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Methods of test for full-flow lubricating oil filters for internal combustion engines —

Part 12:
Filtration efficiency using particle counting and contaminant retention capacity

Méthodes d'essai des filtres à huile de lubrification à plein débit pour les moteurs à combustion interne —

Partie 12: Efficacité de filtration par comptage des particules et capacité de rétention des contaminants

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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.

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 on 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.

The committee responsible for this document is ISO/TC 70, *Internal combustion engines*, Subcommittee SC 7, *Tests for lubricating oil filters*.

This second edition cancels and replaces the first edition (ISO 4548-12:2000), which has been technically revised.

A list of all parts in the ISO 4548 series can be found on the ISO website.

Introduction

ISO 4548 establishes standard test procedures for measuring the performance of full-flow lubricating oil filters for internal combustion engines. It has been prepared in separate parts, each part relating to a particular performance characteristic.

Together, the tests provide the information necessary to assess the characteristics of a filter, but if agreed between the purchaser and the manufacturer, the tests may be conducted separately.

Methods of test for full-flow lubricating oil filters for internal combustion engines —

Part 12: Filtration efficiency using particle counting and contaminant retention capacity

1 Scope

This document specifies a multi-pass filtration test with continuous contaminant injection and using the online particle counting method for evaluating the performance of full-flow lubricating oil filters for internal combustion engines. The scope of this document is limited to steady state conditions and does not address fluctuations in the flow rate.

The test procedure determines the contaminant capacity of a filter, its particulate removal characteristics and differential pressure.

This test is intended for application to filter elements with an efficiency of less than 99 % at particle size greater than 10 µm.

NOTE Several test flow loops built into one test rig, or several test rigs, would be necessary to cover the complete flow range of 2 l/min to 600 l/min.

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 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 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 12103-1:2016, *Road vehicles — Test contamintants 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 11841-1 and ISO 11841-2 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
multi-pass test
test which requires the recirculation of unfiltered fluid through the filter element

3.2
base upstream gravimetric level
upstream contaminant concentration if no contaminant is recirculated

3.3
filtration efficiency
ability of the filter to retain particles expressed as the percentage of particles of a given size retained by the filter under test

3.4
overall efficiency
efficiency calculated from the average upstream and downstream particle counts

3.5
***X* % micrometer (µm) rating**
particle size corresponding to an overall efficiency of a given percentage *X*

Note 1 to entry: The unit given in µm should be in accordance with data presentation expressed in ISO 11171.

4 Symbols

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

5 Test equipment and materials

5.1 Test equipment

5.1.1 Test rig

5.1.1.1 Generality

The test rig is shown diagrammatically in Figure 1. It shall comprise a filter test circuit and a contaminant injection circuit, as described in 5.1.1.2 and 5.1.1.3.

5.1.1.2 Filter test circuit

The filter test circuit shall include the following components:

a) reservoir (1) constructed with a conical bottom having an included angle of not more than 90 degrees and where the oil entering is diffused below the fluid surface;

b) oil pump (2) which does not alter the contaminant particle size distribution and which does not exhibit excessive flow pulses;

c) device, such as a filter head to accommodate spin-on filters, to connect the test filter (6) which can be by-passed or replaced by a straight section of the pipe;

d) system clean-up filter (9) capable of providing an initial system contamination level of less than 15 particles greater than 10 µm/ml;

e) sampling valves in accordance with ISO 4021, for turbulent sampling upstream and downstream of the test filter, for on-line particle counting (18) and for gravimetric analysis (11);

f) pressure gauges in accordance with ISO 3968;

g) piping sized to ensure that turbulent mixing conditions exist throughout the filter test circuit.

5.1.1.3 Contaminant injection circuit

The contaminant injection circuit shall include the following components:

a) reservoir (12) constructed with a conical bottom having an included angle of not more than 90 degrees and where the oil entering is diffused below the fluid surface;

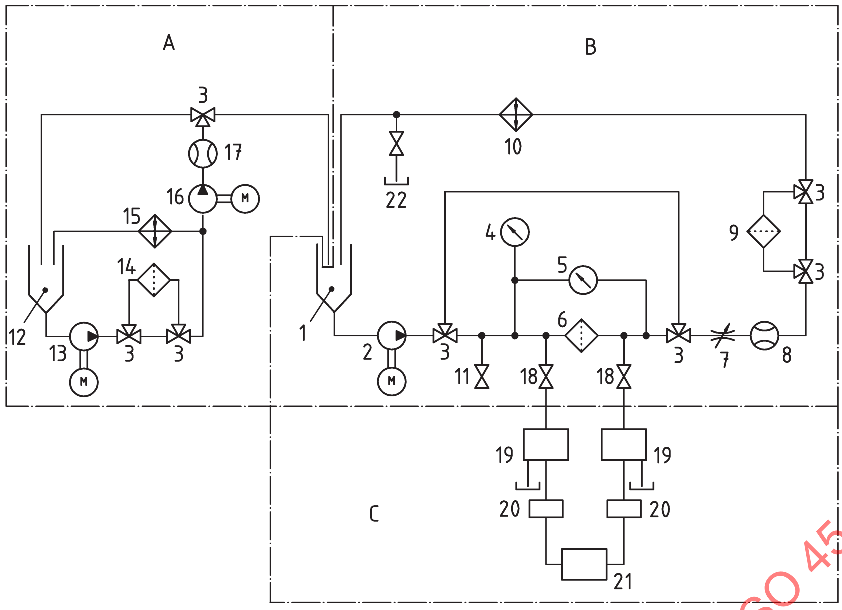
b) oil pump (13), centrifugal or of another type which does not alter the contaminant particle size distribution;

c) system clean-up filter (14) capable of providing either of the following conditions:

   1) an initial system contamination level of less than 1 000 particles per millilitre having a size greater than 10 µm;

   2) a gravimetric level less than 2 % of the calculated level at which the test is being conducted, measured in accordance with the gravimetric method described in ISO 4405;

d) piping sized to ensure that turbulent mixing conditions exist throughout the contaminant injection circuit.



Key

A contaminant injection circuit
B filter test circuit
C dilution and counting system
1 reservoir incorporating a thermostatically controlled heater
2 pump
3 three-way valve
4 pressure gauge
5 differential pressure gauge
6 test filter
7 throttle valve (for pressure regulation)
8 flow meter
9 clean-up filter
10 heat exchanger
11 sampling valve
12 reservoir incorporating a thermostatically controlled heater
13 pump
14 clean-up filter
15 heat exchanger
16 injection pump
17 flow meter
18 sampling valve
19 dilution system
20 particle sensor
21 particle counter
22 volume control valve

Figure 1 — Diagrammatic arrangement of test rig

5.1.2 Online dilution and particle counting system

The online dilution and particle counting system shall include the following components:

a) online sample delivery pipework sized to maintain a fluid velocity which will prevent silting;

b) dilution system (19) comprising a reservoir, pump, clean-up filters, flowmeters and flow regulation valves;

c) two optical particle sensors (20) connected to a counter (21) having a minimum of five channels.

