INTERNATIONAL STANDARD

ISO 3968

Third edition
2017-07

Hydraulic fluid power — Filters — Evaluation of differential pressure versus flow

Transmissions hydrauliques — Filtres — Évaluation de la perte de charge en fonction du débit

Reference number
ISO 3968:2017(E)

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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 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 the following URL: 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 third edition cancels and replaces the second edition (ISO 3968:2001), which has been technically revised. It also incorporates the Technical Corrigendum ISO 3968:2001/Cor1:2002.

Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a fluid under pressure circulating within a closed circuit. Filters maintain the cleanliness of the fluid by retaining the insoluble contaminants.

Hydraulic filters normally include a housing that serves as the pressure-containing vessel to direct the flow of fluid through a filter element that separates contaminants from the test fluid.

This document foresees the possibility to test spin-on filters in which the replaceable unit does or does not include a filter head.

In operation, fluid flowing through a filter meets resistance due to kinetic and viscous effects. The pressure required to overcome this resistance and to maintain flow is known as the differential pressure. The differential pressure is the total pressure difference observed between the filter inlet port and outlet port and represents the sum of the losses recorded in the housing and filter element.

Factors which affect clean filter differential pressure are fluid viscosity, fluid specific gravity, flow rate, filter element media type and construction, as well as housing design.

Hydraulic fluid power — Filters — Evaluation of differential pressure versus flow

1 Scope

This document specifies a procedure for evaluating differential pressure versus flow characteristics of hydraulic filters and constitutes a basis for agreement between the filter manufacturer and user.

It also specifies a method for measurement of the differential pressure generated at different flow rates and viscosities by the relevant parts of a filter assembly, spin-on and any valves contained within the filter which are in the flow stream. The typical types of filter to be tested are as follows:

Type 1: which are spin-on filters in which the replaceable unit does not include a filter head (it might or might not include the element by-pass valve);

Type 2: which are spin-on filters in which the replaceable element is tested together with a filter head (it might or might not include the element by-pass valve);

Type 3: which are filter assembly, usually of the replacement element type, that is the housing (head and bowl) and element.

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 2909, *Petroleum products — Calculation of viscosity index from kinematic viscosity*

ISO 3448, *Industrial liquid lubricants — ISO viscosity classification*

ISO 3675, *Crude petroleum and liquid petroleum products — Laboratory determination of density — Hydrometer method*

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

ISO 4406, *Hydraulic fluid power — Fluids — Method for coding the level of contamination by solid particles*

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

ISO 6415, *Internal combustion engines — Spin-on filters for lubricating oil — Dimensions*

3 Terms and definitions

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

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

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

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

3.1
filter rated flow rate
flow rate recommended by the filter manufacturer for a specified kinematic viscosity

3.2
viscosity index
empirical measure of the viscosity/temperature characteristics of a fluid

Note 1 to entry: The smaller the change in viscosity within a given temperature range, the higher the viscosity index.

3.3
differential pressure
difference between the tested component inlet and outlet pressures under specified conditions

3.4
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.

4 Symbols

4.1 Letter symbols

The letter symbols used in this document are shown in Table 1.

Table 1 — Letter symbols

Symbol	Unit	Description or explanation
q_V	litres per minute	Test flow rate
q_R	litres per minute	Filter rated flow rate
p	kilopascals	Static pressure
p_1	kilopascals	Static pressure measured upstream of the filter
p_2	kilopascals	Static pressure measured downstream of the filter
Δ_p	kilopascals	Differential pressure ($\Delta_P = p_1 - p_2$)
D	millimetre	Internal pipe diameter

4.2 Graphical symbols

The graphical symbols used in this document are in accordance with ISO 1219-1.

5 Operational characteristics to be tested

Filters installed on a closed circuit generate a pressure drop that reduces the effective oil pressure available to the working parts.

In order to ensure an adequate oil pressure to the working parts, it is customary for the filter to be designed to pass its full rated flow with no more than a specified differential pressure. The tests specified in this document measure the differential pressure across a complete filter, in a clean condition, over the whole range of oil flow rates.

The differential pressure across the filter is due to the pressure at the inlet and outlet of the filter, including any casting or adaptor which is part of the filter assembly, and at the anti-drain back valve, if one is fitted, as well as to the differential pressure across the filter element itself. For some purposes, it is necessary to know the differential pressure across the filter alone, for example in assessing the performance of the element in the case of some combinations of filter medium and contaminant. In addition to the tests indicated above, the tests specified measure the differential pressure across a clean filter element over the whole range of oil flow rates.

6 Filter to be tested

6.1 Filter type

6.1.1 Type 1: spin-on filters in which the replaceable unit does not include a filter head (it might or might not include the element by-pass valve).

6.1.2 Type 2: spin-on filters in which the replaceable element is tested together with a filter head (it might or might not include the element by-pass valve).

