
Determination of the filtration efficiency of urea filter modules

Détermination de l'efficacité de filtration des modules de filtres à urée

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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 document 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).

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

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 34, *Propulsion, powertrain and powertrain fluids*.

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

Determination of the filtration efficiency of urea filter modules

1 Scope

This document specifies requirements relating to the testing method for AUS 32/diesel exhaust fluid (DEF) filters for the removal of suspended matter. This applies to urea filters dedicated to passenger vehicles as well as to commercial vehicles. This method applies to filters with flow rates from 3 l/h to 30 l/h depending on the application (by default 5 l/h for passenger vehicles and 25 l/h for commercial vehicles). This method can be used for other flow rates, provided the validation requirement can be met.

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 11218, *Aerospace — Cleanliness classification for hydraulic fluids*

ISO 11923, *Water quality — Determination of suspended solids by filtration through glass-fibre filters*

ISO 21501-3, *Determination of particle size distribution — Single particle light interaction methods — Part 3: Light extinction liquid-borne particle counter*

3 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

cumulative overall mean filtration efficiency

E_x

cumulative efficiency calculated from the total number of particles greater than size x [μm] counted upstream and downstream of a filter during the initial 60 min counting period at 5 mg/l

Note 1 to entry: The efficiency is expressed in [%].

3.2

differential pressure

ΔP

pressure difference between the inlet and outlet of the complete filter unit measured under predetermined conditions

Note 1 to entry: The differential pressure generated by the complete filter is equal to the sum of the differential pressures generated by the housing and by the filter element (in case the filter element is removable from the housing).

Note 2 to entry: The differential pressure is expressed in kPa.

3.3

ISO MTD

ISO medium test dust

siliceous test powder having a particle size distribution by volume in accordance with ISO 12103-1, A3

Note 1 to entry: It may also be referred as ISO 12103-1 A3 dust.

3.4

nominal flow rate

Q

flow rate for the filter specified by the manufacturer

Note 1 to entry: The flow rate is expressed in l/h.

3.5

reference filtration rating

S

dimension of the ISO MTD particles at which the overall mean cumulative filtration efficiency of the integral filter (or the filter element) tested in accordance with the procedure described in this document, is greater than or equal to 99 %

Note 1 to entry: The reference filtration rating is expressed in μm .

4 Symbols

The symbols used in this document are given in [Table 1](#).

Table 1 — Symbols

Symbol	Parameter	Unit
C_e	Test concentration	mg/l
C_i	Injection concentration	mg/l
C_R	Retention capacity	g
C_{NR}	Concentration of the downstream fluid during the clogging period	mg/l
C_{ov}	Coefficient of variation	%
d	Size of the particle	μm
ΔP_0	Loss of pressure due to the clean filter alone	kPa
ΔP_F	Loss of pressure at the end of the test	kPa
E_x	Cumulative efficiency at size greater than $x \mu\text{m}$	%
M	Mass of contaminant necessary for the test	g
M_{i1}	Injected mass of contaminant in injection reservoir 1	g
M_{i2}	Injected mass of contaminant in injection reservoir 2	g
$N_{iUP} > x \mu\text{m}$	i^{th} particle count upstream at size $>x \mu\text{m}$	-/ml
$N_{iDW} > x \mu\text{m}$	i^{th} particle count downstream at size $>x \mu\text{m}$	-/ml
Q	Flow rate	l/h
Q_r	Recirculation flow rate	l/h
Q_{C1}	Injection flow rate circuit 1 (relative to the efficiency concentration)	l/h
Q_{C2}	Injection flow rate circuit 2 (relative to the capacity concentration)	l/h
S_{sc}	Suspended solid concentration	mg/l
V_{i1}	Injection circuit N°1 fluid volume	l

Table 1 (continued)

Symbol	Parameter	Unit
V_{i2}	Injection circuit N°2 fluid volume	l
V_{iM}	Injection circuit maximum fluid volume	l
V_{CP}	Recovered downstream volume during the clogging period	l
V_{CPV}	Recovered downstream volume during the validation of the clogging period	l
ΔT_{CP}	Time duration of the clogging period	h