5.1.3 Timer

A timer capable of measuring minutes and seconds.

5.2 Test materials

5.2.1 Test contaminant

5.2.1.1 Contaminant grade

The contaminant shall be in accordance with the specification given for ISO 12103-1, A.3 medium grade test dust.

5.2.1.2 Contaminant preparation

The test dust shall be pre-dried in quantities not larger than 200 g for at least 1 h at 105 °C ± 5 °C and cooled to room temperature. Maintain in a desiccator until required for use.

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 (see ISO 16889).

5.2.2 Test fluid

The test fluid shall have a petroleum base and conform to the specifications given in Annex A.

6 Accuracy of measuring instruments and test conditions

The measuring instruments shall be capable of measuring to the levels of accuracy given in Table 1. The last column in Table 1 gives the limits within which the test conditions shall be maintained.

Table 1 — Instrument accuracy and test condition variation

Test condition	Units	Instrument reading accuracy	Allowed test condition variation
Test flow rate	l/min	±2 %	±5 %
Injection flow rate	ml/min	±2 %	±5 %
Pressure	Pa	±5 %	—
Temperature	°C	±1 °C	±2 °C
Volume	l	±5 %	±10 %
Base upstream gravimetric level	mg/l	—	±10 %
Initial conductivity	pS/m	±10 %	1 500 ± 500
Final conductivity	pS/m	±10 %	
Viscosity [a]	mm^2/s	±5 %	/
Counting flow rate (APC)	ml/min	±1,5 %	±3 %
Injection circuit volume	l	±2 %	/
Test circuit volume	l	±2 %	±5 %
Mass	g	0,1 mg	/
Time	sec	1 s	

[a] The viscosity of the test liquid should be checked at regular intervals to ensure that the test is conducted at a liquid temperature which corresponds to a viscosity of 15 ± 1 mm^2/s.

7 Test rig validation

NOTE These validation procedures reveal the effectiveness of the test rig in maintaining contaminant entrainment and/or preventing contaminant size modification.

7.1 Validation of filter test circuit

NOTE The filter test circuit is validated at the minimum flow rate at which the circuit will be operated.

7.1.1 Install a straight section of pipe in place of a test filter during the validation procedure.

7.1.2 For flows of not more than 60 l/min, adjust the total circuit volume to be numerically equal to one-half of the value of the minimum flow volume per minute through the filter, with a minimum of 6 l. For flows higher than 60 l/min, adjust the total circuit volume to be numerically equal to one-quarter of the value of the minimum flow volume per minute through the filter.

7.1.3 Contaminate the fluid to the calculated gravimetric level of 5 mg/l using ISO 12103-1, A.3 test dust.

NOTE This contamination level is below the coincidence limit of automatic particle counters.

7.1.4 Circulate the fluid in the test system for 1 h and obtain downstream cumulative counts at 10 µm and 20 µm without online dilution at the 10 min sample intervals.

7.1.5 Calculate and record the online count (C_0) in particles per millilitre, using Formula (1):

$$C_o = \frac{N_c}{V} \tag{1}$$

where

N_c is the cumulative count for the selected sample period, in number of particles;

V is the volume of fluid in millilitres passed through the particle counter sensor during the sample period.

7.1.6 Accept the validation test only if each particle count obtained at 10 µm and 20 µm does not deviate by more than 10 % from the average particle counts for these sizes and complies with ISO 11943.

7.2 Validation of contaminant injection circuit

7.2.1 Validate the contaminant injection circuit at the maximum volume and the maximum gravimetric level to be used.

7.2.2 Add the required quantity of contaminant in a slurry form to the injection circuit fluid and circulate for sufficient time to completely disperse the contaminant.

NOTE It is possible that not all systems be able to disperse contaminant at the same rate. A period of 10 min to 20 min can be necessary for complete dispersion.

7.2.3 Extract fluid samples at the point where the injection fluid is discharged into the filter test circuit reservoir at 30 min intervals over 2 h and analyse each sample gravimetrically.

These samples should be taken at the intended test injection flow rate.

7.2.4 Accept the validation test only if the gravimetric level of each sample is within ±5 % of the average of the four samples and if this average is within ±5 % of the gravimetric value selected in 7.2.1.

7.3 Validation of online dilution and particle counting system

Proceed as described in ISO 11943 to validate the online dilution system and proceed in accordance with ISO 11171 to validate the particle counter.

NOTE A round robin exercise has been performed and demonstrated that reducing the matching tolerances of the sensors improves the reproducibility of the procedure (see Annex D).

8 Preliminary preparation

8.1 Test filter assembly

8.1.1 Ensure that the test fluid cannot bypass the filter element to be evaluated. Unless agreed between the purchaser and manufacturer, the bypass valve of the filter element shall be kept operative. If the bypass valve has been made inoperative, this shall be clearly stated in the test report.

8.1.2 Subject the test filter element to a fabrication integrity test in accordance with ISO 2942 using MIL-H-5606 fluid prior to the multi-pass test or following the multi-pass test if the element is not readily accessible as in the spin-on configuration.

8.1.3 If the integrity test has been made prior to the multi-pass test and if it fails to meet the test pressure agreed between the purchaser and the manufacturer, disqualify the element from further testing.

8.2 Contaminant injection circuit

8.2.1 Using 10 mg/l as the base upstream gravimetric level, calculate the predicted test time (T_e) in minutes from Formula (2):

$$T_e = \frac{F_c}{G \times Q} = \frac{F_c}{10 \times Q} \tag{2}$$

where

F_c is the estimated capacity of the filter element, in mg;

G is the base upstream gravimetric level, in mg/l;

Q is the test flow rate, in l/min.

A test duration of more than 30 min is recommended.

NOTE If the estimated capacity of the filter element (F_c) is not supplied by the manufacturer, the capacity can be determined by testing an element, if needed.

The base upstream gravimetric level (G) of 10 mg/l should be adhered to unless otherwise agreed upon by the purchaser and the manufacturer. Base upstream gravimetric levels up to 25 mg/l may be used to shorten test times but only the results of filter tests using the same base upstream gravimetric level can be compared.