6.1.3 Type 3: filter assembly, usually of the replacement element type, that is the housing (head and bowl) and element.

6.2 Filter element

The filter element for the test shall be unused. Test liquid and the test rig shall be cleaned in accordance with 9.2.

7 Test equipment

7.1 General indications

A suitable test rig consists of a pump, a reservoir, a clean-up filter, the filter under test and, if required, a heat exchanger and appropriate heat source for temperature control, together with all the necessary equipment for measuring the pressure, the flow rate, the temperature and the fluid cleanliness level (see 8.5). Figure 1 shows a typical test rig in schematic form.

The test rig shall be constructed so that it does not contain dead legs or zones or quiescent areas where contaminant can settle out and re-entrain later during the test.

When testing return filters to be half-immersed in the reservoir, the test equipment located downstream of the test filter in Figure 1 [flow meter, heat exchanger (counter pressure valve is not necessary)] shall be located upstream of the test filter.

7.2 Pump

Use a pump with a flow rate equal to or greater than the maximum flow rate required for the test. The delivery pressure shall be sufficient for pumping the required flow through the filter under test and for supplying simultaneously the clean-up filter and the remainder of the rig. A device shall make it possible to continuously vary the flow rate from zero to maximum. Pressure ripple shall be suppressed, if required, to guarantee pressure readings with the required accuracy.

7.3 Reservoir

Use a reservoir with a conical bottom; minimum volume expressed in litres should be equal to the maximum flow rate in litres per minute scheduled for the test. It should be designed to eliminate air entrainment (for example, by means of a return of the fluid beneath the test fluid surface) and ingression of airborne contamination.

NOTE Lower volumes increase the likelihood of air entrainment.

7.4 Temperature control

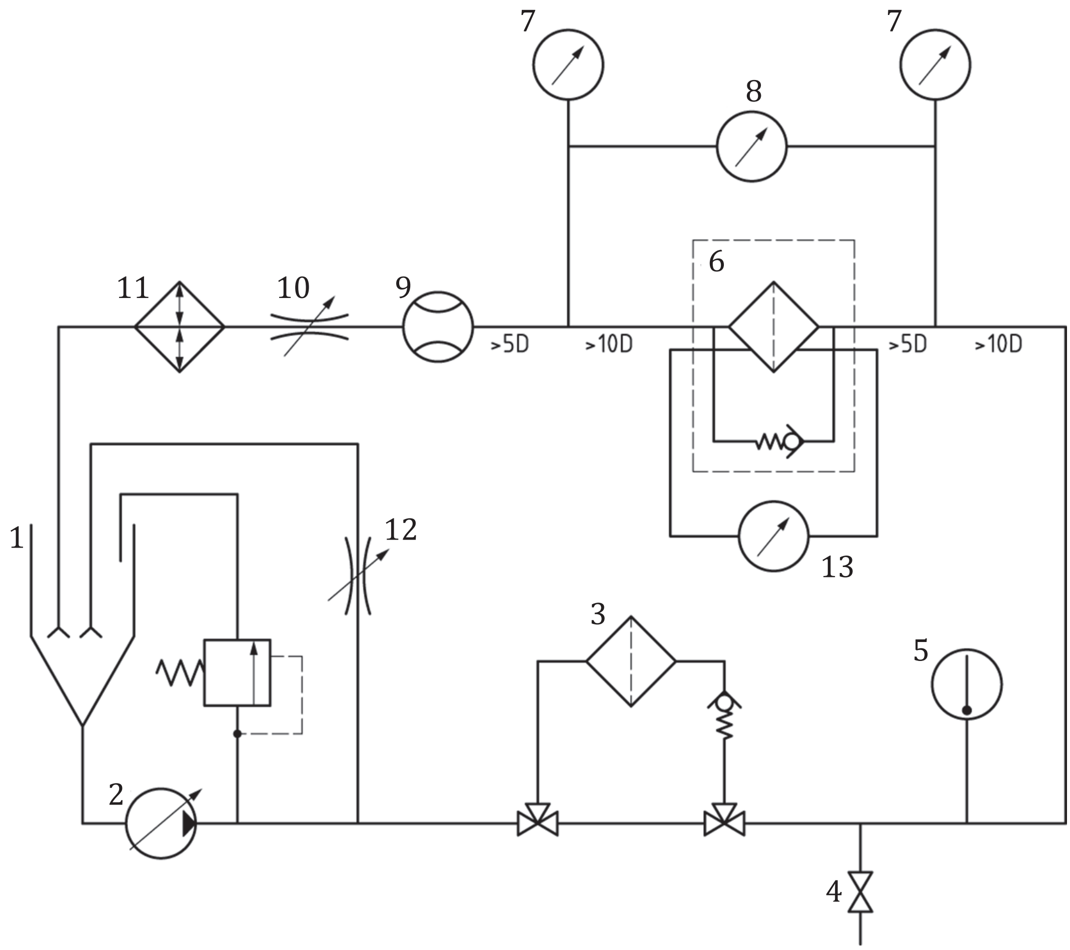
Use a heat exchanger and appropriate heat source to control the temperature measured upstream of the filter under test to the required value with an accuracy conforming to Table 2.

