INTERNATIONAL STANDARD

ISO 3968

Second edition
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Hydraulic fluid power — Filters — Evaluation of differential pressure versus flow characteristics

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

Reference number
ISO 3968:2001(E)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 3968 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 3968:1981), which has been technically revised. Its primary objective is to bring procedures and equipment as close as possible to those of ISO 16889. It also integrates some recommendations of ISO 9110-1[1] and ISO 9110-2[2], which deal with pressure measurements, and of other standards pertaining to the subject matter.

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.

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 characteristics

1 Scope

This International Standard 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, that is the housing, the filter element and any valves contained within the housing that are in the flow stream.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1219-1, *Fluid power systems and components — Graphic symbols and circuit diagrams — Part 1: Graphic symbols*

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

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

3 Terms and definitions

For the purposes of this International Standard, the definitions given in ISO 5598 and the following apply.

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 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

4 Symbols

4.1 Literal symbols

The following literal symbols are used in this International Standard:

a) q_V is the test volume flow rate;

b) q_R is the filter rated volume flow rate;

c) p is the static pressure;

d) p_1 is the static pressure measured upstream of the filter;

e) p_2 is the static pressure measured downstream of the filter;

f) Δp is the differential pressure ($\Delta p = p_1 - p_2$);

g) D is the internal pipe diameter.

4.2 Graphical symbols

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

5 Test equipment

5.1 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, together with all the necessary equipment for measuring the pressure, the flow rate, the temperature and the fluid cleanliness level (see 6.5). Figure 1 shows a typical test rig in schematic form.

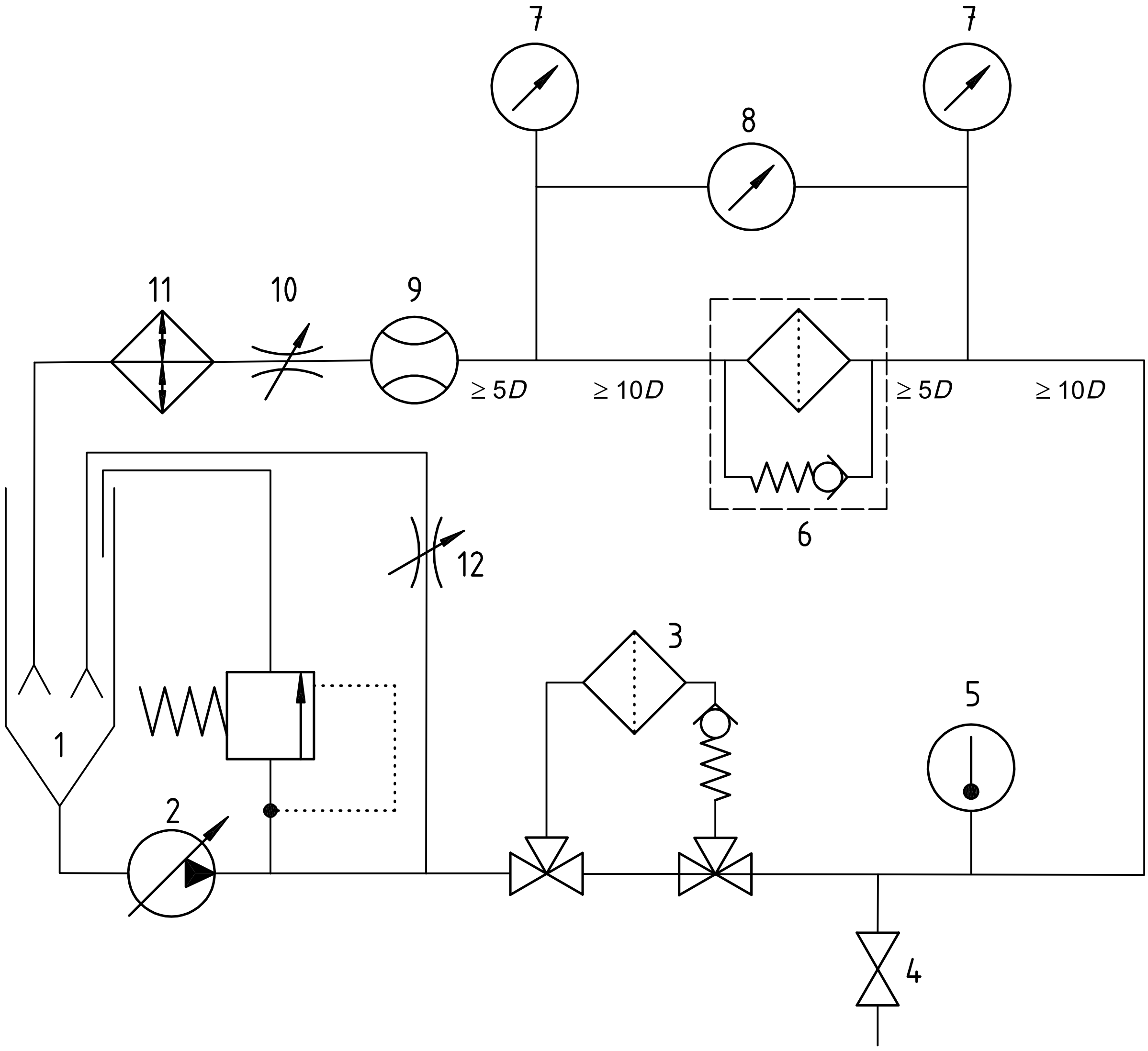
A test rig in accordance with ISO 16889 is suitable for this test.