8.2.2 Calculate the minimum volume of fluid (Vm) in litres, required for the operation of the injection circuit, which is compatible with the predicted test time and an injection flow rate of 0,25 /min, using Formula (3):

$$Vm = 1{,}2T_e \times Q_i + V_0 \tag{3}$$

where

T_e is the predicted test time, in min, obtained in 8.2.1;

Q_i is the injection flow rate, in l/min;

V_0 is the minimum volume of fluid in the injection circuit necessary to avoid air entrainment, in litres.

The calculated minimum volume should ensure a sufficient quantity of contaminant fluid to load the element, plus 20 % for adequate circulation throughout the test and to avoid entrainment. Larger injection volumes may be used.

It is strongly recommended to use an injection flow rate of 0,25 l/min. Higher injection flow rates may be used if they are less than 4 % of the test flow rate, in order to minimize the effects of extraction on the filter capacity. Lower injection rates may be used if the system is validated in accordance with ISO 11943.

8.2.3 Calculate the gravimetric level (G_i) in mg/l of the injection fluid, using Formula (4):

$$G_i = \frac{G \times Q}{Q_i} = \frac{10Q}{Q_i} \tag{4}$$

where

G is the base upstream gravimetric level, in mg/l, established in 8.2.1;

Q is the test flow rate, in l/min;

Q_i is the injection flow rate, in l/min.

8.2.4 Calculate the quantity of contaminant (W) in g, needed for the contaminant injection circuit, using Formula (5):

$$W = \frac{G_i \times V_i}{1\,000} \tag{5}$$

where

G_i is the gravimetric level, in mg/l, obtained in 8.2.3;

V_i is the volume of fluid contained in the injection circuit, in l.

8.2.5 Adjust the injection flow rate at stabilized temperature to within ±5 % of the value selected in 8.2.2 and maintain throughout the test.

8.2.6 Circulate the fluid in the contaminant injection circuit through the clean-up filter (14) until either of the following conditions is attained:

a) a contamination level of less than 1 000 particles per millilitre having a size greater than 10 µm;

b) a gravimetric level of less than 2 % of the value determined in 8.2.3.

8.2.7 Bypass the system clean-up filter (14) after the required initial contamination has been achieved.

8.2.8 Adjust the total volume of the contaminant injection system to the value determined in 8.2.2.

8.2.9 Ensure that the conductivity of the test fluid and the injection fluid is at least 1 000 pS/m by measuring fluid conductivity prior each test.

A level of 1 500 pS/m ± 500 pS/m is recommended. An initial level of 100 ppm of an antistatic agent has been shown to produce conductivity within this range.

8.2.10 Add, in slurry form to the contaminant injection circuit reservoir (12), the quantity of contaminant (W) determined in 8.2.4, and circulate until the contaminant is completely dispersed.

NOTE Complete dispersal of the contaminant can take between 10 min and 20 min.

8.3 Filter test circuit

8.3.1 Install a straight section of pipe in place of the test filter.

8.3.2 Circulate the fluid in the filter test circuit through the clean-up filter (9) until a contamination level of less than 15 particles per millilitre having a size greater than 10 µm is attained. Record this value as the initial cleanliness level of the system.

The contamination level should be checked with the online particle counting system which will, at the same time, clean the sampling lines.

8.3.3 Adjust the fluid volume of the filter test circuit to the value determined in 7.1.2 and record this value.

8.3.4 Ensure that the conductivity of the test fluid is at least 1 000 pS/m by measuring fluid conductivity prior to each test.

A level of 1 500 pS/m ± 500 pS/m is recommended. An initial level of 100 ppm of an antistatic agent has been shown to produce conductivity within this range.

8.3.5 Install the filter housing, without the test element, in the filter test circuit. For a spin-on type filter, install this spin-on filter body without an element inside.

8.3.6 Circulate the fluid in the filter test circuit at the rated flow and at the stabilized test temperature ±2 °C. Measure and record the differential pressure of the empty filter housing (Δp_3).

8.3.7 Adjust the channels on the particle counter to read the following particle sizes (expressed as per ISO 11171):

- 5 (6) channels counter : (5), 10, 15, 20, 30, 40.
- 16 channels counter : 4, 5, 6, 7, 8, 9, 10, 11, 13, 15, 17, 20, 25, 30, 40, 50.

9 Test procedure

9.1 Initial measurement

9.1.1 Install the filter element (6) in its housing and subject the assembly to the flowrate required by the purchaser and to the temperature required to maintain an oil viscosity of 15 mm²/s ± 1 mm²/s. Recheck the fluid level.

9.1.2 Measure and record the differential pressure of the clean assembly (Δp_1).

9.1.3 Calculate and record the differential pressure of the clean element (Δp_2) from Formula (6):

$$\Delta p_2 = \Delta p_1 - \Delta p_3 \tag{6}$$

where

Δp_1 is the differential pressure of the clean assembly measured in 9.1.2;

Δp_3 is the differential pressure of the empty filter housing measured in 8.3.6.

9.1.4 Calculate the differential pressures (Δp_5) corresponding to increases of 100 % of the net differential pressure using Formula (7):

$$\Delta p_5 = \Delta p_4 - \Delta p_2 \tag{7}$$

where

Δp_4 is the element terminal differential pressure;

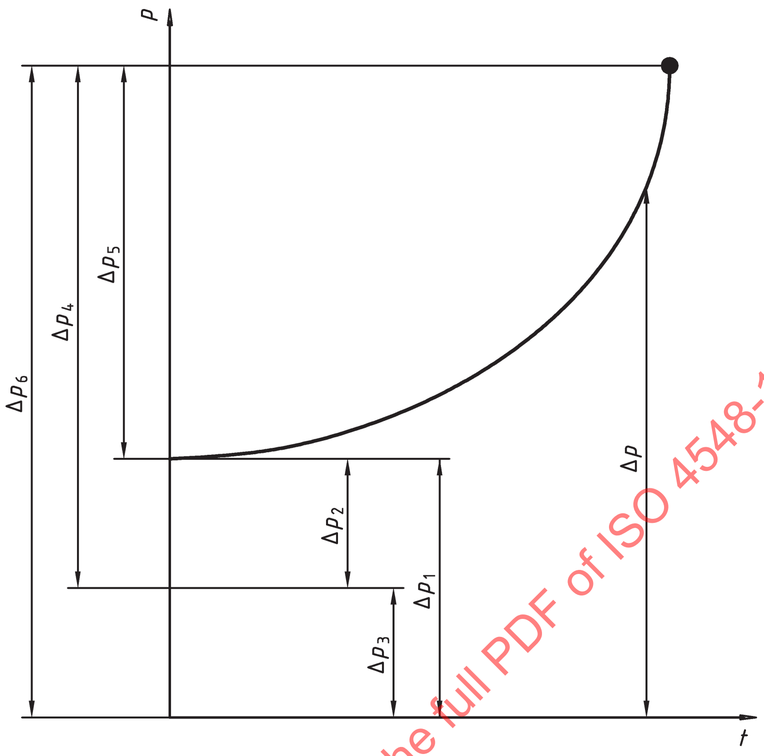
Δp_2 is the differential pressure of the clean element obtained from 9.1.3.