5 Test procedures

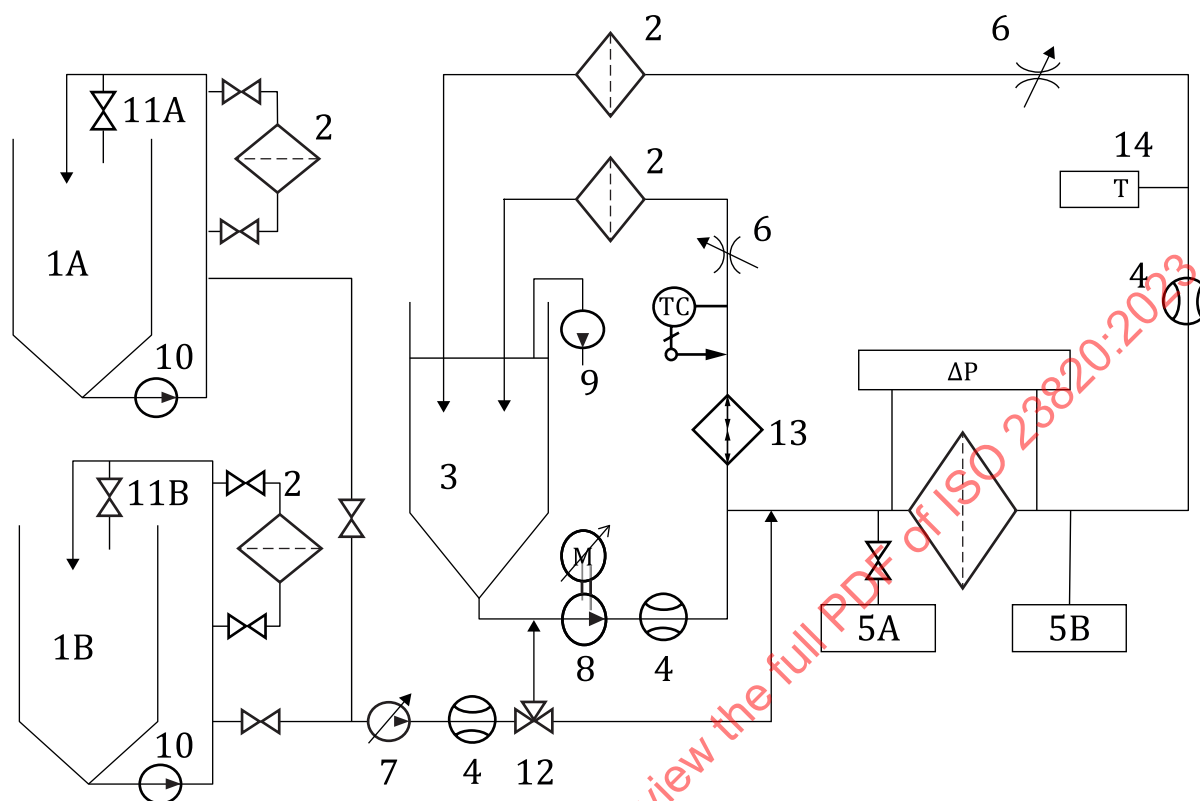
5.1 Principle

The performance of the filter to be tested is determined by measuring its hydraulic and separative properties when subjected to a constant flow rate of water conveying a known quantity of contaminant. The test is performed with the water after passage through clean-up filters to produce a single pass configuration. The test is conducted in two stages.

The first stage determines the initial efficiency of the test filter. It is conducted with a contaminant concentration of 5 mg/l upstream to the test filter for 60 min. The second stage determines the mass of contaminant needed to reach a specified differential pressure. This stage is conducted with an upstream concentration of 800 mg/l, or as specified according to the customer specification. The retention capacity shall be determined from the mass of contaminant required for obtaining a predetermined differential pressure of 10 kPa or other value according to customer's specifications. Several operating parameters are specified as a function of the type of filter under test, e.g. the standard flow rate of 5 l/h is recommended for testing a standard urea filter module for passenger vehicles and 25 l/h for commercial vehicles, unless otherwise specified.

5.2 Test equipment and materials

5.2.1 Test rig



Key

1A	injection reservoir for efficiency period at 5 mg/l (N°1)	8	main recirculation pump
1B	injection reservoir for clogging period at maximum 800 mg/l (N°2)	9	regulating level volume system
2	clean up filter	10	recirculation injection loop pump
3	main reservoir (6 l)	11A	injection circuit (N°1) sampling valve
4	flow meter	11B	injection circuit (N°2) sampling valve
5A	upstream side particle counter	12	three-way valves
5B	downstream side particle counter	13	heat exchanger
6	counter pressure control valve	14	temperature sensor
7	injection pump		

Figure 1 — Diagram of filtration efficiency and retention capacity test rig

5.2.2 Filter test circuit

The filter test circuit is designed to permit the recycling of the fluid being filtered. Both return line and recirculation loops are equipped with clean-up filters which retain all of the test particles that have passed through the test filter or before going back to the main reservoir (a filtration efficiency of 99 % at 1 µm is suitable for such clean up filters). In case of multiple usage of the test liquid, the risk of biological growth is given. Suitable control and countermeasures shall be implemented.

