INTERNATIONAL STANDARD

ISO 23369

Second edition
2022-12

Hydraulic fluid power — Multi-pass method of evaluating filtration performance of a filter element under cyclic flow conditions

Transmissions hydrauliques — Évaluation des performances d'un élément filtrant par la méthode de filtration multi-passe sous débit cyclique

Reference number
ISO 23369:2022(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 6, *Contamination control.*

This second edition cancels and replaces the first edition (ISO 23369:2021), which has been technically revised.

The main changes are as follows:

— calculation of ramp time.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

In hydraulic fluid power systems, one of the functions of the hydraulic fluid is to separate and lubricate the moving parts of components. The presence of solid particulate contamination produces wear, resulting in loss of efficiency, reduced component life and subsequent unreliability.

A hydraulic filter is provided to control the number of particles circulating within the system to a level that is commensurate with the degree of sensitivity of the components to contaminants and the level of reliability required by the users.

Test procedures enable the comparison of the relative performance of filters so that the most appropriate filter can be selected. 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).

In practice, a filter is subjected to a continuous flow of contaminant entrained in the hydraulic fluid until some specified terminal differential pressure (relief-valve cracking pressure of differential-pressure indicator setting) is reached.

Both the length of operating time (prior to reaching terminal pressure) and the contaminant level at any point in the system are functions of the rate of contaminant addition (ingression plus generation rates) and the performance characteristics of the filter.

Therefore, a realistic laboratory test establishes the relative performance of a filter by providing the test filter with a continuous supply of ingressed contaminant and allowing the periodic monitoring of the filtration performance characteristics of the filter. A standard multi-pass method for evaluating the performance of hydraulic fluid power filter elements under steady-state flow conditions has been developed as ISO 16889. That test procedure provides a basis for the comparison of the relative performance characteristics of various filter elements. The results from such a test, however, might not be directly applicable to most actual operating conditions.

In actual operation, a hydraulic fluid power filter is generally not subjected to steady-state flow but to varying degrees of cyclic flow. Tests have shown that, in many instances, the filtration capabilities of an element are severely reduced when subjected to varying cyclic flow conditions. It is therefore important to evaluate the filtration performance of a filter for applications under cyclic flow conditions.

The cyclic flow multi-pass test procedure for hydraulic filters specified in this document has been developed to supplement the basic steady-state flow test (ISO 16889) for filter elements that are expected to be placed in service with cyclic flow. The recommended flow cycle rate of 0,1 Hz is a result of an industry survey and a broad range of test results. If much higher cycle rates are expected in actual service, the test should be conducted at that frequency to produce more meaningful results. The procedure specified in this document may be applied at a cycle rate other than 0,1 Hz, if agreed upon between the supplier and user. However, only values resulting from testing at the 0,1 Hz cycle rate may be reported as having been determined in accordance with this document.

Fluid samples are extracted from the test system to evaluate the filter element’s particulate removal characteristics. To prevent this sampling from adversely affecting the test results, a lower limit is placed upon the rated flow rate of filter elements that should be tested with this procedure.

The current maximum flow rate specified in this document is based upon the maximum gravimetric level of injection systems that have been qualified to date.

Hydraulic fluid power — Multi-pass method of evaluating filtration performance of a filter element under cyclic flow conditions

1 Scope

This document specifies:

a) A multi-pass filtration performance test under cyclic flow conditions with continuous contaminant injection for hydraulic fluid power filter elements.

b) A procedure for determining the contaminant capacity, particulate removal and differential pressure characteristics.

c) A test currently applicable to hydraulic fluid power filter elements that exhibit an average filtration ratio greater than or equal to 75 for particle sizes ≤25 µm(c), and a final test system reservoir gravimetric level of less than 200 mg/L. It is necessary to determine by validation the range of flow rates and the lower particle size limit that can be used in test facilities.

d) A test using ISO 12103-1 A3 medium test dust contaminant and a test fluid.

This document provides a test procedure that yields reproducible test data for appraising the filtration performance of a hydraulic fluid power filter element without influence of electrostatic charge.

This document is applicable to three test conditions:

— Base upstream gravimetric level of 3 mg/L;

— Base upstream gravimetric level of 10 mg/L;

— Base upstream gravimetric level of 15 mg/L.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2160, *Petroleum products — Corrosiveness to copper — Copper strip test*

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

ISO 3722, *Hydraulic fluid power — Fluid sample containers — Qualifying and controlling cleaning methods*

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

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 11171, *Hydraulic fluid power — Calibration of automatic particle counters for liquids*

ISO 11943:2021, *Hydraulic fluid power — Online automatic particle-counting systems for liquids — Methods of calibration and validation*

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

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

3.2
differential pressure
difference between the tested component inlet and outlet pressures as measured under the specified conditions

Note 1 to entry: See Figure 1 for a graphical depiction of differential pressure terms.