NOTE For clarity, Δp_1 to Δp_6 are illustrated in Figure 2.

9.1.5 Obtain a fluid sample from the contaminant injection circuit, at the point where the fluid return pipe discharges into the reservoir (12).

9.1.6 Measure and record the injection flow rate.

9.1.7 Adjust the dilution at the start of the test to the anticipated maximum dilution required during the test to avoid particle counter saturation.



Key

Δp_1 differential pressure of the clean assembly
Δp_2 differential pressure of the clean element
Δp_3 differential pressure of the housing
Δp_4 terminal differential pressure of the element
Δp_5 net differential pressure
Δp_6 differential pressure across the filter assembly at the end of the test
Δp measured differential pressure

Figure 2 — Diagrammatic representation of filter differential pressures

9.2 Performance test

9.2.1 Bypass the clean-up filter (9).

9.2.2 Allow the injection flow to enter the filter test circuit reservoir.

9.2.3 Start the timer.

9.2.4 Start the upstream and downstream sample flows.

9.2.5 Record the differential pressure and count particles upstream and downstream during 50 s every minute at the specified flow within the sensor.

9.2.6 Calculate and record the online count (Co) using Formula (8):

$$C_o = \frac{N_c \times D}{V} \tag{8}$$

where

N_c is the cumulative count for the sample interval, in number of particles;

D is the dilution factor;

V is the volume of fluid passed through the particle counter sensor during the sample interval, in ml.

9.2.7 Record the test time, in minutes, required for the differential pressure across the filter assembly (Δp) to increase by 80 % and 100 % of the net differential pressure (Δp_5).

9.2.8 Take an upstream sample at valve (11) for gravimetric analysis when the differential pressure across the filter assembly has increased by 80 % of the net differential pressure.

NOTE The sample is taken at the 80 % point because it often overlaps the 100 % point.

9.2.9 Stop the flow to the test filter and measure and record the exact final volume of test fluid (V_f).

NOTE If 100 % net differential pressure is reached during sampling, complete sampling before stopping the flow to the test filter.

9.2.10 Accept the test if the final volume V_f is within ±10 % of the initial volume.

9.2.11 Obtain a final fluid sample from the contaminant injection circuit at the point where the injection fluid is discharged into the filter test circuit.

9.2.12 Measure and record the final injection flow rate.

9.2.13 Measure and report the final conductivity.

9.2.14 Remove the element and check that there is no visual evidence of filter damage as a result of performing this test.

10 Calculations and report of test results

10.1 Calculations

10.1.1 General

Carry out the following calculations and record the results in the test report.

10.1.2 Gravimetric levels

10.1.2.1 Conduct a gravimetric analysis according to ISO 4405 on the two samples extracted from the contaminant injection circuit (see 9.1.5 and 9.2.11) and on the upstream sample extracted from the filter test circuit at the 80 % sample point (see 9.2.8)

10.1.2.2 Record the non-retained contaminant concentration, in mg/l, at the 80 % sample point as the final system gravimetric level (G_f).

10.1.2.3 Calculate and record the average of the gravimetric levels (G_{ia}) for the two samples taken from the contaminant injection circuit in 9.1.5 and 9.2.11.

10.1.2.4 Accept the test only if the gravimetric level of each sample is within ±10 % of the average G_{ia} calculated in 10.1.2.3.

10.1.2.5 Calculate and record the injection flow rate (Q_{ia}) by averaging the measurements taken in 9.1.6 and 9.2.12.

10.1.2.6 Accept the test only if the value of Q_{ia} is equal to the selected value ±5 % (see 8.2.2).

10.1.2.7 Calculate and record the actual base upstream gravimetric level (G_a) in mg/l, using Formula (9):

$$G_a = \frac{G_{ia} \times Q_{ia}}{Q} \qquad (9)$$

where

G_{ia} is the average injection gravimetric level, in mg/l, obtained in 10.1.2.3;

Q_{ia} is the average injection flow rate, in l/min, obtained in 10.1.2.5;

Q is the test flow rate, in l/min.

10.1.2.8 Accept the test only if the base upstream gravimetric level (G_a) is equal to 10 mg/l ± 1 mg/l.

10.1.3 Filtration efficiencies

10.1.3.1 Average intermediate efficiencies

From the upstream and downstream particle counts recorded from each channel of the counter in 9.2.6, calculate the average intermediate efficiencies at each particle size, as described in C.1 and C.2.

Identify the maximum and minimum calculated intermediate efficiencies for each particle size and record them in the overall filtration efficiency table in the test report.

10.1.3.2 Overall efficiencies

Calculate the overall efficiency, at each particle size, as described in C.3.

Record the calculated overall efficiency at each particle size in the overall filtration efficiency table in the test report.

Prepare a graph of overall efficiency versus particle size, as shown in Figure B.2 and, if required by the purchaser, also provide a graph as shown in Figure B.3.

10.1.4 Micrometer ratings

The graph of overall efficiency versus particle size may highlight the particle sizes which correspond to overall efficiencies of 50 %, 75 % and 90 % as shown in Figure B.2. These particle sizes may also be recorded in the test report sheet.

Optionally, and only in the case of high-efficiency filters, identify the particle sizes which correspond to overall efficiencies of 98,7 % and 99 %.

The particle sizes which correspond to overall efficiencies of 98,7 % and 99 % cannot be determined graphically with acceptable accuracy. These values should therefore be calculated by linear interpolation.

10.1.5 Injected mass of contaminant

Calculate the mass of contaminant injected into the filter element (M_i) in g, using Formula (10):

$$M_i = Q_{ia} \text{ x } G_{ia} \times T / 1\,000 \tag{10}$$

where

Q_{ia} is the average injection flow rate, in l/min, calculated in 10.1.2.5;

G_{ia} is the average gravimetric level of the injection fluid, in mg/l, calculated in 10.1.2.3;

T is the time required to reach the terminal differential pressure, in min (from 9.2.7).

Record the calculated value of M_i in the test report.

10.1.6 Non-retained mass of contaminant

Calculate the non-retained mass of contaminant (M_{nr}) in g, using Formula (11):

$$M_{nr} = V_f \times G_f / 1\,000 \tag{11}$$

where

V_f is the final volume of test fluid, in l, obtained in 9.2.9;

G_f is the final system gravimetric level, in mg/l, obtained in 10.1.2.2.

Record the calculated value of M_{nr} in the test report.