7.5 Clean-up filter

Use a clean-up filter with a filtration ratio (see ISO 16889) greater than that of the filter under test, so that no measurable increase in differential pressure of the filter under test due to partial blocking can occur.

7.6 Sampling valve

To verify fluid cleanliness, equip the circuit with a sampling valve in accordance with ISO 4021. The sample point shall allow connection of an online monitor or extraction of a fluid sample for off-line analysis.



Key

1	reservoir	8	differential pressure transducer or two single pressure transducers to measure the differential pressure
2	variable flow pump	9	flow meter
3	clean-up filter	10	counter pressure regulating valve
4	sampling valve	11	heat exchanger
5	thermometer	12	bypass flow regulating valve
6	filter under test	13	differential pressure transducer or two single pressure transducers to measure the differential pressure across the spin-on filter – element
7	absolute pressure transducer		

Figure 1 — Example of a test circuit suitable for measuring the differential pressure versus flow rate characteristics of filter assemblies and spin-on filters

7.7 Mounting of filter

7.7.1 In the case of the types of filter indicated in 6.1.1, a special test head is required and a typical example is shown in Figure 2. The differential pressure across the complete filter assembly or element shall be measured in accordance with 8.1.1.

7.7.2 In the case of the types of filter indicated in 6.1.2 and 6.1.3, mount the filter on the test rig in the normal orientation. Use the correct sizes of standard unions to connect the filter. Use pipes between the filter and the pressure measuring points maintaining the same internal diameters as the unions. Take the differential pressure across the filter in accordance with 8.1.2.

7.8 Test fluid

The type of test fluid shall be either that agreed with the customer, one recommended by the filter manufacturer or a fluid with standard properties. The fluid used shall be reported in the report sheet (see Clause 10).

If it is a fluid with standard properties, it should be a mineral oil with few additives and the following characteristics:

— viscosity grade VG 32 in accordance with ISO 3448;

— viscosity index 95 to 105 in accordance with ISO 2909;

— mass density of 850 kg/m^3 to 900 kg/m^3 in accordance with ISO 3675.

Caution should be exercised when testing fine filters (β_{10} > 75) on hydraulic fluids with viscosity index improvers at lower temperatures (<30 °C), as the additives can be temporarily removed and can partially block the element.

Without specific requirement, the viscosity should be set at 32 mm^2/s.

NOTE Verify that the rest conductivity of the test fluid is maintained within the range of 1 000 pS/m to 10 000 pS/m (see ASTM D4308-95). If it is outside this range, either add anti-static agent to increase the conductivity or more new fluid to reduce it.