3.3
clean assembly differential pressure
difference between the tested component inlet and outlet pressures as measured with a clean filter housing containing a clean filter element

3.4
clean element differential pressure
differential pressure of the clean element calculated as the difference between the *clean assembly differential pressure* (3.3) and the *housing differential pressure* (3.6)

3.5
final assembly differential pressure
assembly differential pressure at the end of a test, equal to the sum of the housing differential pressure and the terminal element differential pressure

3.6
housing differential pressure
differential pressure of the filter housing without an element

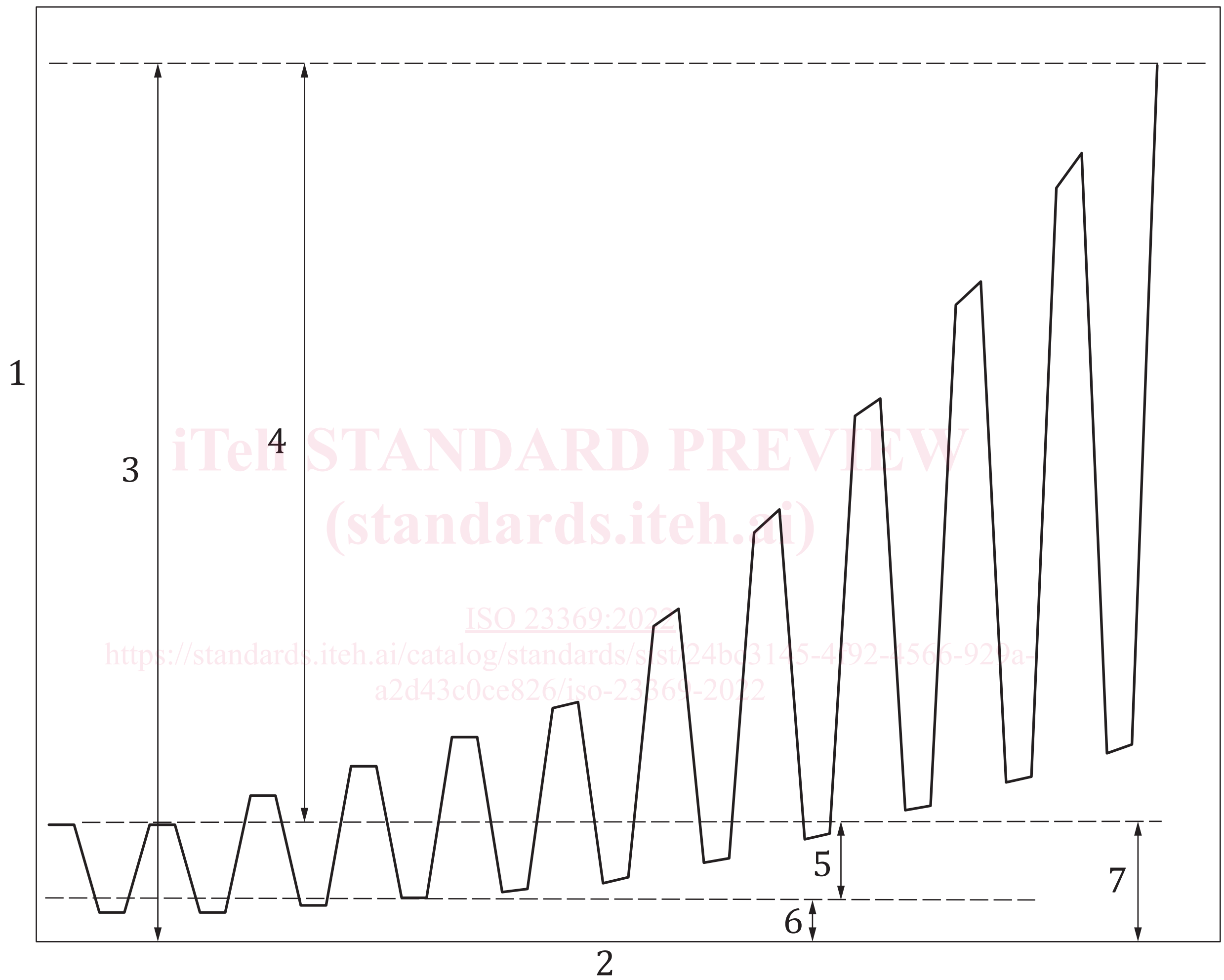
3.7
terminal element differential pressure
maximum differential pressure across the filter element as designated by the manufacturer to limit useful performance

3.8
rest conductivity
electrical conductivity at the initial instant of current measurement after a DC voltage is impressed between electrodes

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

3.9
retained capacity
m_R
mass of specific particulate contaminant effectively retained by the filter element when terminal element differential pressure is reached