10.1.7 Retained filter capacity

Calculate the retained filter capacity (C_r) in g, using Formula (12):

$$C_r = M_i - M_{nr} \tag{12}$$

where

M_i is the mass of contaminant injected into the filter element, in g, obtained in 10.1.5;

M_{nr} is the non-retained mass of contaminant, in g, obtained in 10.1.6.

Record the calculated value of C_r in the test report.

NOTE The retained capacity as calculated here is an approximate value since it does not take into account the contaminant extracted upstream and downstream for particle counting.

10.2 Test report

A typical test report is given in Annex B.

Annex A
(normative)

Specification of test fluid for oil filter test[1)]

A.1 Petroleum base stock

The petroleum base stock shall have the following properties.

— pour point: −59,4 °C (minimum)

— flash point: 93,3 °C (minimum)

— acid or base number: 0,10 mg KOH/g(maximum)

— precipitation number: 0

A.2 Additives

The test fluid shall contain the following additive materials.

— viscosity-temperature coefficient improver: 10 % (maximum)

— oxidation inhibitors: 2 % (maximum)

— tricresyl phophate anti-wear agent: 0,5 % ± 0,1 %

The free phenol content of the tricresyl phosphate anti-wear agent should not exceed 0,05 %.

A.3 Properties

The test fluid shall have the following properties.

— viscosity at 40 °C: 13,2 mm^2/s (minimum)

— viscosity at −40 °C: 500 mm^2/s (minimum)

— pour point: −59,4 °C (minimum)

— flash point: 93,3 °C (minimum)

— precipitation number: 0

— acid or base number: 0,2 mg KOH/g (maximum)

NOTE 1 mm^2/s = 1 cSt.

A.4 Colour

The test fluid shall be clear and transparent. For identification, it shall contain a red dye in a proportion not greater than one part of dye per 10 000 parts of oil.

1) Suitable test fluids are aircraft hydraulic oils MIL-H-5606 and AIR 3520.

Annex B
(informative)

Typical filter test report

Typical test report sheets are illustrated in Tables B.1 and B.2. The test report should include the following additional information presented in graphical form:

a) a graph of differential pressure with respect to time and mass of contaminant added, as illustrated in Figure B.1;

b) a graph of overall efficiency with respect to particle size, as illustrated in Figure B.2.

If required by the purchaser, the manufacturer should also include a graph of overall efficiency with respect to particle size (semi-logarithmic presentation), as illustrated in Figure B.3.

Table B.1 — Test report sheet

TEST IDENTIFICATION

TEST DATE:	TEST LOCATION:	TEST ID:
TEST TIME:	OPERATOR:	PROJECT:

FILTER IDENTIFICATION

FILTER ID:	BYPASS VALVE		FABRICATION INTEGRITY: (hPa)
HOUSING TYPE:	OPERATIVE:	YES/NO	DATE OF MANUFACTURE

OPERATING CONDITIONS

TEST FLUID	Type :		Viscosity:	(mm^2/s)
	Initial Conductivity:	(pS/m)	Temperature:	(°C)
	Final conductivity:	(pS/m)		
TEST DUST	Type:		Batch no:	
INJECTION SYSTEM	Dust added W:	(g)	Injection grav. initial:	(mg/l)
	Volume V_i:	(l)	Injection grav. final:	(mg/l)
	Injection flowrate Q_{ia}:	(ml/min)	Injection grav. average G_{ia}:	(mg/l)
TEST SYSTEM:	Flowrate Q:	(l/min)	Initial cleanliness:	(#>10 µm/ml)
	Volume:	(l)	Base gravimetric level G_a:	(mg/l)
	Final volume V_f:	(l)	Final gravimetric level G_f:	(mg/l)
DILUTION SYSTEM	Sensor type:		Sample time:	(s)
	Flowrate:	(ml/min)	Hold time:	(s)
			Sampling time:	(min)
	Upstream dilution ratio:		Number of counts to average:	
	Downstream dilution ratio:		Total counts:	

TEST RESULTS

DIFFERENTIAL PRESSURE	CLEAN ASSY ΔP_1: (kPa) HOUSING ΔP_3: (kPa)			CLEAN ELEMENT ΔP_2: (kPa) FINAL NET ΔP_5: (kPa)			
% NET ΔP	5	10	15	20	40	80	100
ASSY ΔP (kPa)							
TEST TIME (min)							

OVERALL FILTRATION EFFICIENCY

Particle size	>5 µm	>6 µm	>7 µm	>8 µm	>9 µm	>10 µm	>11 µm	>13 µm
Max. Eff. (%)								
Min. Eff. (%)								
Overall Eff. (%)								
Particle size	>15 µm	>17 µm	>20 µm	>25 µm	>30 µm	>35 µm	>40 µm	>50 µm

Max. Eff. (%)								
Min. Eff. (%)								
Overall Eff. (%)								

Efficiency (%)	50	75	90	97,8[1)]	99[1)]
Micrometer rating (µm):					
[1)] Optional, and only in the case of high efficiency filters					

Injected mass M_I : (g)	Non retained mass M_{nr}: (g)	Retained capacity C_r: (g)

Table B.2 — Presentation of test results

TEST DATE:	TEST LOCATION:	TEST ID:
TEST TIME:	OPERATOR:	PROJECT:

FILTRATION EFFICIENCY - ELAPSED TIME: (MIN) - DIFF. PRESSURE: (kPa)								
Particle size	>5 µm	>6 µm	>7 µm	>8 µm	>9 µm	>10 µm	>11 µm	>13 µm
UPSTREAM								
DOWNSTREAM								
EFFICIENCY %								
Particle size	>15 µm	>17 µm	>20 µm	>25 µm	>30 µm	>35 µm	>40 µm	>50 µm
UPSTREAM								
DOWNSTREAM								
EFFICIENCY %								

FILTRATION EFFICIENCY - ELAPSED TIME: (MIN) - DIFF. PRESSURE: (kPa)								
Particle size	>5 µm	>6 µm	>7 µm	>8 µm	>9 µm	>10 µm	>11 µm	>13 µm
UPSTREAM								
DOWNSTREAM								
EFFICIENCY %								
Particle size	>15 µm	>17 µm	>20 µm	>25 µm	>30 µm	>35 µm	>40 µm	>50 µm
UPSTREAM								
DOWNSTREAM								
EFFICIENCY %								

FILTRATION EFFICIENCY - ELAPSED TIME: (MIN) - DIFF. PRESSURE: (kPa)								
Particle size	>5 µm	>6 µm	>7 µm	>8 µm	>9 µm	>10 µm	>11 µm	>13 µm
UPSTREAM								
DOWNSTREAM								
EFFICIENCY %								
Particle size	>15 µm	>17 µm	>20 µm	>25 µm	>30 µm	>35 µm	>40 µm	>50 µm
UPSTREAM								
DOWNSTREAM								
EFFICIENCY %								