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 on Figure 1 [flow meter, heat exchanger (counter pressure valve is not necessary)] shall be located upstream of the test filter.

5.2 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.



Key

1 Reservoir	7 Absolute pressure transducer
2 Variable flow pump	8 Differential pressure transducer
3 Clean-up filter	9 Flow meter
4 Sampling valve	10 Counter pressure regulating valve
5 Thermometer	11 Heat exchanger
6 Filter under test	12 Bypass flow regulating valve

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

5.3 Reservoir

Use a reservoir with a conical bottom and sized for containing a volume in litres of test fluid of between one and two times the maximum flow rate in litres per minute scheduled for the test. It should be designed to minimize air entrainment (for example by means of a return of the fluid beneath the test fluid surface) and ingression of airborne contamination.

5.4 Temperature control

Use a heat exchanger to control the temperature measured upstream of the filter under test to the required value with an accuracy conforming to Table 1.

5.5 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.

5.6 Sampling valve

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

5.7 Mounting of filter

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 with substantially the same internal diameters as the unions.

5.8 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 clause 8.

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

a) a viscosity grade of VG 32 (see ISO 3448);

b) a viscosity index of 95 to 105;

c) a mass density of 850 kg/m^3 to 900 kg/m^3.

Caution should be exercised when testing fine filters ($\beta_{10} > 75$) 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.