3.10
cyclic flow
change of flow from the specified rated flow rate to 25 % of rated flow rate at a specified frequency and waveform



Key

1 differential pressure (ΔP))
2 test time or contaminant mass injected
3 final assembly differential pressure (end of test)
4 terminal element differential pressure
5 clean element differential pressure at q_{max}
6 housing differential pressure at q_{max}
7 clean assembly differential pressure at q_{max}

Figure 1 — Differential pressure conventions for multi-pass test under cyclic flow conditions

4 Symbols

Table 1 — Symbols

Symbol	Unit	Description
$\bar{A}_{u,x}$	particles per millilitre	overall average upstream count of particles larger than size x
$\bar{A}_{d,x}$	particles per millilitre	overall average downstream count of particles larger than size x
$\alpha_{x(c)}$ [a]	–	filtration ratio at particle size x (ISO 11171 calibration)
$\alpha_{x,t}$	–	filtration ratio at particle size x and time interval t
$\bar{\alpha}_{x(c)}$	–	average filtration ratio at particle size x (ISO 11171 calibration)
a	litres per second squared	rise and fall ramp flow rate acceleration
$\bar{c}_b$	milligrams per litre	average base upstream gravimetric level
c_b'	milligrams per litre	desired base upstream gravimetric level
$\bar{c}_i$	milligrams per litre	average injection gravimetric level
c_i'	milligrams per litre	desired injection gravimetric level
c_{80}	milligrams per litre	test reservoir gravimetric level at 80 % assembly differential pressure
m	grams	mass of contaminant needed for injection
m_e	grams	estimated filter element contaminant capacity (mass injected)
m_i	grams	contaminant mass injected
m_P	grams	contaminant mass injected at element differential pressure
m_R	grams	retained capacity
N	–	number of counts in specific time period
$N_{u,x,i}$	particles per millilitre	number of upstream particles larger than size x at count i
$N_{d,x,i}$	particles per millilitre	number of downstream particles larger than size x at count i
$\bar{N}_{u,x,t}$	particles per millilitre	average upstream count of particles larger than size x at time interval t
$\bar{N}_{d,x,t}$	particles per millilitre	average downstream count of particles larger than size x at time interval t
p	Pa or kPa (bar)	Pressure
ΔP	Pa or kPa (bar)	differential pressure
q	litres per minute	test flow rate
$\bar{q}$	litres per minute	average test flow rate
q_{min}	litres per minute	minimum test flow rate (25 % of q_{max})
q_{max}	litres per minute	maximum test flow rate
q_d	litres per minute	discarded downstream sample flow rate
$\bar{q}_i$	litres per minute	average injection flow rate
q_i'	litres per minute	desired injection flow rate
q_u	litres per minute	discarded upstream sample flow rate
t	minutes	test time
t_{pr}	minutes	predicted test time
t_f	minutes	final test time

[a] The subscript (c) signifies that the filtration ratio, $\alpha_{x(c)}$, and the average filtration ratio, $\bar{\alpha}_{x(c)}$, are determined in accordance with the method in this document using automatic particle counters calibrated in accordance with ISO 11171.

Table 1 *(continued)*

Symbol	Unit	Description
t_P	minutes	test time at element differential pressure
t_F	seconds	fall ramp time
t_R	seconds	rise ramp time
t'	seconds	predicted test time
V_{if}	litres	final measured injection system volume
V_{ii}	litres	initial measured injection system volume
V_{min}	litres	minimum required operating injection system volume
V_{tf}	litres	final measured filter test system volume
V_v	litres	minimum validated injection system volume
x_1, x_2	micrometres	particle sizes
x_{int}	micrometres	interpolated particle size

[a] The subscript (c) signifies that the filtration ratio, $\alpha_{x(c)}$, and the average filtration ratio, $\bar{\alpha}_{x(c)}$, are determined in accordance with the method in this document using automatic particle counters calibrated in accordance with ISO 11171.

5 General procedure

5.1 Set up and maintain apparatus in accordance with Clauses 6 and 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 test data in accordance with Clause 12.

5.5 Present data from Clauses 10, 11 and 12 in accordance with the requirements of Clause 13.

6 Test equipment

6.1 Calibrated timer, a digital or mechanical stopwatch calibrated by a facility meeting the requirements of ISO/IEC 17025.

6.2 Automatic particle counter(s) (APC), calibrated in accordance with ISO 11171.

6.3 ISO medium test dust (**ISO MTD**) (in accordance with ISO 12103-1, A3 medium test dust), dried at 110 °C to 150 °C for not less than 1 h for quantities less than 200 g. For use in the test system, 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.

For quantities greater than 200 g, dry for at least 30 min per additional 100 g. For use in the test system, mix the test dust into the test fluid, mechanically agitate, then disperse ultrasonically with a power density of 3 000 W/m^2 to 10 000 W/m^2.