The test circuit comprises the following:

- a conical bottom reservoir having a recommended cone angle less than or equal to 90°. Its volume is of 6 l. The residence time inside the reservoir shall be of 30 s and the height shall be preferably

between twice and three times its diameter. Other type reservoir with other volumes can be used if requirements of 5.3.1.2 are fulfilled. The recycled water return line penetrates beneath the free face so as to avoid the risk of air entrainment;

- b) a main circulation pump which ensures a constant, non-pulsed flow rate Q_r of at least twice the volume unit (when expressed in l/min) (i.e. at least 12 l/min or 720 l/h) throughout the test duration, particularly when the filter is clogged. It shall be resistant to the test contaminant by not modifying the particle size distribution;
- c) a bypass circuit from the main recirculation loop allowing to circulate through the urea filter under test in a single pass way;
- d) two clean-up filters dedicated to the main recirculation loop and the bypass filter test loop to restore the level of the test fluid's particulate contamination at less than 10 particles/ml $>5 \mu\text{m}$;
- e) instruments for measuring the flow rate, the temperature, the differential pressures at the filter connections;
- f) two sampling devices in accordance with ISO 4021 put upstream and downstream of the filter in order to ensure representative sampling of the water and contaminant and connected to automatic particle counting devices (see 5.2.4);
- g) interconnecting pipe and fittings, dimensioned and selected so as to ensure a turbulent flow throughout the whole circuit, thereby preventing the formation of traps, segregation and quiescent zones. The length of the piping shall be reduced to the minimum;
- h) clean water level control device in the test reservoir to regulate the level within 5 %;
- i) temperature regulator to control the temperature at the specified value of $(23 \pm 2) ^\circ\text{C}$;
- j) all the pipes, connections, reservoirs shall be 316L INOX with the best polishing procedure available to avoid the abrasive mix of sand and water.

5.2.3 Contaminant injection circuits

There are two injection circuits: one is allocated to 5 mg/l injection (injection circuit N° 1), the other one to 800 mg/l injection (injection circuit N° 2).

Each injection circuit includes the following equipment:

- a) conical bottom reservoir having a recommended cone angle less than or equal to 90° . Its height is preferably between twice or three times its diameter. Other configured reservoir can be used if requirements of 5.3.1.1 are fulfilled. It is equipped with a level indicator. The recycled water returns beneath the free face;
- b) recirculation pump which generates a flow rate to ensure sufficient mixing to meet the requirements in 5.3. It shall be resistant to the test contaminant by not modifying the particle size distribution;
- c) temperature regulation device to control the water temperature at $23 \pm 2 ^\circ\text{C}$;
- d) clean-up filter, installed to by-pass the injection loop, capable of achieving a cleanliness level at less than 40 particles/ml $>5 \mu\text{m}$;
- e) contaminant injection pump which draws the concentrated contaminant into the recirculation system at a point where the flow is turbulent and discharges it via a flexible pipe into the main pump suction in case of injection circuit N°1 or upstream to the urea filter in case of injection circuit N°2. There is a three-way valve to switch from injection circuit N°1 to injection circuit N°2. It shall not generate any excessive flow rate pulsation and shall have no effect on the contaminant. The injection flow rate shall be sufficient to prevent segregation of the test dust;
- f) sampling device conforming to ISO 4021;

- g) device for measuring the injection flow rate, insensitive to the contaminant and without effect on its particle size distribution at the concentrations scheduled for the test.

5.2.4 Automatic particle counting devices

These devices comprise one or two counters and two optical units.

These devices operate on the light extinction principle; they shall be properly calibrated using certified monosized latex spheres as per ISO 21501-3.

Ensure the concentration level of the particle sensors is capable of operating in the required system concentration levels.

5.2.5 Test fluid

The test fluid shall be demineralized and filtered water with a cleanliness level of less than 10 particles /ml >5 μm .

NOTE Using demineralized water will prevent a chemical reaction of the silica inside the injection and test circuits.

5.2.6 Test contaminant

The test contaminant shall be silica test dust specified as ISO MTD.

5.2.7 Stop watch

5.2.8 Ultra clean bottles

Use thoroughly cleaned sample bottles when filled with micro-filtered water. The cleanliness level of the bottle shall be CSC (0) as per ISO 11218.

5.2.9 Ultra-sonic bath

The characteristics should be the following one: power of 25 W/l with an ultra-sonic frequency varying between 30 and 40 kHz.

5.3 Test rig validation

5.3.1 General

The purpose of the validation is to demonstrate that the test rig complies with the test requirements. The validation shall be carried out again whenever a component of the installation is modified or changed.

5.3.1.1 Validation of the injection circuits

The two injection circuits for attaining test concentrations of 5 mg/l and 800 mg/l shall be successively validated.