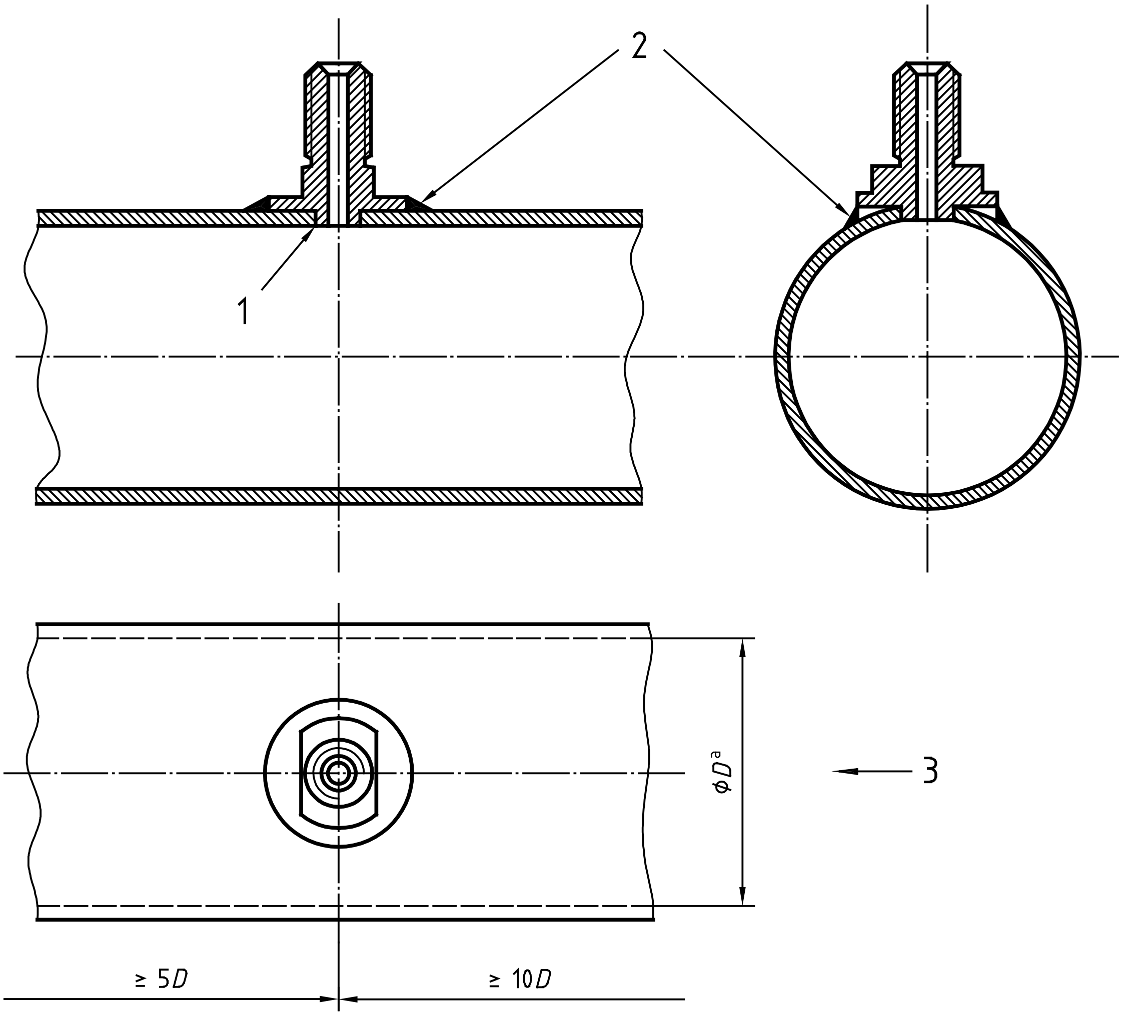
6 Measurements

6.1 Pressure measurement

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 1.

The pressure points shall be of the truncated end type (see Figure 2) and placed on pipework without any hydraulic irregularity (for example union, valve, bend) over a length not less than $10D$ upstream and $5D$ downstream of the measuring point.

NOTE 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 g).

Figure 2 — Typical design of pressure taps with a truncated end

6.2 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 1.

6.3 Kinematic viscosity measurement

Determine the viscosity and report the measuring technique used.

NOTE Viscosity should be determined in accordance with a national standard.

6.4 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 1.

6.5 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.

6.6 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 1.

Table 1 — 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	—

[a] 0,01 kPa = 1 bar

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

7 Procedure

7.1 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/differential pressure characteristic curve of the measurement section between zero and the maximum flow rate scheduled for the testing of the filter in $0{,}2q_R$ increments. The test fluid shall have the same viscosity as that used in 7.3, 7.4, 7.5 and 7.6.

7.2 Cleanliness of test circuit

Install the housing of the filter under test without its filter element 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.

7.3 Characteristics of the filter housing

7.3.1 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.

7.3.2 If the filter housing is equipped with a bypass valve, immobilize it in the closed position during the test.

7.3.3 Adjust the test flow rate q_V to 0,2q_R and record Δp and/or p_1, p_2 as well as the temperature.

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

7.3.5 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.

7.3.6 In order to obtain the characteristic curve of the housing only, subtract the pipework correction values measured in 7.1 from the averaged values calculated in 7.3.5.

7.4 Characteristics of the filter assembly

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

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

7.4.3 Repeat 7.3.3 to 7.3.5 taking care to use the same flow rate increments.

7.4.4 If required, repeat the tests in 7.4.3 with the complete filter equipped with its bypass free to operate.

7.5 Characteristics of the filter element only

Calculate the differential pressure generated by the filter element only by deducting the values obtained with the housing (7.3.5) from those measured on the filter housing together with its filter element (7.4).