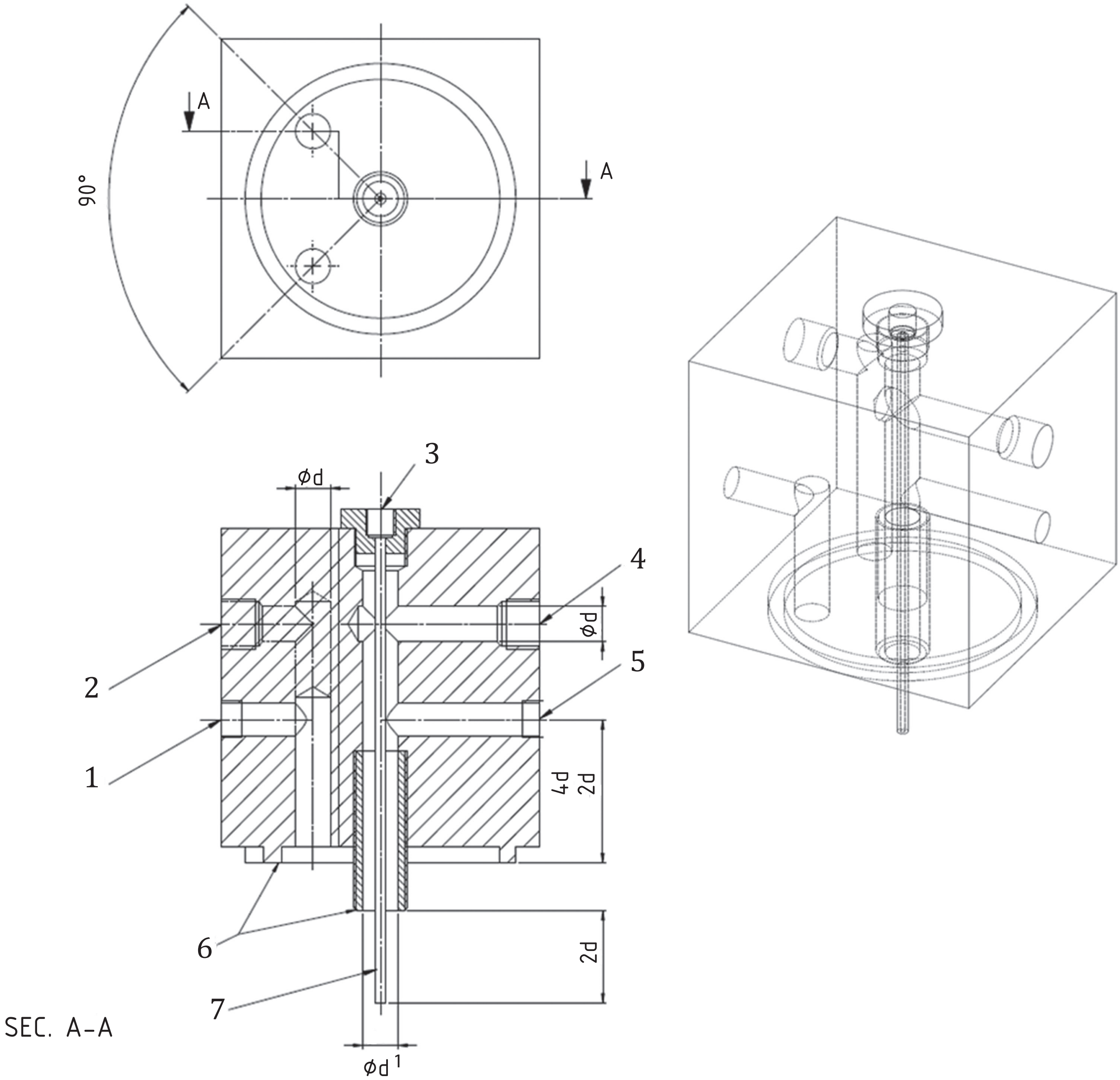
8 Measurements

8.1 Pressure measurement

8.1.1 Measure the differential pressure upstream and downstream of the filter under test using a differential pressure transducer or two gauge pressure transducers with an accuracy conforming to Table 2.

NOTE Errors from two gauge transducers are cumulative and the combined error is used to determine accuracy.

8.1.2 In the case of the types of filter indicated in 6.1.1, the differential pressure across the complete filter assembly shall be measured using the pressure tappings marked A and B with C removed (see Figure 2). The differential pressure across the filter element shall be measured using an inlet pressure tapping marked A and the outlet pressure probe marked C (see Figure 2).



Key

1 inlet pressure tapping "A" made directly to inlet annulus

2 inlet connection

3 filter element outlet pressure tapping "C"

4 outlet connection

5 outlet pressure tapping "B"

6 face dimensions and thread in accordance with ISO 6415, or to suit filter under test