The validation is conducted with the maximum volume (V_{IM}) in each tank and at the minimum flow rates for the injection circuits. Before starting, make sure that both injection reservoirs N°1 and N°2 are clean enough (initial cleanliness level of less than 40 particles /ml >5 μm).

- a) Calculate the two injection circuit contamination concentrations so that the concentration in the test circuit.

$C_e = 5 \text{ mg/l}$ (injection circuit N° 1) or $C_e = 800 \text{ mg/l}$ (injection circuit N° 2):

$$C_i = \frac{QC_e}{Q_i} \quad (1)$$

where

Q is the flow rate expressed in l/h:

— (circulation loop flowrate Q_r of 720 l/h (or either) in case of injection circuit N°1);

or

— (urea/DEF filter test flowrate Q in case of injection circuit N°2);

Q_i is the minimum value of the injection flow rate, in l/h;

C_i is the injection circuit contaminant concentration, in mg/l.

- b) Prepare a mass M of test dust ISO MTD, previously dried at a temperature between 110 °C to 150 °C for at least 1 h and cooled to room temperature in a desiccator, to obtain the previously calculated concentration C_i :

$$M = V_{iM} C_i \quad (2)$$

where

M is the mass of test dust, in mg;

V_{iM} is the injection circuit maximum fluid volume, in l;

C_i is the injection circuit contaminant concentration, in mg/l.

- c) Disperse the contaminant in 200 ml of water taken from the injection reservoir ensuring complete homogenization (e.g. by using ultra sonics and then mixing with a non-magnetic stirrer).
- d) Introduce the fluid volume into the injection reservoir, start the recirculation pump (see [Figure 1](#), key 10), introduce the test contaminant prepared in b) and c) above, and allow to circulate for at least 15 min.
- e) Set the injection flow rate at the minimum Q_i value, continuously controlling the value displayed by the flow rate meter and the height of the fluid in the injection reservoir. Start the injection into the test reservoir.

NOTE It is preferable to inject the contaminant by means of a flexible pipe in order to facilitate the sampling operations at the injection point.

- f) Every 30 min, during a 6 h period, take a 200 ml sample via sampling valve (see [Figure 1](#), key 11A or 11B) and at the injection point in the main circuit. Determine the suspended solids concentration in accordance with ISO 11923.
- g) The injection circuit is validated if the following conditions are satisfied:
- the injection flow recorded values does not differ by more than 5 % in terms of coefficient of variation (see definition in [5.3.1.2 h](#) 1);
 - suspended solids for each of the injection concentrations do not differ by more than 5 % of the average measured concentration;
 - real average measured concentration does not differ by more than 10 % of the theoretical concentration.

5.3.1.2 Validation of the test circuit

- a) Adjust the volume of the fluid V_F in the main circuit to 6 l or the volume depending of reservoir configuration.
- b) After fitting a tubular sleeve in place of the filter to be tested, set up the temperature regulation system and the main recirculation pump adjusting the recirculation flow rate Q_r to 720 l/h.

Operate until the conditions have stabilized and, if necessary, readjust the fluid volume in the circuit at 6 l.

- c) To the upstream and downstream sample valves (see [Figure 1](#), keys 5A and 5B), connect on-line automatic counters previously calibrated, regulate the flow rate through the sensors to the values recommended by the manufacturer of the automatic counters.
- d) Introduce into the reservoir of each injection circuit, mass M_{i1} and M_{i2} of contaminant, previously oven-dried and desiccated, to obtain the theoretical test concentrations of $C_e = 5$ mg/l and $C_e = 800$ mg/l, respectively.
- e) Start the validation with a 1 h phase at the test concentration $C_e = 5$ mg/l during which in-line counts are carried out, via upstream and downstream sample valves (see [Figure 1](#), keys 5A and 5B), for 30 s every minute, at the thresholds selected in [Table 2](#).
- f) Close the upstream sampling valve (see [Figure 1](#), key 5A).
- g) The downstream sensor having been previously disconnected, follow this by a 6 h phase with a concentration $C_e = 800$ mg/l. Collect the entire volume V_{CPV} which has run off via downstream sampling valve (see [Figure 1](#), key 5B) at the nominal counting flow rate and determine its suspended solids concentration (S_{SC}) in accordance with ISO 11923.
- h) The test circuit is validated if the following four conditions are satisfied:
 - 1) The coefficient of variation C_{OV} [%] for each sensor during the phase e) of this clause is less than or equal to that given in [Table 2](#). The coefficient of variation is calculated as per [Formula \(3\)](#):

$$C_{OV} = \frac{\sigma}{\bar{x}} \times 100, \quad (3)$$

$$\sigma = \sqrt{\frac{n \sum_{i=1}^n (x_i^2) - \left(\sum_{i=1}^n x_i \right)^2}{n(n-1)}} \quad (4)$$

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n} \quad (5)$$

NOTE C_{OV} is expressed as a percentage [%].

