TECHNICAL SPECIFICATION

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Diesel engines — Fuel filters — Method for evaluating fuel/water separation efficiency

Moteurs diesels — Filtres à carburant — Méthode d'évaluation de l'efficacité des séparateurs carburant-eau

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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 2.

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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

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.

ISO/TS 16332 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 7, *Injection equipment and filters for use on road vehicles*.

Annexes A and B form normative parts of this Technical Specification. Annexes C and D are for information only.

Introduction

Modern fuel injection systems, installed in passenger cars, as well as in heavy duty or off-road vehicle applications, require high and stable separation efficiencies for all insoluble contaminants in the fuel to ensure a prolonged life. Beside solid contamination, undissolved water, in finely or coarsely emulsified form, can also reduce the lifetime of injection systems. Suitable fuel filters, having a high level water separation efficiency, are an absolute necessity for system longevity.

Factors found to affect the separation efficiency of undissolved water in the field are mainly due to the fuel quality, which is strongly influenced by the performance of additives in the fuel itself, as well as the actual characteristics of the fuel/water-emulsion, the specific flow rate of the system, the type of media in the filter element, as well as the size and design of the filter housing itself. To ensure laboratory test results are comparable, these various parameters have to be taken into account in the test method, in order to reduce their influence on the test results.

NOTE A variety of tests were investigated prior and parallel to the preparation of this Technical Specification to specify the required test conditions. Additional work is underway to validate, confirm and if necessary to modify the following parameters:

- test fuel (5.1.1);
- water concentration of 1 500 ppm (6.4);
- volume of fuel (6.1);
- total test duration t_{total} (6.6).

At the time of publication of this Technical Specification, interlaboratory tests are being organized to establish the repeatability and reproducibility of the results.

Diesel engines — Fuel filters — Method for evaluating fuel/water separation efficiency

1 Scope

This Technical Specification specifies a fuel/water separation test with continuous water injection, using an offline water concentration measuring method, for evaluating the ability of a fuel filter to separate either finely or coarsely dispersed undissolved water out of fuel. This test is intended for application to filter elements which are installed upstream or downstream of the low pressure pump, having a rated flow (in litres per hour) between 50 l/h and 900 l/h. By agreement between customer and filter manufacturer, and with some modification, the procedure may be used for fuel filters with higher flow rates.

2 Normative references

The following referenced documents are indispensable for the application 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 760, *Determination of water — Karl Fischer method (General method)*

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

ISO 6889, *Surface active agents — Determination of interfacial tension by drawing up liquid films*

ISO 13320-1, *Particle size analysis — Laser diffraction methods — Part 1: General principles*

ASTM D 1401, *Standard Test Method for Water Separability of Petroleum Oils and Synthetic Fluids*

CEC RF-06-03:2003 [1], *CEC Legislative fuel RF-06-03 (reference fuel specification)*

3 Terms and definitions

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

3.1
interfacial tension
IFT
force required to increase the surface area of the interface between two liquids by a unit amount

NOTE Interfacial tension is expressed in millinewtons per metre (mN/m).

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[1] The reference fuel specification is provided by CEC secretariat services: Interlynk Administrative Services Ltd., PO Box 6475, Earl Shilton, Leicester LE9 9ZB, UK; T +44(0)1455 21993; F +44(0)1455 821994.

3.2
droplet size distribution
DSD
curve of the percentage of the droplet population in different size ranges

See Figure B.1.

3.3
base water concentration
concentration of water in water saturated fuel

3.4
undissolved water
difference between total and base water concentration

3.5
test time
t
"point of time" when a test or a measurement is started or running respectively

NOTE In contrast to the total test duration t_{total}, see 6.6.

4 Symbols

Graphical symbols used in this Technical Specification for fluid power system components are in accordance with ISO 1219-1.

5 Test equipment

5.1 Test fluids

5.1.1 Test fuels

The test fuel shall be according to CEC RF-06-03 [2] and processed to achieve the following requirements by adding a multifunctional fuel additive (see Note 1):

a) IFT

15 mN/m ± 3 mN/m measured according to ISO 6889 after 60 s;

b) water separability

270 s ± 30 s, when 75 % of test fuel is separated (sedimentation test according to ASTM D 1401 at 25 °C). Within this document, the water separability is defined through the point of time, when 75 % of the test fuel is separated.