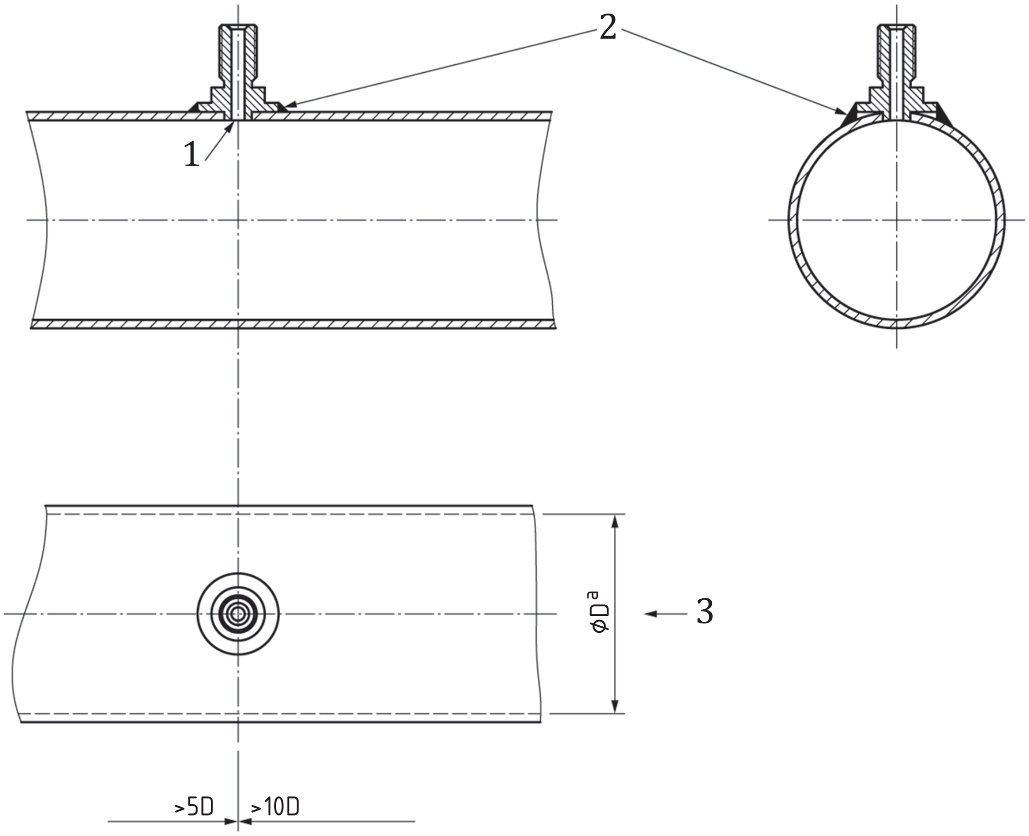
7 tube ϕ 3 mm outside, ϕ 1,5 mm inside

NOTE 1 d = 10 mm, 14 mm, 24 mm or 28 mm depending on diameter of filter outlet.

Figure 2 — Typical special test head for spin-on cartridge filters in which the replaceable unit does not include a filter head (type 1)

8.1.3 In the case of the types of filter indicated in 6.1.2 and 6.1.3, the pressure points shall be of the truncated end type (see Figure 3) and placed on pipework without any hydraulic irregularity (for example, union, valve and bend) over a length not less than 10 *D* upstream and 5 *D* downstream of the measuring point.

The connecting lines to pressure transducers and gauges should be bled of air before testing.



Key

1 no burr

2 weld

3 flow

a See 4.1, Table 1.

Figure 3 — Typical design of pressure taps with a truncated end

8.2 Temperature measurement

Measure the temperature of the fluid upstream of the filter using a temperature gauge immersed directly in the fluid stream. Adjust the fluid temperature so that the viscosity remains within the target value limits specified in Table 2.

8.3 Kinematic viscosity measurement

Determine the viscosity and report the measuring technique used.

Viscosity should be determined by ISO 3104 or a technically equivalent national standard.

8.4 Flow rate measurement

Use a flow rate meter with a measurement range compatible with the range of flow rates, to be measured during the test and an accuracy conforming to Table 2.

8.5 Fluid cleanliness measurement

Determine the test fluid initial cleanliness level by performing a particle count analysis either on line using an automatic particle counter, or off line on a sample extracted from the system in accordance with ISO 4021 and using a counting method approved by ISO. Report the result in accordance with ISO 4406 on the data sheet.

8.6 Accuracy of measuring instruments and test conditions

The accuracy of the measuring instruments and the test conditions shall conform to the limits specified in Table 2.

Table 2 — Accuracy of measuring instruments and test conditions

Test parameter	**SI unit**	**Instrument accuracy** (of actual value)	**Permitted variations in test conditions** (of target value)
Differential pressure[a]	kPa	±2 %	—
Gauge pressure[a]	kPa	±2 %	±5 %
Test flow rate	L/min	±2 %	±5 %
Kinematic viscosity[b]	mm^2/s	±2 %	—
Temperature	°C	±0,1 °C	±1°C
Conductivity	pS/m	±10 %	1 000 to 10 000

[a] 100 kPa = 1 bar.

[b] 1 mm^2/s = 1 cSt (centistoke).

9 Procedure

9.1 Pipework correction

In place of the filter under test, install a pipe with the same diameter as that of the test rig pipework. Determine the flow rate versus differential pressure characteristic curve of the measurement section between zero and the maximum flow rate scheduled for the testing of the filter in 0,2 q_R increments. The test fluid shall have the same viscosity as that used in 9.3 to 9.6.

9.2 Cleanliness of test circuit

Install the housing of the filter under test without its filter element (6.1.3) or a head and its empty spin-on (without internal element, 6.1.1 to 6.1.2) and start the pump to obtain a flow rate of approximately the maximum flow rate scheduled for the test. Let the fluid circulate to allow the temperature to stabilize and until the required fluid cleanliness level is achieved. The fluid cleanliness level should be selected to suit the grade of filter tested and not to contribute to blockage. Bleed the circuit to eliminate any entrained air if required.

When the required cleanliness level is achieved, report in the test report and if necessary, bypass the clean-up filter.

In the case of change of the test fluid, ensure that no residual fluid can mix with the new fluid by completely flushing the test stand.

9.3 Characteristics of the filter housing (filter type 6.1.3)

9.3.1 Prior to determining the differential pressure of the filter housing without a filter element as a function of the flow rate, ensure that exclusion of the filter element does not cause any flow perturbation. If there is flow perturbation, replace the filter element with a substitute element that creates a flow path as identical as possible to that caused by the filter element. The section for passage through the substitute element shall be as large as possible to reduce pressure drop. Record in the test report the characteristics of the filter housing with the substitute element as those of the filter housing and identify that a substitute element was used.

9.3.2 If the filter housing is equipped with a bypass valve, set it to the closed position during the test.

9.3.3 Adjust the test flow rate q_V to 0,2 q_R. Record Δ_p and temperature.

9.3.4 Repeat these operations for increasing flow rate values corresponding to increments of 0,2 q_R up to 1,2 q_R. Repeat the procedure for decreasing values of q_V.