7.6 Characteristics of the bypass valve

7.6.1 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.

7.6.2 Determination of full flow rate characteristics

7.6.2.1 Determine the bypass valve differential pressure versus flow rate characteristics as specified in 7.3.3 to 7.3.5.

7.6.2.2 Determine the characteristics of the valve by subtracting the pipe work correction values obtained in 7.1. Plot the results for increasing and decreasing pressure, as shown in Figure 3, and average the results.

7.6.3 Determination of opening pressure

7.6.3.1 Open the valve (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.

7.6.3.2 Combine the results from 7.6.2.2 and 7.6.3.1 and plot the curve “pressure versus flow rate” and graphically determine the opening pressure as corresponding to 1 % of the flow rate.

7.6.3.3 Repeat 7.6.3.1 and 7.6.3.2 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.

7.6.4 Determination of closing pressure

7.6.4.1 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.

7.6.4.2 Plot the curve “pressure versus flow rate” and graphically determine the closing pressure as corresponding to 1 % of the flow rate.

7.6.4.3 Repeat 7.6.4.1 and 7.6.4.2 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.

7.6.5 Measurement of leakage rate

7.6.5.1 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.

7.6.5.2 Open the valve (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 7.6.3. If leakage occurs, record the time for a suitable leakage volume of at least 25 mL.

7.6.5.3 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.

7.6.5.4 Repeat 7.6.5.2 and 7.6.5.3 for decreasing pressure values. Plot results for increasing and decreasing pressure and average the results.

8 Presentation of results

The report sheet shall present, at least, the information listed in Table 2. Plot the corrected values of Δp against q_V for element (see 7.5), housing (see 7.3.6) and bypass valve (see 7.6.2.2) as shown in Figure 3.

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

Table 2 — 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 Δp (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						

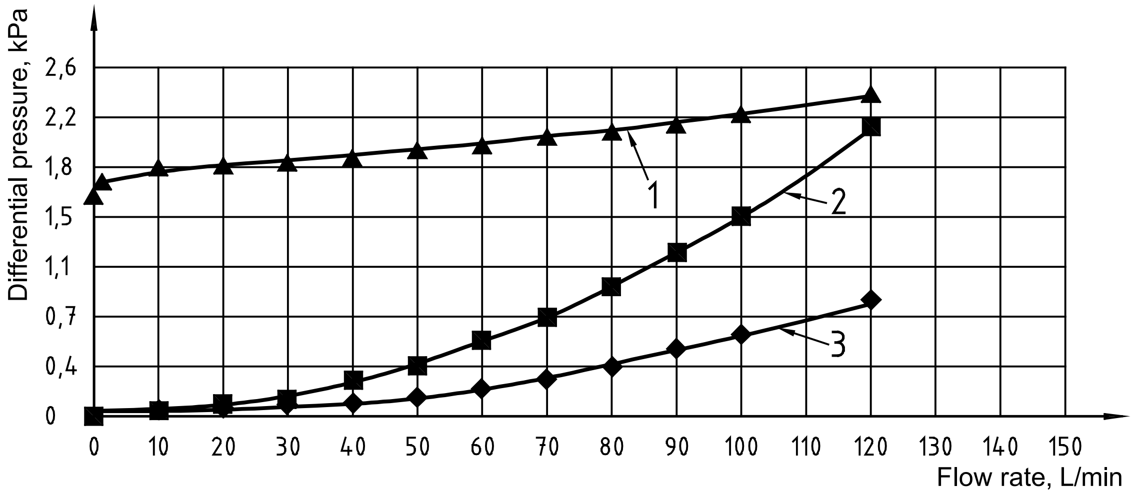
Bypass valve characteristics

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

1 Bypass valve (see 7.6)

2 Housing and element (see 7.4)

3 Housing (see 7.3)

Figure 3 — Examples of curves of differential pressure versus flow rate of a filter component (filter housing, filter housing + element and bypass valve)

9 Identification statement (Reference to this International Standard)

For manufacturers who have chosen to comply with this International Standard, 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 3968:2001, *Hydraulic fluid power — Filters — Evaluation of differential pressure versus flow characteristics.*"

Bibliography

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

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

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

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