Table 2 — Percentage of variation in the number of particles per counter

Thresholds [μm]	$d > 5$	$d > 10$	$d > 15$	$d > 25$	$d > 40$
ISO MTD [%]	5	7	10	32	55

- 2) The percentage difference at different thresholds in the counting results between the two sensors during the phase e) is less than or equal to that given in [Table 3](#).

Table 3 — Percentage difference in the number of particles between two counters

Thresholds [μm]	> 5	> 7	> 10	> 12	> 15	> 20	> 30	> 40
Difference [%]	5,1	5,3	5,6	5,6	6,3	7	10	10

If the conditions of [Table 3](#) are not met, repeat the phase e) and adjust the downstream sensor **only** in order to reduce the variation at the corresponding sizes.

- 3) The mass of contaminant collected during the phase g) at downstream sampling valve (see [Figure 1](#), key 5B) does not deviate by more than 30 % from the injected masses.

This mass of contaminant is calculated by multiplying the collected volume V and the corresponding suspended solids concentration S_{sc} as per [Formula \(6\)](#):

$$m = V \times S_{sc} \quad (6)$$

- 4) The particle size distribution of ISO MTD obtained at e) should comply with the [Table 4](#).

Table 4 — Particle size distribution of ISO MTD (informative data)

Size [> μm]	Cumulative counts in 1 ml of solution of ISO MTD at 1 mg/l
5	725 +/- 160
6	415 +/- 100
8	182 +/- 46
10	92 +/- 54
15	18,2 +/- 9
20	5,6 +/- 2,8

5.4 Procedure

5.4.1 Operating conditions

5.4.1.1 Fixed conditions

The following operating conditions shall be used:

- test flow rate: manufacturer's specified flow rate as defined on the product label; (it should include the upstream counting flowrate);
- test contaminant: ISO MTD;
- sampling method: during $C_e = 5$ mg/l phases both upstream (sampling valve see [Figure 1](#), key 5A) and downstream (sampling valve see [Figure 1](#), key 5B) of the filter; and during $C_e = 800$ mg/l (or other value) phases only downstream of the filter;
- counting method: on-line automatic particle counter using absorption of white light or laser beam calibrated as per ISO 21501-3 with monosized latex beads;
- level of initial cleanliness:
 - injection circuit: less than 40 particles /ml >5 μm;
 - main circuit: less than 10 particles /ml >5 μm;

- f) duration of phases:
- 1) counting phase ($C_e = 5 \text{ mg/l}$): 1 h;
 - 2) clogging phase ($C_e = 800 \text{ mg/l}$ or other agreed concentration): 6 h;
- g) end of test: final differential pressure of 10 kPa or another agreed final differential pressure.

5.4.2 Preparation of the contaminant injection circuits

5.4.2.1 Calculation of the test conditions for injection circuit N° 1 (5 mg/l test concentration)

- a) Select the injection flow rate value (Q_{i1}) as a function of the sampling flow rates upstream and downstream of the filter under test and of a possible additional draw-off flow rate in order to guarantee the stability of the fluid volume in the main circuit throughout the test. The sampling flow rates are set to the flow rates required for the particle counters.
- b) Calculate the total volume V_{i1} in litres of fluid required for injecting the contaminant during the scheduled hour for the test, from the injection flow rate Q_{i1} [l/h] and with adding a safety margin of 20 %:

$$V_{i1} = 1,2 Q_{i1} \quad (7)$$

- c) Calculate the concentration C_{i1} [mg/l] of the contaminant in injection circuit N° 1:

$$C_{i1} = \frac{(C_e \times Q_r)}{Q_{i1}} \quad (8)$$

where $C_e = 5 \text{ mg/l}$ and Q_r (recirculation flow rate) = 720 l/h (by default).

- d) Calculate the quantity M_{i1} in grams of contaminant required to be introduced into the injection water in order to conform to the previously calculated test conditions, according to [Formula \(9\)](#):

$$M_{i1} = \frac{(C_{i1} \times V_{i1})}{1000} \quad (9)$$

5.4.2.2 Calculation of the test conditions for injection circuit N° 2 (800 mg/l test concentration or other concentration according with the customer)

- a) Select the injection flow rate value (Q_{i2}) as a function of the sampling flow rates downstream of the filter under test and of a possible additional draw-off flow rate in order to guarantee the stability of the fluid volume in the main circuit throughout the test. The sampling flow rates are set to the flow rates required for the particle counters.
- b) Calculate the total volume V_{i2} in litres of fluid required for injecting the contaminant during 6 h (at maximum scheduled) for the test, from the injection flow rate Q_{i1} [l/h] and with adding a safety margin of 20 %:

$$V_{i2} = 1,2 \times 6 \times Q_{i2} \quad (10)$$

- c) Calculate the concentration C_{i2} [mg/l] of the contaminant in injection circuit N° 2:

$$C_{i2} = \frac{C_e \times Q}{Q_{i2}} \quad (11)$$

where

C_e is the test concentration which is 800 (or other agreed concentration), in mg/l;

Q is the urea /DEF filter flowrate, in l/h.