9.3.5 For each flow rate increment, calculate and record the differential pressure of the filter housing, as well as the end of test temperature, and calculate the average of the ascending and descending sets of results.

9.3.6 In order to obtain the characteristic curve of the housing only, subtract the pipework correction values measured in 9.1 from the averaged values calculated in 9.3.5.

9.4 Characteristics of the filter assembly (filter type 6.1.3)

9.4.1 Verify that the required cleanliness level is achieved and that the bypass valve is blocked before installing the element into the test housing.

9.4.2 Initiate the flow at its lowest flow rate to evacuate the air from the filter housing and circuit.

9.4.3 Repeat 9.3.3 to 9.3.5 taking care to use the same flow rate increments.

9.4.4 If required, repeat the tests in 9.4.3 for the filter assembly ensuring that the bypass valve is operational.

9.5 Characteristics of the filter element only (filter type 6.1.3)

Calculate the differential pressure generated by the filter element only by deducting the values obtained with the housing (9.3.5) from those measured on the filter housing together with its filter element (9.4).

9.6 Characteristics of the head and spin-on (filter type 6.1.2)

9.6.1 Verify that the required cleanliness level is achieved and that the bypass valve is blocked before installing the head and spin-on on the circuit.

9.6.2 Initiate the flow at its lowest flow rate to evacuate the air from the filter and circuit.

9.6.3 Repeat 9.3.3 to 9.3.4 taking care to use the same flow rate increments.

9.6.4 For each flow rate increment, calculate and record the differential pressure of the filter, as well as the end of test temperature, and calculate the average of the ascending and descending sets of results.

9.6.5 If required, repeat the tests in 9.6.3 with the complete filter equipped with its bypass free to operate.

9.7 Characteristics of the spin-on (filter type 6.1.1)

9.7.1 Verify that the required cleanliness level is achieved and that the bypass valve is blocked before installing the spin-on on the circuit.

9.7.2 Repeat 9.6.2 to 9.6.3.

9.7.3 For each flow rate increment, calculate and record the differential pressure of the spin-on, as well as the end of test temperature, and calculate the average of the ascending and descending sets of results.

9.7.4 If required, repeat the tests in 9.7.2 with the spin-on equipped with its bypass free to operate.

9.8 Characteristics of the bypass valve

9.8.1 Preliminary installation

For these tests, a means of activating the bypass filter is required, for example a “solid” element or a plug in the element attachment post. The integrity of the arrangement used should be confirmed to avoid leakage.

Activate the bypass valve and install the blocked filter.

Increase the system flow to actuate the bypass valve and bleed all air from pressure transducers or gauges.

Increase the system flow to rated flow and back to zero. If required, bleed the differential pressure again to zero. Repeat this step twice, more to ensure that all valve parts are aligned and lubricated.

9.8.2 Determination of full flow rate characteristics

9.8.2.1 Determine the bypass valve differential pressure versus flow rate characteristics as specified in 9.3.3 to 9.3.5.

9.8.2.2 Determine the characteristics of the valve by subtracting the pipe work correction values obtained in 9.1. Plot the results for increasing and decreasing pressure, as shown in Figure 4, and average the results.

9.8.3 Determination of opening pressure

9.8.3.1 Open the valve (Figure 1, key 12) and gradually increase the pressure upstream of the test bypass valve by either slowly increasing the pump output or by closing the valve, until the flow rate reaches about 0,5 %, 1 %, 2 % and 5 % of q_R. Record the exact values of flow rate and pressure.

9.8.3.2 Combine the results from 9.8.2.2 and 9.8.3.1 and plot the curve “pressure versus flow rate” and graphically determine the opening pressure as corresponding to 1 % of the flow rate.

9.8.3.3 Repeat 9.8.3.1 and 9.8.3.2 twice and average the results of the opening pressure values.

NOTE If these measurements are made impossible due to the unsteady opening/closing, the opening/closing pressure is the one corresponding to the lowest measurable flow rate. Report this value.

9.8.4 Determination of closing pressure

9.8.4.1 Start the test by setting the flow rate at about 15 % of q_R and gradually reduce the flow rate to about 5 %, 2 %, 1 % and 0,5 % of q_R. Record the exact values of flow rate and pressure.

9.8.4.2 Plot the curve "pressure versus flow rate" and graphically determine the closing pressure as corresponding to 1 % of the flow rate.

9.8.4.3 Repeat 9.8.4.1 and 9.8.4.2 twice and average the results of the closing values.

NOTE If these measurements are made impossible due to the unsteady opening/closing, the opening/closing pressure is the one corresponding to the lowest measurable flow rate. Report this value.