NOTE 1 Fundamental tests lead to a mass fraction of approximately 0,1 % of the multifunctional fuel additive HiTEC 4620 [2] to reach the required values.

The test fuel shall be stored protected from humidity, dust and light.

The batch of test fuel shall be changed when the fuel no longer meets the specified requirements.

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[2] Suitable products are available commercially. Details may be obtained from the Secretariat of Technical Committee ISO/TC22 or from the ISO Central Secretariat.

Optionally, if agreed between customer and filter manufacturer, the test can be performed with a fuel used in the application, but the deviations of the relevant fuel parameters shall be recorded in the test report.

NOTE 2 By using other fuel qualities (e.g. fuels used in application), the test results may not be comparable with the results obtained with the test fuel according to 5.1.1.

5.1.2 Test water

Clean, distilled, or deionized water with a surface tension of at least 70 mN/m, measured at 20 °C ± 1,5 °C.

5.2 Laboratory equipment

5.2.1 General

All laboratory equipment and glassware, required to determine the water concentration, shall be according to ISO 760.

5.2.2 Sampling bottles and glassware, 100 ml sampling bottles with 45 mm screw caps carefully rinsed with clean petroleum ether and dried in an oven.

5.2.3 Karl Fischer titration system [3], as commercially available and validated according to 8.2.3.

Recommended equipment should be composed of a coulometric, diaphragmless titration cell and a codistillation unit.

Humidity is probably the largest source of error during the titration process. Special precautions should be taken during setup and testing. The recommended amount of water per sample should be $\geqslant 50$ µg to reach a good relation between titration time and accuracy.

5.2.4 Analytical balance, with an accuracy of ± 1 mg.

5.2.5 Sampling syringe, with a volume of 1 ml ± 0,1 ml.

5.2.6 High-speed mixer

Mixer of the ULTRA-TURRAX type [3] with

- a stator of 18 mm ± 1 mm,
- a rotor of 12,5 mm ± 1 mm, and
- a rotational speed of 15 000 $\text{min}^{-1} \pm 500\ \text{min}^{-1}$.

5.3 Test stand

5.3.1 General

The test stand, shown diagrammatically in Figure 1, shall comprise a filter test circuit as described in 5.3.2.

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[3] This equipment has been found satisfactory. This information is given for the convenience of users of this Technical Specification and does not constitute an endorsement by ISO. Details may be obtained from the Secretariat of Technical Committee ISO/TC22 or from the ISO Central Secretariat.

5.3.2 Filter test circuit (see Figure 1)

5.3.2.1 Fuel sump (1) [4] : conical bottom, stainless steel or corrosion resistant container with a fuel outlet at the bottom of the container.

The container shall be able to contain the volume as specified in 6.1. The fuel sump has to be covered with a non transparent cover to protect the fuel from light.

5.3.2.2 Water sump (6): stainless steel or corrosion resistant container with approximate capacity of 30 l.

NOTE Instead of the container, continuous water supply may be used.

5.3.2.3 Test pump (2) which does not exhibit pressure pulsation with an amplitude greater than 10 % of the average pressure at the inlet of the water emulsifying device.

5.3.2.4 Adjustable water injection pump (7) [5], capable of delivering a water flow between 0,15 % and 2 % of the fuel flow.

5.3.2.5 Fuel flow meter (5a), capable of measuring with an accuracy as specified in Table 1.

5.3.2.6 Water flow meter (5b) [5], capable of measuring with an accuracy as specified in Table 1.

5.3.2.7 Injection device (8), with a maximum inner diameter of the injection pipe of 1 mm.

5.3.2.8 Water emulsifying device (9): fixture with an exchangeable orifice plate, as described in Annex A.

5.3.2.9 Upstream (12) and **downstream** (17) **sampling devices**, as shown in Figure 3.

5.3.2.10 Temperature indicator (13) with an accuracy as specified in Table 1.

5.3.2.11 Pressure gauge (10) with an accuracy as specified in Table 1.

5.3.2.12 Differential pressure gauges (11) with an accuracy as specified in Table 1.

5.3.2.13 Water drainage system (15): closed collector (e.g. laboratory measuring cylinder), located directly below the test filter (water separator) (14) and capable to collect the injected amount of water; it is connected to the water outlet of the test filter with pressure-tight fittings.