FILTRATION EFFICIENCY - ELAPSED TIME: (MIN) - DIFF. PRESSURE: (kPa)								
Particle size	>5 µm	>6 µm	>7 µm	>8 µm	>9 µm	>10 µm	>11 µm	>13 µm
UPSTREAM								
DOWNSTREAM								
EFFICIENCY %								
Particle size	>15 µm	>17 µm	>20 µm	>25 µm	>30 µm	>35 µm	>40 µm	>50 µm
UPSTREAM								
DOWNSTREAM								
EFFICIENCY %								

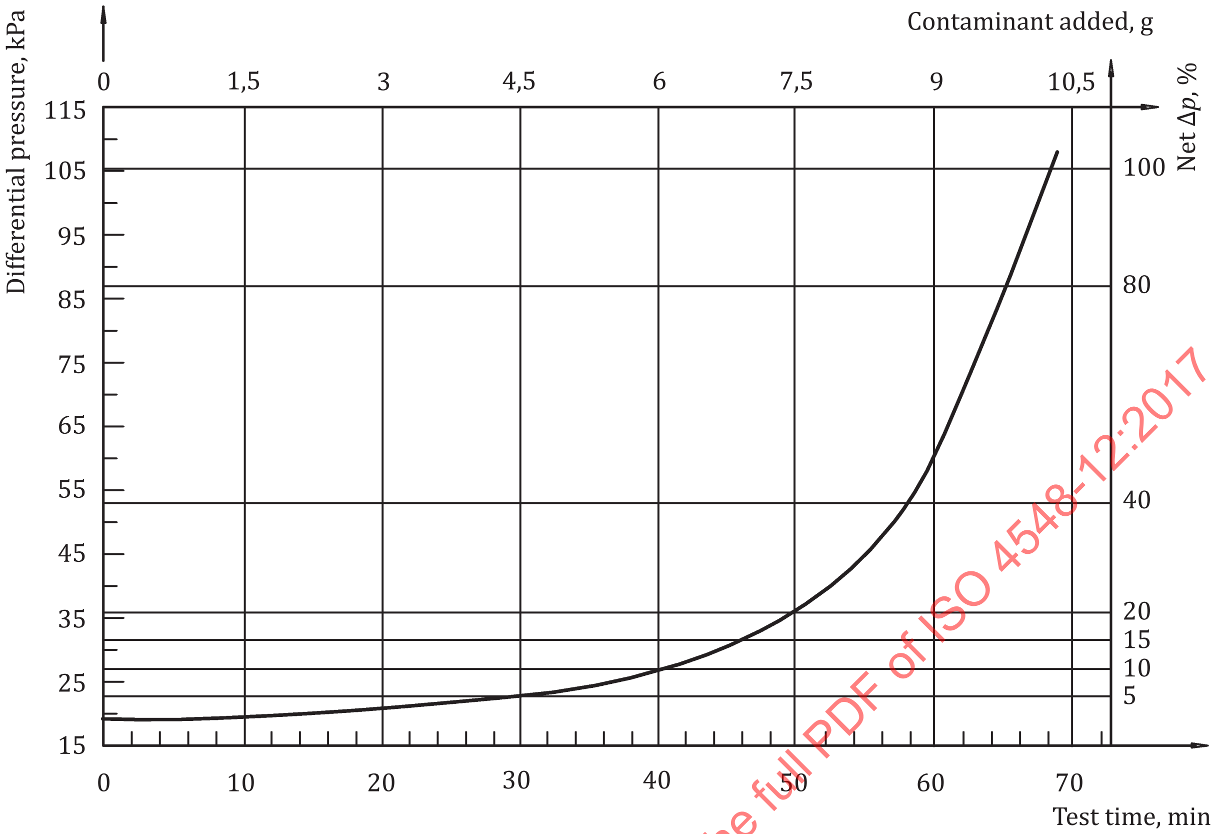


Figure B.1 — Graph of differential pressure vs. test time

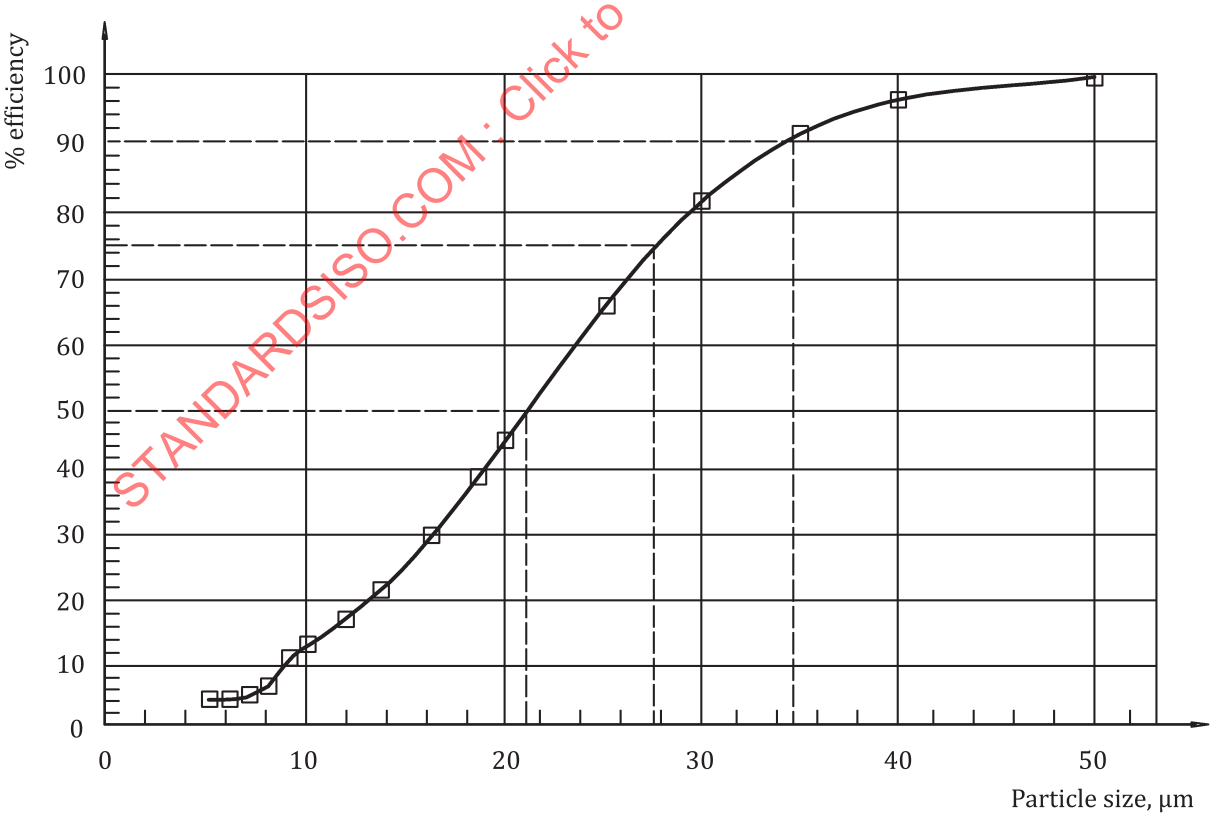


Figure B.2 — Graph of overall efficiency vs. particle size

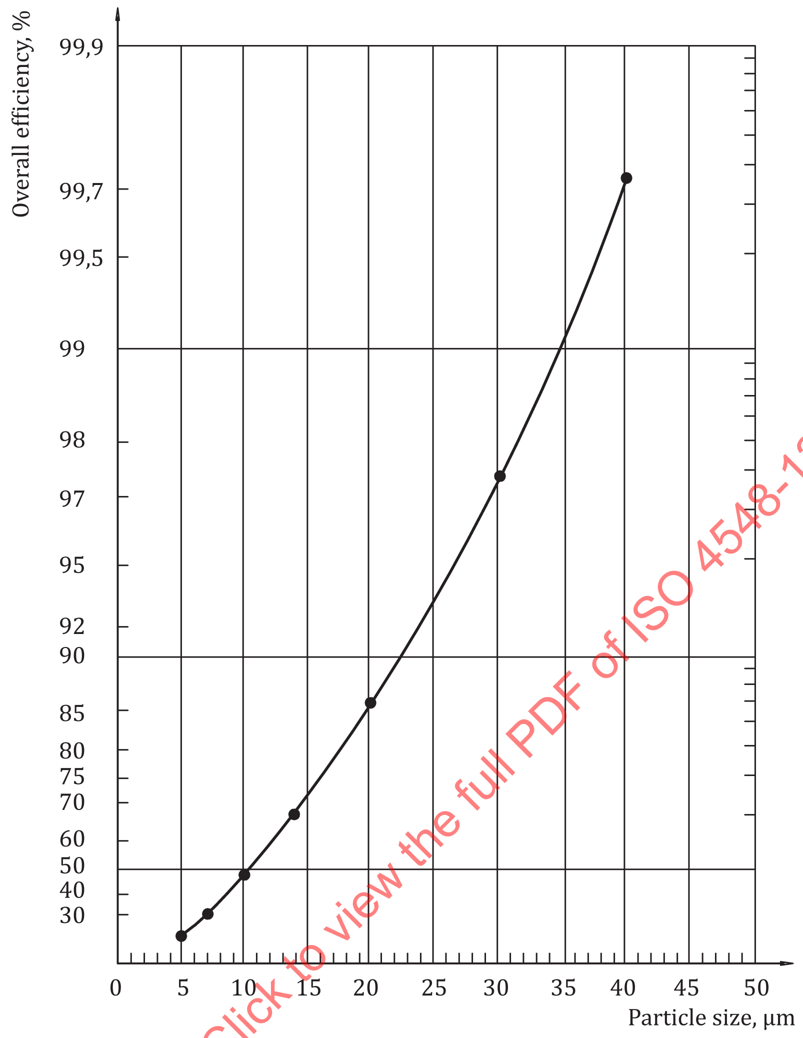


Figure B.3 — Graph of overall efficiency versus particle size (semi-logarithmic presentation)

Annex C
(normative)

Filter efficiency calculations

C.1 General conditions

For the purpose of this example, it is assumed that particles were counted at 1 min intervals, upstream and downstream, in 16 channels, during a test time of 86 min. These example calculations relate to one channel in which the particle size was >20 µm and the readings taken at 1 min intervals were as shown in Table C.1.

Table C.1 — Particle counter readings in one channel

TIME INTERVAL (MIN)	PARTICLE COUNT		TIME INTERVAL (MIN)	PARTICLE COUNT	
	UPSTREAM	DOWNSTREAM		UPSTREAM	DOWNSTREAM
1	14,4	1,0	16	209,6	77,0
2	171,4	35,3	17	217,8	73,1
3	191,7	53,8	18	193,3	68,9
4	163,7	47,3	19	204,2	84,3
5	190,9	51,5	20	224,4	85,5
6	182,8	54,9	—	—	—
7	165,2	41,8	—	—	—
8	191,5	66,7	—	—	—
9	186,4	57,5	80	382,6	207,8
10	218,4	49,4	81	350,9	198,2
11	190,7	54,9	82	347,7	208,3
12	174,8	59,1	83	308,3	165,2
13	210,6	55,0	84	309,0	157,7
14	242,3	66,9	85	297,5	162,0
15	188,0	82,8	86	295,7	147,4

NOTE The readings taken at time intervals 21 min to 79 min have been omitted from the table since they are not relevant to the example calculations.