9.8.5 Measurement of leakage rate

9.8.5.1 Disconnect the pipe downstream of the filter under test and install an appropriate means for measuring low flow rates (for example a range of measuring cylinders to maximize measurement accuracy and a chronometer). When testing immersed return filters, use a proper funnel to collect leaking fluid in a cylinder.

9.8.5.2 Open the valve (Figure 1, key 12) so that the flow is directed back to the reservoir and start the pump at its slowest rate. Gradually close the valve until the upstream pressure is equal to about 25 % of the opening pressure determined in 9.8.3. If leakage occurs, record the time for a suitable leakage volume of at least 25 mL.

9.8.5.3 Measure the leakage rate when the applied upstream pressure is 50 %, 75 %, 100 % and 120 % of the opening pressure. If the valve opens with little increase in pressure beyond the opening pressure, limit the measurement of flow rate to 3 L/min.

9.8.5.4 Repeat 9.8.5.2 and 9.8.5.3 for decreasing pressure values. Plot the results for increasing and decreasing pressure and average the results.

10 Presentation of results

The report sheet shall present, at least, the information listed in Table 3. Plot the corrected values of Δ_p against q_V for element (see 9.5), housing (see 9.3.6) and bypass valve (see 9.8.2.2) as shown in Figure 4.

Indicate clearly any deviation with respect to the method used in this document.

Table 3 — Report sheet

Test laboratory: ____________________ Test date: _________________ Operator:

FILTER AND ELEMENT IDENTIFICATION

Element identification: ___________________________ Housing identification:
Spin on: YES / NO _________________________________ Filter rated flow rate (L/min) q_R:
Substitute element: YES / NO Description:

OPERATING CONDITIONS

Test fluid
Type: ___________________________________ Ref: ___________________________ Batch no.:
Viscosity at the test temperature (mm^2/s): ______________________________ Temperature (°C):
Initial cleanliness level: ISO 4406 code

TESTS RESULTS

Differential pressure versus flow rate						
	Average Δ_p (kPa)					
Flow ratio (q_V/q_R)	0,2	0,4	0,6	0,8	1,0	1,2
Filter assembly						
Filter housing						
Filter element						
Bypass						

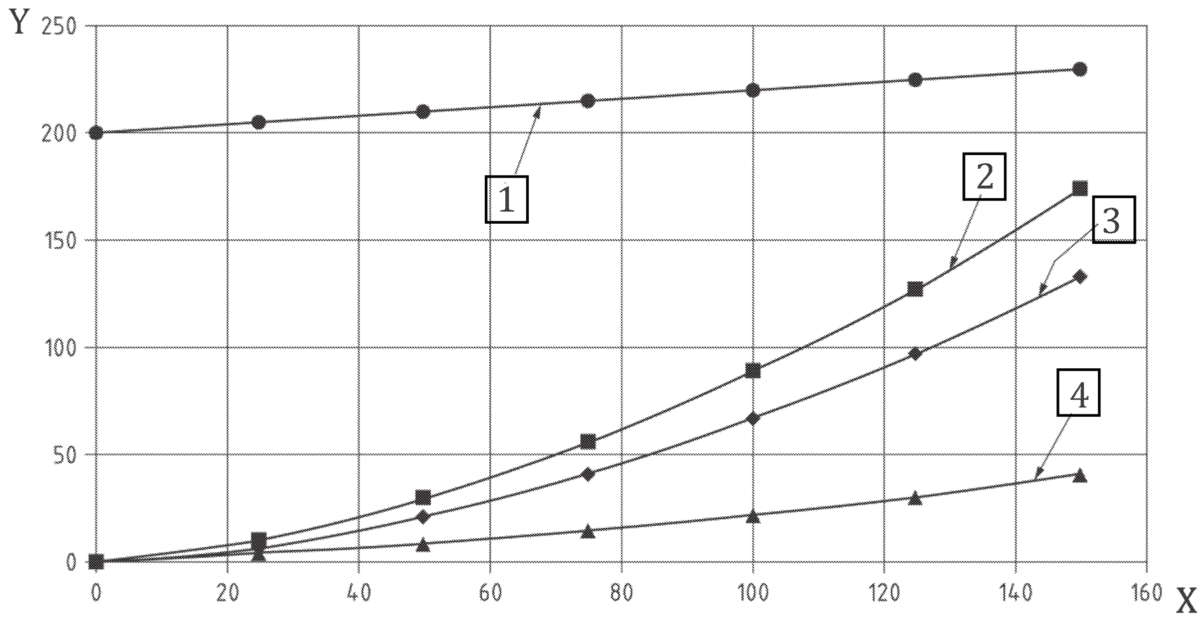
Bypass valve characteristics

Opening pressure (kPa): ____ flow rate (L/min)

Closing pressure (kPa): ____ flow rate (L/min)

Leakage rate

% **opening pressure**	**Pressure** (kPa)	**Average leakage rate** (ml/min)
50		
75		
100		
120		