- d) Calculate the quantity M_{i2} in grams of contaminant required to be introduced into the injection water in order to conform to the previously calculated test conditions, according to the following equation:

$$M_{i2} = \frac{(C_{i2} \times V_{i2})}{1000} \quad (12)$$

NOTE M_{i2} is expressed in grams.

5.4.2.3 Setting up injection circuits

- Fill up both the two injection reservoirs and start the two recirculation pumps.
- Set the injection flow rates at the values selected respectively in 5.4.2.1 a) and 5.4.2.2 a).
- Put the clean-up filters of the injection circuits (see Figure 1, key 2) into service and operate the systems during at least 30 min.
- By-pass the clean-up filters (see Figure 1, key 2).
- Accurately measure the fluid volumes (V_i) in the injection circuits and add to each reservoir the masse M_{i1} and M_{i2} of contaminant determined respectively in 5.4.2.1 d) and 5.4.2.2 d). This contaminant shall be dispersed in a small quantity of water taken from the injection circuit. Care should be taken to properly rinse the containers.

Special attention should be paid to the dispersion of the high concentration contaminant. It is recommended to pour the completely dehydrated test dust into a bottle with a screw-cap having a capacity of 80 times the bulk volume of the contaminant, then to introduce a volume of fluid equal to 50 times this same bulk volume. The bottle is immersed in an ultrasonic tank for 1 min, then placed for 10 min in a pigment and paint shaker.

- Operate the injection circuits for 10 min in order to homogenize the suspensions prior to starting to inject the contaminant into the test circuit.

5.4.3 Preparation of the test circuit

- Install a pipe instead of the filter into the main circuit.
- Adjust the volume of water in the circuit to 6 l.
- Start the circulation pump and the temperature regulation system. Set the recirculation flow rate Q_r at 720 l/h and the temperature at $(23 \pm 2) ^\circ\text{C}$ and set the flow rate through the pipe at the specified test flow rate.
- Circulate the water until the particulate contamination levels reach the values specified in 5.4.1.1 and remain stable for at least 15 min.
- Note the differential pressure ΔP across the pipe.

5.4.4 Filter efficiency and retention capacity test

- Install the filter into the main circuit.
- Circulate the water at the specified test flow rate Q (within $\pm 2 \%$) and control the temperature at $(23 \pm 2) ^\circ\text{C}$.

- c) Take at least one sample from each injection circuit and determine suspended solids concentration in accordance with ISO 11923.
- d) Set the particle counter thresholds at the values defined in [Table 5](#) (sizes given for information). Start the counters.

Table 5 — Particle thresholds (in μm and in a cumulative way)

> μm	5	7	10	12	15	20	30	40
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- e) Record the results obtained over a 5 min period in order to measure the initial cleanliness level.
- f) Measure the differential pressure (ΔP_0) across the clean filter.
- g) Begin the test by starting the stopwatch and the injection pump of circuit N° 1 to obtain an upstream concentration $C_e = 5 \text{ mg/l}$ (injection point directly into the recirculating loop upstream the main pump).
- h) Operate the sampling devices upstream and downstream of the filter and count the particles every minute for at least 30 s during 1 h. Collect all the 60 counts $N_{i,\text{up}, > x \mu\text{m}}$ and $N_{i,\text{dw}, > x \mu\text{m}}$ at the different particle threshold ($> x \mu\text{m}$), i varying from 1 to 60.
- i) Interrupt only the upstream counts by isolating the sensor with upstream sampling valve (see [Figure 1](#), key 5A) and stop inject from circuit N°1. Switch to injection circuit N°2 to obtain an upstream concentration $C_e = 800 \text{ mg/L}$ (or other agreed concentration). Switch with the three-way valves (see [Figure 1](#), key 12) the injection point from the recirculation loop directly upstream to the test filter.
- j) Collect all of the fluid from the downstream sensor and measure the total final volume collected V_{CP} .
- k) The test is continued until the initial differential pressure ΔP_0 of the filter increases by 10 kPa (or other agreed rise). Note the ΔP_F value. If, at the end of 6 h, this value is not reached, stop the test.
- l) Stop the test as follows:
 - note the end of test time (T_F) and the duration of the clogging period ΔT_{CP} ;
 - disconnect the particle counters;
 - stop the main circuit pump;
 - note the volume of both injection circuits and take at least one sample and determine suspended solids concentration C_{i1} and C_{i2} in accordance with ISO 11923;
 - stop the injection circuit pumps;
 - thoroughly mix the volume V_{CP} of fluid collected from the downstream sensor. Take a sample and determine suspended solids concentration C_{NR} in accordance with ISO 11923.