C.2 Calculation of filter intermediate efficiencies

Intermediate efficiencies are calculated from the average particle counts, upstream and downstream, at either of the following time intervals:

a) 5 min if the duration of the test did not exceed 1 h;

b) 10 min if the duration of the test exceeded 1 h.

In the present example, the duration of the test was 86 min. Therefore, the intermediate efficiencies are calculated for each 10 min interval.

C.2.1 First 10 min interval

In order to eliminate potentially erroneous particle counts obtained prior to stabilization of the system, the first three minutes of the test are disregarded.

The intermediate efficiency of the filter at the 10 min interval (E_{10}) is calculated using Formula (C.1):

$$E_{10} = \frac{C_{u10} - C_{d10}}{C_{u10}} \times 100 \tag{C.1}$$

where

C_{U10} is the average of the upstream counts taken at the 4 min to 10 min intervals

$$\text{(i.e. } \frac{163,7 + 190,9 + \ldots\ldots\ldots\ldots + 218,4}{7} = 185,56) ;$$

C_{d10} is the average of the downstream counts taken at the 4 min to 10 min intervals

$$\text{(i.e. } \frac{47,3 + 51,5 + \ldots\ldots\ldots\ldots + 49,4}{7} = 52,73) ;$$

therefore,

$$E_{10} = \frac{185,56 - 52,73}{185,56} \times 100 = 71,58\ \%.$$

C.2.2 Subsequent 10 min intervals

The intermediate efficiency is calculated for each of the subsequent 10 min intervals in accordance with Formula (C.2) as an example (E_{20}) which corresponds to the 20 min interval:

$$E_{20} = \frac{C_{u20} - C_{d20}}{C_{u20}} \times 100 \tag{C.2}$$

where

C_{u20} is the average of the upstream counts taken at the 11 min to 20 min intervals

$$\text{(i.e. } \frac{190,7 + 174,8 + \ldots\ldots\ldots\ldots + 224,4}{10} = 205,57) ;$$