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

6.4 Online particle counting system (if necessary) with optional dilution system that has been validated in accordance with ISO 11943.

6.5 Sample bottles, containing less than 20 particles larger than 6 µm(c) per millilitre of bottle volume, qualified in accordance with ISO 3722, to collect samples for gravimetric analyses.

6.6 Petroleum base test fluid, with properties as specified in Annex A.

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.

6.7 Filter performance test circuit, composed of a filter test system and a contaminant injection system.

6.7.1 Filter test system, consisting of:

a) a reservoir, pump, fluid conditioning apparatus and instrumentation that are capable of accommodating the range of flow rates, pressures and volumes required by the procedure and capable of meeting the validation requirements of Clause 8;

b) a clean-up filter capable of providing an initial system contamination level as specified in Table 3;

c) a configuration that is relatively insensitive to the intended contaminant level and capable of meeting the validation requirements of Clause 8;

d) a configuration that does not alter the test contaminant particle size distribution over the anticipated test duration and that is capable of meeting the validation requirements of Clause 8;

e) pressure taps in accordance with the requirements of ISO 3968;

f) fluid sampling sections upstream and downstream of the test filter, in accordance with the requirements of ISO 4021;

g) cyclic flow bypass line equipped with an automatically controlled shut-off valve (e.g., an electrically-actuated ball valve or poppet type valve or alternative system (e.g., direct drive), which have been shown to be satisfactory for this application) capable of producing the required flow rate cycle at the designated frequency.

NOTE For typical configurations that have proved to be satisfactory, see the filter test system design guide in Annex B.

6.7.2 Contaminant injection system, consisting of:

a) a reservoir, pump, fluid conditioning apparatus and instrumentation that are capable of accommodating the range of flow rates, pressures and volumes required by the procedure and capable of meeting the validation requirements of Clause 8;

b) a configuration that is relatively insensitive to the intended contaminant level and capable of meeting the validation requirements of Clause 8;

c) a configuration that does not alter the test contaminant particle size distribution over the anticipated test duration and capable of meeting the validation requirements of Clause 8;

d) a fluid sampling section in accordance with the requirements of ISO 4021.

NOTE For typical configurations that have proved to be satisfactory, see the contaminant injection system design guide in Annex B.

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

7 Measurement accuracy and test condition variation

7.1 Use and maintain instrument accuracy and test conditions within the limits given in Table 2.

Table 2 — Instrument accuracy and test condition variation

Test parameter	SI unit	Instrument accuracy (±) of reading	Allowed test condition variation (±)
Conductivity	pS/m	10 %	1 500 pS/m ± 500 pS/m
Differential pressure	Pa or kPa (bar)	5 %	—
Base upstream gravimetric level	mg/L	—	10 %
Injection flow rate	mL/min	2 %	5 %
Test flow rate	L/min	2 %	5 %
APC sensor and dilution flow rates	mL/min	1,5 %	3 % [a]
Kinematic viscosity [b]	mm^2/s	2 %	1 mm^2/s
Mass	g	0,1 mg	—
Temperature	°C	1 °C	2 °C [c]
Time	s	0,1 s	—
Injection system volume	L	2 %	—
Filter test system volume	L	2 %	5 %

[a] Sensor flow variation to be included in the overall 10 % allowed between sensors.

[b] 1 mm^2/s = 1 cSt

[c] Or as required to guarantee the viscosity tolerance.

7.2 Maintain specific test parameters within the limits given in Table 3, depending on the test condition being conducted.

Table 3 — Test condition values

Parameter	Filter test condition		
	Condition 1	Condition 2	Condition 3
Initial contamination level for filter test system	Less than 1 % of the minimum level specified in ISO 11943:2021, Table C.2 measured at the smallest particle size to be counted.		
Initial contamination level for injection system	Less than 1 % of injection gravimetric level.		
Base upstream gravimetric level, based on the average test flow rate while cycling, $\overline{q}$ [a]	(3 ± 0,3) mg/L	(10 ± 1,0) mg/L	(15 ± 1,5) mg/L
Recommended particle sizes to be counted [b]	Minimum of five sizes selected to cover the presumed filter performance range from $\alpha_{x(c)}$ = 2 to $\alpha_{x(c)}$ = 1 000. Typical sizes are: (4, 5, 6, 7, 8, 10, 12, 14, 20, 25, 30) µm(c).		
Sampling and counting method	Online automatic particle counting		
Cyclic flow rate conditions	From q_{max} to q_{min} at a frequency of 0,1 Hz (6 cycles/min) in accordance with the waveform specified in Figure 2.		

[a] When comparing test results between two filters, the base upstream gravimetric level and the wave form shall be the same.

[b] Particle sizes where α is low (α = 2, 10...) can be unobtainable for fine filters, and particle sizes where α is high (α = 200, 1 000) can be unobtainable for coarser filters.