5.5 Expression of results

From the concentration value (C_{NR}) and the total circulated volume $Q\Delta T_{CP}$, calculate the mass of ISO MTD not retained. Determine the retention capacity (C_R) by subtracting the non-retained mass of ISO MTD ($Q\Delta T_{CP}\cdot C_{NR}$) from the total injected mass of ISO MTD as per the [Formula \(13\)](#):

$$C_R = \frac{Q_{i2} \cdot C_{i2} \cdot \Delta T_{CP} - Q \cdot \Delta T_{CP} \cdot C_{NR}}{1000} \quad (13)$$

Calculate from the cumulative mode particle counts the cumulative filtration efficiencies (without taking account the first three upstream and downstream particle counts) as per [Formula \(14\)](#):

$$E_x = \frac{\sum_4^{60} N_{i,up>x \mu m} + \sum_4^{60} N_{i,dw>x \mu m}}{\sum_4^{60} N_{i,up>x \mu m}} \times 100 \quad (14)$$

NOTE E_x is expressed as a percentage [%].

Graphically determine the reference filtration rating (S) at 99 % of filtration efficiency as per [Figure 2](#).

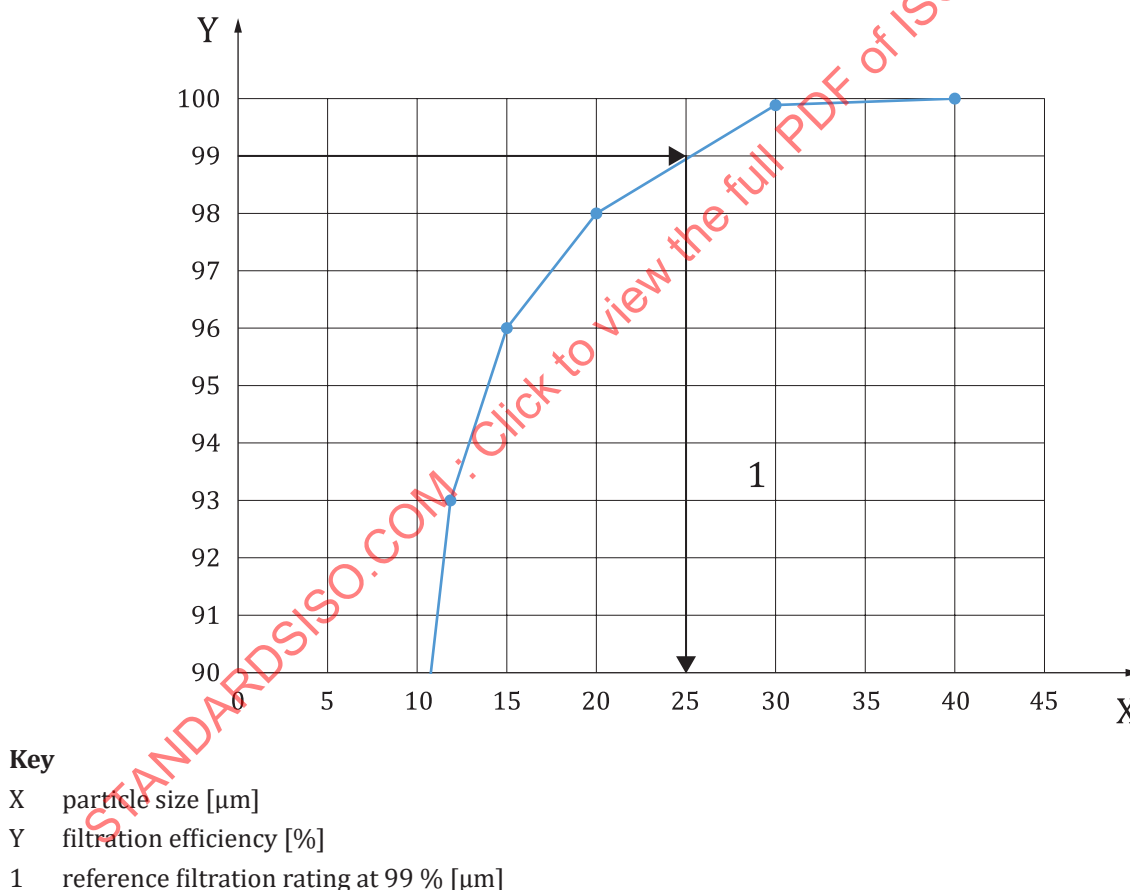


Figure 2 — Graphical representation of the filtration efficiency and determination of the reference filtration rating (informative data)