C_{d20} is the average of the downstream counts taken at the 11 min to 20 min intervals

$$\text{(i.e. } \frac{54,9 + 59,1 + \ldots\ldots\ldots\ldots + 85,5}{10} = 70,75) ;$$

therefore,

$$E_{20} = \frac{205,57 - 70,75}{205,57} \times 100 = 65,58\ \%.$$

C.2.3 Final interval

The intermediate efficiency for the final interval of 6 min (i.e. period 81 min to 86 min) is calculated using Formula (C.3):

$$E_{86} = \frac{C_{u86} - C_{d86}}{C_{u86}} \times 100 \qquad (C.3)$$

where

C_{u86} is the average of the upstream counts taken at the 81 min to 86 intervals

(i.e. $\frac{350,9 + 347,7 + \ldots\ldots\ldots\ldots + 295,7}{6} = 318,18$);

C_{d86} is the average of the downstream counts taken at the 81 min to 86 min intervals

(i.e. $\frac{198,2 + 208,3 + \ldots\ldots\ldots\ldots + 147,4}{6} = 173,13$);

therefore,

$$E_{86} = \frac{318,18 - 173,13}{318,18} \times 100 = 45,59\ \%.$$

C.3 Calculation of filter overall efficiencies

The overall efficiency of the filter at the >20 µm(c) particle size, selected for this example, is calculated using Formula (C.4):

$$E_{o20} = \frac{C_{uo20} - C_{do20}}{C_{uo20}} \times 100 \qquad (C.4)$$

where

C_{uo20} is the average of the upstream counts taken at the 1 min intervals from 4 min to 86 min

(i.e. $\frac{163,7 + 190,9 + \ldots\ldots\ldots\ldots + 295,7}{83} = 287,35$);

C_{do20} is the average of the downstream counts taken at the 1 min intervals from 4 min to 86 min

(i.e. $\frac{47,3 + 51,5 + \ldots\ldots\ldots\ldots + 147,4}{83} = 142,5$);

therefore;

$$E_{o20} = \frac{287,35 - 142,5}{287,35} \times 100 = 50,41\ \%.$$

Annex D
(informative)

Round robin exercise

D.1 General

There is a need to quantify the uncertainties relative to the determination of the filtration efficiency and the retention capacity of a lubricating oil filters according to this document.

A round robin exercise has been performed among four laboratories to quantify the repeatability and the reproducibility of the procedure of this document by measuring the overall efficiency (Figure D.1) and retention capacity (Figure D.2) of a typical oil filter.

D.2 Test conditions

— Flow rate: 25 l/min;

— Test dust: ISO MTD specified according to ISO 12103-1, A.3;

— Final differential pressure = Initial differential pressure +100 kPa;

— Online particle counting and online dilution calibrated as per ISO 11171 and ISO 11943 [particle size expressed in µm (c)];

— Base upstream gravimetric level (bugl) = 10 mg/l.

D.3 Test results

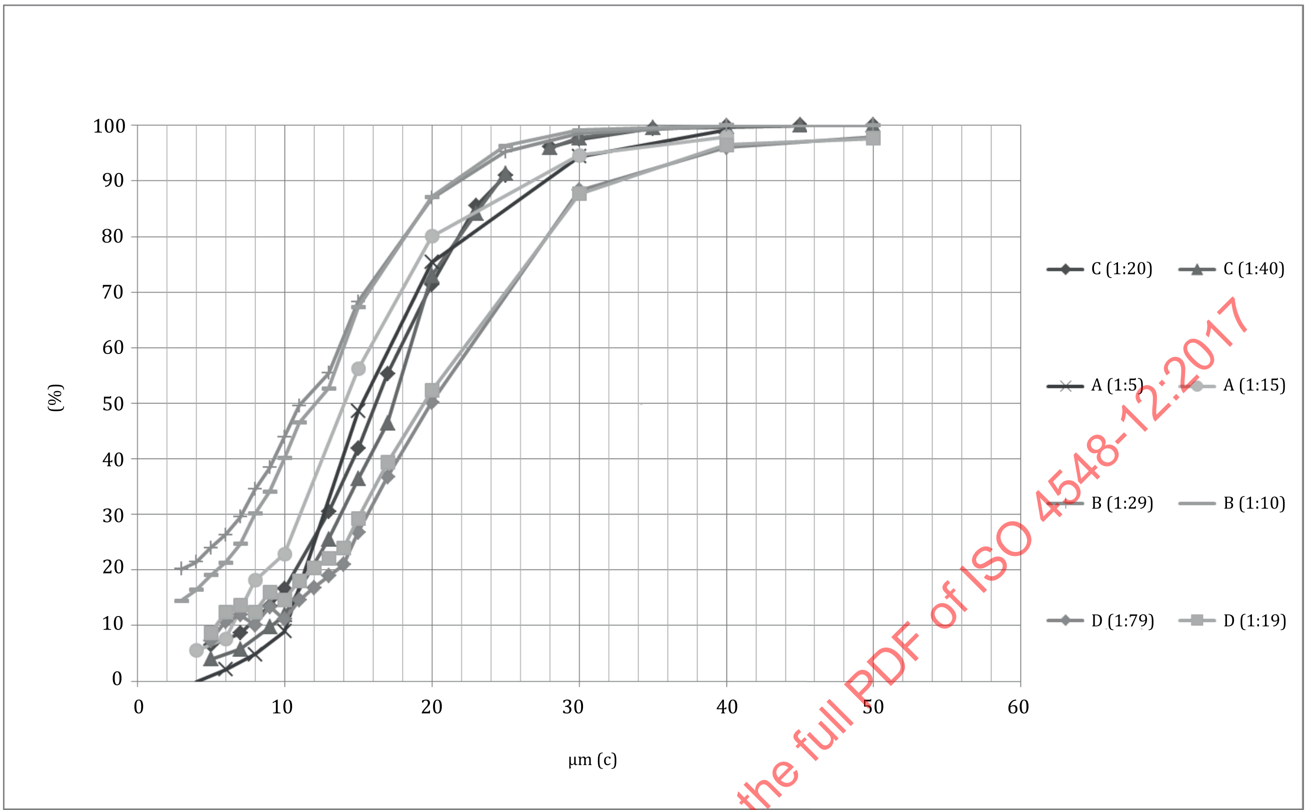


Figure D.1 — Filtration efficiency of a typical oil filter (using different ISO MTD batches and different dilution ratio)