Key

X flow rate, L/min

Y differential pressure, kPa

1 bypass valve (see 9.8)

2 housing and element or head and spin-on (see 9.4 or 9.6)

3 housing (see 9.3)

4 element or spin-on (see 9.5 or 9.7)

Figure 4 — Examples of curves of differential pressure versus flow rate of a filter component (filter housing, filter housing and element or filter head and spin-on, element or spin-on and bypass valve)

11 Identification statement (reference to this document)

For manufacturers who have chosen to conform to this document, it is strongly recommended to use the following identification statement in their test reports, catalogues and sales literature:

"Evaluation of differential pressure versus flow characteristics in accordance with ISO 3968, *Hydraulic fluid power — Filters — Evaluation of differential pressure versus flow characteristics.*"

Annex A
(informative)

Introduction to the power loss equation and method to calculate

A.1 Background

Differential pressure can also be quantified as power loss. For hydraulic components, any energy converted into internal energy (such as heat generated by friction) is seldom recoverable. Consequently, it becomes a portion of the power loss.

A.2 Terms and Definition

A.2.1 power loss – the unrecoverable internal energy consumed by friction calculated in watts based on the formula:

Power loss (W) = 0,016 67 × Δ_p × q

where Δ_p is in kPa and q is in L/min.

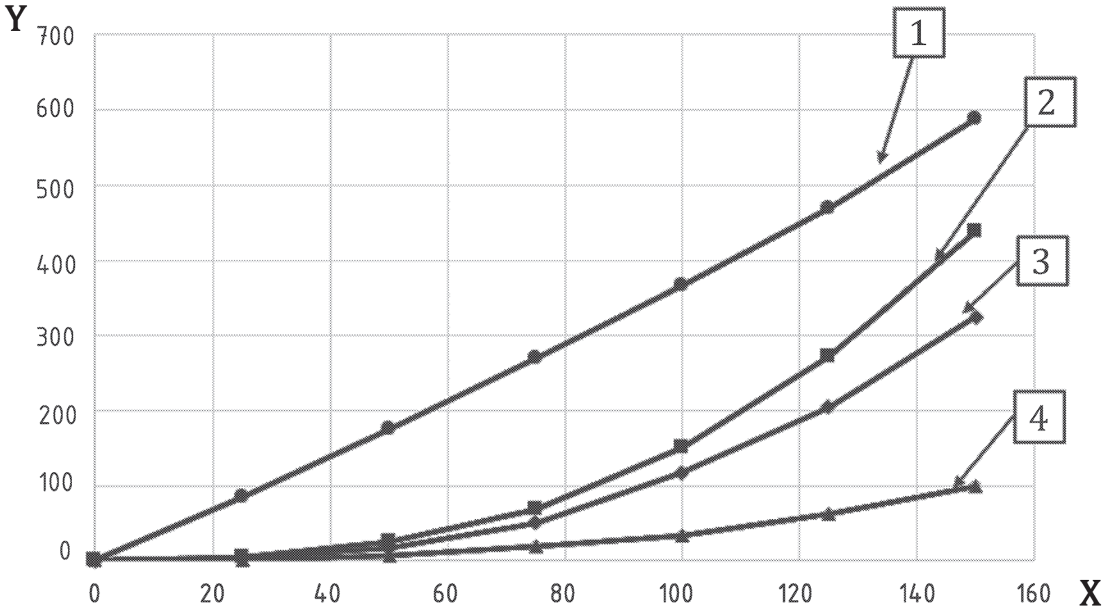
A.3 Method to present

Table A.1 — Power loss versus flow rate

Power loss versus flow rate						
	Average power loss (watts)					
Flow ratio (q_V/q_R)	0,2	0,4	0,6	0,8	1,0	1,2
Filter assembly						
Filter housing						
Filter element						
Bypass						

Table A.1 can be appended onto Table 3 and calculated values for power loss can be added.

Power loss can also be expressed graphically as shown on the Figure A.1.



Key

X flow rate, L/min

Y power loss, watts

1 bypass valve (see 9.8)

2 housing and element or head and spin-on (see 9.4 or 9.6)

3 housing (see 9.3)

4 element or spin-on (see 9.5 or 9.7)

Figure A.1 — Examples of calculated power loss versus flow rate of a filter component (filter housing, filter housing and element or filter head and spin on, element or spin on and bypass valve)

Bibliography

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

[2] ISO 2944, *Fluid power systems and components — Nominal pressures*

[3] ISO 9110-1, *Hydraulic fluid power — Measurement techniques — Part 1: General measurement principles*

[4] ISO 9110-2, *Hydraulic fluid power — Measurement techniques — Part 2: Measurement of average steady-state pressure in a closed conduit*

[5] ISO 16889, *Hydraulic fluid power — Filters — Multi-pass method for evaluating filtration performance of a filter element*

[6] ASTM D4308-95, *Standard test method for electrical conductivity of liquid hydrocarbons by precision meter*

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