5.6 Test report

In addition to the reference to this document, the test report shall give the following information:

- a) name of test laboratory;
- b) operator's name;

- c) test date;
- d) filter identification;
- e) batch number of the test dust;
- f) specified reference filtration rating;
- g) test fluid;
- h) test temperature;
- i) test flow rate;
- j) test circuit volume;
- k) test concentration;
- l) initial cleanliness level of the system upstream and downstream;
- m) end of test or final differential pressure;
- n) type and reference of the sensors and particle counters;
- o) injected mass;
- p) total non-retained mass;
- q) retention capacity: C_R in g;
- r) curves and tables of the cumulated and differential, upstream and downstream, raw instantaneous counts vs test time;
- s) cumulative overall mean filtration efficiency versus particle size;
- t) calculated reference filtration rating S in μm .

An example of the test report in two parts is given in [Annex A](#) (see [Tables A.1](#) to [A.3](#)), a first part relative to the determination of the initial filtration efficiency and a second part relative to the determination of the retention capacity.

Some additional figures are given for information to display the initial filtration efficiency curve versus particle size ([Figure A.1](#)), the instantaneous particle counts versus time ([Figure A.2](#)) and the clogging curve versus time ([Figure A.3](#)).

Annex A (informative)

Determination of the initial filtration efficiency as per this document

Determination of the initial filtration efficiency as per this document

Test identification

Test date:	operator
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Filter identification

Sample ref.	housing ref.
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Operating conditions

Test fluid type temperature [°C]	Test dust type batch n°
Main circuit nominal flow rate [l/h] bugl [mg/l]:	volume [l]
Injection circuit n°1 injection flow rate concentration [mg/l]	initial final average

Counting circuit

	counter	sensor	flow rate [ml/min]	counting time [sec]	waiting time [sec]
upstream					
downstream					

Table A.1 — Test results (see Figure A.1)

Size [μm]	>5	>7	>10	>12	>15	>20	>30	>40
Average E [%]	29,9	70,1	87,9	93,4	96,1	98,0	99,5	100,0
E [%]	50	75	90	95	99	99,5	99,8	
Filter rating [μm]	6	8	11	14	27	30	36	
Reference filtration rating S [μm]	36							

Table A.2 — Instantaneous particle counts versus time (see Figure A.2)

Time duration [min]	Initial level/ml	Particle size [$\mu\text{m}/\text{ml}$]							
		>5	>7	>10	>12	>15	>20	>30	>40
		15,0	10,0	7,0	4,0	2,0	0,0	0,0	0,0
1	Up	2 225,0	1 000,0	300,0	150,0	50,0	11,0	5,0	3,5
	Down	1 557,5	290,0	33,0	9,0	2,0	0,2	0,0	0,0
2	Up	3 782,5	1 290,0	333,0	159,0	52,0	11,2	5,0	3,5
	Down	2 609,9	438,6	36,6	6,4	1,6	0,2	0,0	0,0
3	Up	4 834,9	1 438,6	336,6	156,4	51,6	11,2	5,0	3,5
	Down	3 481,1	374,0	40,4	7,8	2,1	0,2	0,0	0,0
5	Up	6 105,2	1 357,2	340,8	159,5	51,6	11,2	5,0	3,5
	Down	4 273,6	352,9	37,5	6,4	2,6	0,2	0,0	0,0
10	Up	7 010,8	1 397,6	337,5	156,5	52,1	11,2	5,0	3,5
	Down	4 837,4	363,4	40,5	6,3	2,1	0,2	0,0	0,0
15	Up	7 629,8	1 387,9	337,9	161,7	52,1	11,2	5,0	3,5
	Down	5 188,3	374,7	43,9	16,2	1,6	0,2	0,0	0,0
20	Up	7 282,2	1 425,9	343,9	156,5	52,1	11,2	5,0	3,5
	Down	5 243,2	399,3	44,7	6,3	1,6	0,2	0,0	0,0
25	Up	7 479,1	1 400,9	341,4	159,5	52,1	11,2	5,0	3,5
	Down	5 310,1	476,3	44,4	12,8	2,1	0,2	0,0	0,0
30	Up	7 268,7	1 422,4	337,9	160,0	52,1	11,2	5,0	3,5
	Down	5 233,5	483,6	37,2	11,2	1,6	0,2	0,0	0,0
35	Up	7 332,8	1 450,7	344,3	158,1	51,5	11,2	5,0	3,5
	Down	5 206,3	435,2	41,3	6,3	2,6	0,2	0,0	0,0