_{\mathrm{i}}$	l/min	Average injection flow rate
q_{u}	l/min	Discarded upstream sample flow rate
t	min	Test time
t'	min	Predicted test time
t_{f}	min	Final test time
t_{p}	min	Test time at element differential pressure
$t_{2,5\,\%}$	min	Test time at beginning of 2,5 % stabilization period
$t_{80\,\%}$	min	Test time at beginning of 80 % stabilization period
V_{if}	l	Final measured injection system volume
V_{ii}	l	Initial measured injection system volume
V_{min}	l	Minimum required operating injection system volume
V_{tf}	l	Final measured filter test system volume
V_{v}	l	Minimum validated injection system volume
x, $x1$, $x2$	µm(c)	Particle sizes
β_x	None	Filtration ratio at particle size, x (steady flow)
$\beta_{x,t}$	None	Filtration ratio at particle size, *x*, and time interval, *t* (steady flow)
$\bar{\beta}_x$	None	Average filtration ratio at particle size *x*, (steady flow)
σ_x	None	Filtration ratio at particle size, *x*, (cyclic flow)
$\sigma_{x,t}$	None	Filtration ratio at particle size, *x*, and time interval, *t* (cyclic flow)
$\bar{\sigma}_x$	None	Average filtration ratio at particle size *x*, (cyclic flow)

5 Test procedure overview

5.1 Set up and maintain apparatus in accordance with Clause 6 and Clause 7.

5.2 Validate equipment in accordance with Clause 8.

5.3 Run all tests in accordance with Clauses 9, 10, and 11.

5.4 Analyse and present data from Clause 11 in accordance with Clause 12.

6 Test equipment and supplies

6.1 Suitable timer

6.2 Sample bottles, use applicable sample bottles containing less than 100 particles greater than 6 µm(c) per millilitre of bottle volume, as qualified per ISO 3722, to collect samples for gravimetric analyses.

6.3 Membrane filters and associated equipment, suitable for conducting gravimetric contamination analysis in accordance with ISO 4405.

6.4 Test contaminant, use ISO Fine Test Dust (ISO FTD), grade A2 in accordance with ISO 12103-1, dried at 110 °C to 150 °C for not less than 1 h for quantities less than 200 g.

Ensure that the ISO FTD used conforms to all the requirements of ISO 12103-1 grade A2, especially the volume particle size distribution shown in ISO 12103-1:1997, Table 2

NOTE 1 This dust is commercially available. For availability of ISO Fine Test Dust, contact the ISO Central Secretariat or member bodies of ISO.

NOTE 2 If the total quantity of ISO Fine Test Dust needed is greater than 200 g, batches not exceeding 200 g can be prepared to make up the amount required.

NOTE 3 For use in the test system, it is recommended to mix the test dust into the test fluid, mechanically agitate, then disperse ultrasonically in an ultrasonic bath that has a power density of 3 000 W/m^2 to 10 000 W/m^2 provided it has been demonstrated that ultrasonic energy used does not affect the fluid viscosity.

6.5 Test fluid, petroleum base test fluid with properties as detailed in Annex A.

Another standard test fluid shall be used provided there is agreement between parties. Only filter test results obtained with the same fluid shall be compared.

The temperature of the test fluid, during the test, shall be controlled at a value to result in a test fluid kinematic viscosity of 15 mm^2/s ± 1 mm^2/s.

NOTE 1 The use of this hydraulic fluid ensures greater reproducibility of results and is based upon current practices, other accepted filter standards, and its world-wide availability.

NOTE 2 The addition of an anti-static agent to this test fluid can affect the test results.

6.6 Particle counting systems

6.6.1 An online automatic particle counting system, per ISO 11943, shall be used to determine the number and size distribution of the contaminant particles in the fluid. An online dilution system might be required to ensure that the particulate concentration in the fluid sampled by the automatic particle counters does not exceed the saturation limits specified by the automatic particle counter manufacturer.

The automatic particle counters, including the on-line dilution system, if applicable, should be validated for on-line counting in accordance with ISO 11943.

6.6.2 A turbulent sampling means, in accordance with ISO 4021, shall be located upstream and downstream of the test filter element in order to provide fluid sample flow to the automatic particle counters. The design of the sampling system shall be such as to minimize lag time in fluid flow to the automatic particle counters. The portion of the sampling flow not passing through the automatic particle counters can be returned to the filter element test circuit reservoir via a by-pass line. Flow through the automatic particle counters can also be returned to the filter element test circuit reservoir provided it has not been diluted, or it can be discarded. Do not interrupt sample flow during the test.

6.6.3 Automatic particle counters shall be calibrated in accordance with ISO 11171 for the appropriate particle sizes. Use the recommended particle sizes given in Table 3 unless otherwise agreed.

6.7 Test housing and free flow dummy element

6.7.1 The service filter housing shall be used whenever possible, and it shall be installed in a normal service attitude. If this housing contains a by-pass valve, it shall be blocked and tested for zero leakage at twice the normal cracking pressure.

6.7.2 If a service filter housing is not available, the test housing shall duplicate the inside configuration, including size, direction, and location of the inlet and outlet flow ports used in the service filter housing. The volume beyond the ends of the filter element can vary up to ±10 % of the corresponding volumes of the actual housing.

6.7.3 Install a free flow dummy element in the filter housing when determining the differential pressure of the empty filter assembly (i.e. without the filter element installed) to reduce the impact of any changes in flow patterns on the measured filter element differential pressure. The free flow dummy element shall be the same as the test element without the filter media. If the test filter element is not constructed with a rigid core, the dummy element shall be provided with a core having a minimum open area equal to twice the filter element outlet area (the internal cross-sectional area of the filter assembly outlet tube) and a diameter approximating the inside diameter of the media pack.

6.8 Filter performance test circuits

The filter performance test requires two separate circuits: a filter element test circuit, and a contaminant injection circuit. Schematic diagrams of typical filter performance test set-ups used to measure filtration efficiency in steady and cyclic flow conditions are shown in Annex B.

6.8.1 Filter element test circuit, consisting of the following.

6.8.1.1 A reservoir with a smooth conical bottom that has an included angle of not more than 90°, pump, fluid conditioning apparatus, and instrumentation that are capable of accommodating the range of flow rates, pressures, temperatures, and volumes required by the procedure, and is capable of meeting the validation requirements of Clause 8.

6.8.1.2 A clean-up filter capable of providing an initial system contamination level as specified in Table 3.

6.8.1.3 A configuration that is insensitive to the intended operative contaminant level.

6.8.1.4 A configuration that does not alter the test contaminant distribution over the anticipated test duration.