The internal diameter of the connecting pipe between the test filter and the closed collector shall be of at least 10 mm.

5.3.2.14 Test stand pipes shall be made of stainless steel; painted or coated pipes are not allowed. For the adaptation of the test filter (14) to the test stand piping, flexible lines are allowed.

The piping shall be designed with a minimum number of flanges or fittings and grounded upstream near the test filter (potential difference < 10 V between each point).

The test stand pipes inner diameter d_i between injection device (8) and downstream sampling point (17) (see Figure 2) should allow a flow velocity $\geqslant$ 0,75 m/s.

The pipes, outside of Figure 2, shall be as short as possible.

5.3.2.15 Inline static mixer (16) to provide a representative sample at the downstream sampling point (17).

NOTE Using a water emulsifying device (see 5.3.2.8) has been proven to be suitable as a static mixer.

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[4] The numbers in brackets refer to the key numbers in Figure 1.

[5] Suitable products are available commercially. Details may be obtained from the Secretariat of Technical Committee ISO/TC22 or from the ISO Central Secretariat.

5.3.2.16 Optional: **three-way ball valve** (18) and **collecting sump** (19), if the test stand is used to run as a single pass system (open test circuit).

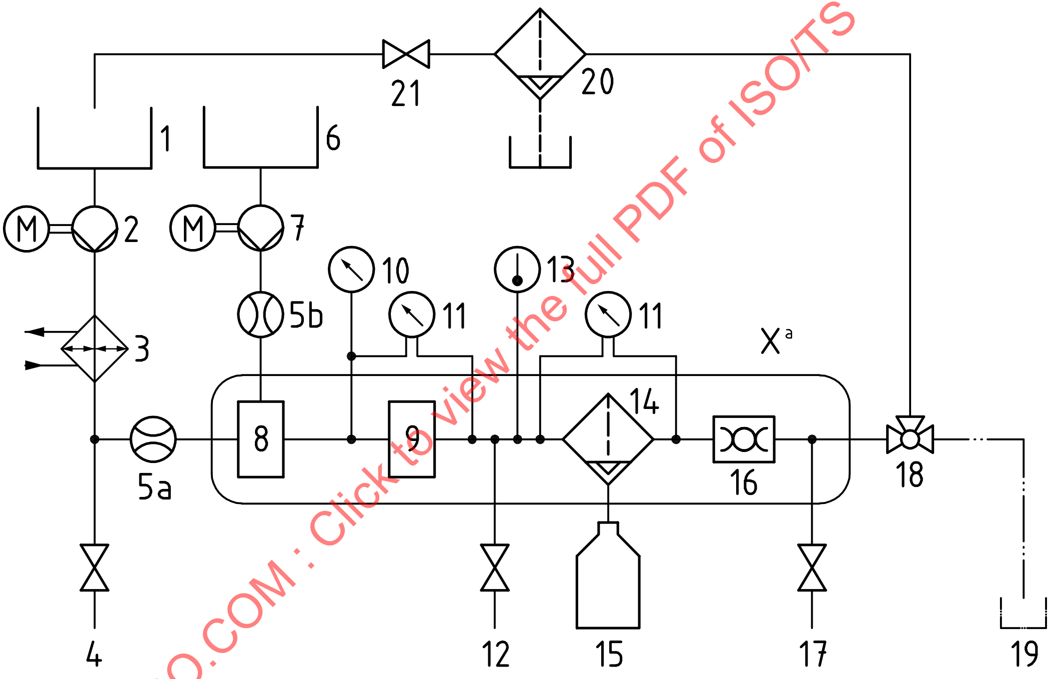
5.3.2.17 **Final water separator assembly** (20),

— with a suitable container in which to drain the water, and

— such that not more than 30 ppm by volume of undissolved water is recycled on an average basis under test conditions.

5.3.2.18 **Back pressure regulating valve** (21) to ease test filter venting and optionally to control the test flow rate Q_T.

5.3.2.19 **Heat exchanger** (3), capable of maintaining the test temperature T within the tolerances given in Table 1.

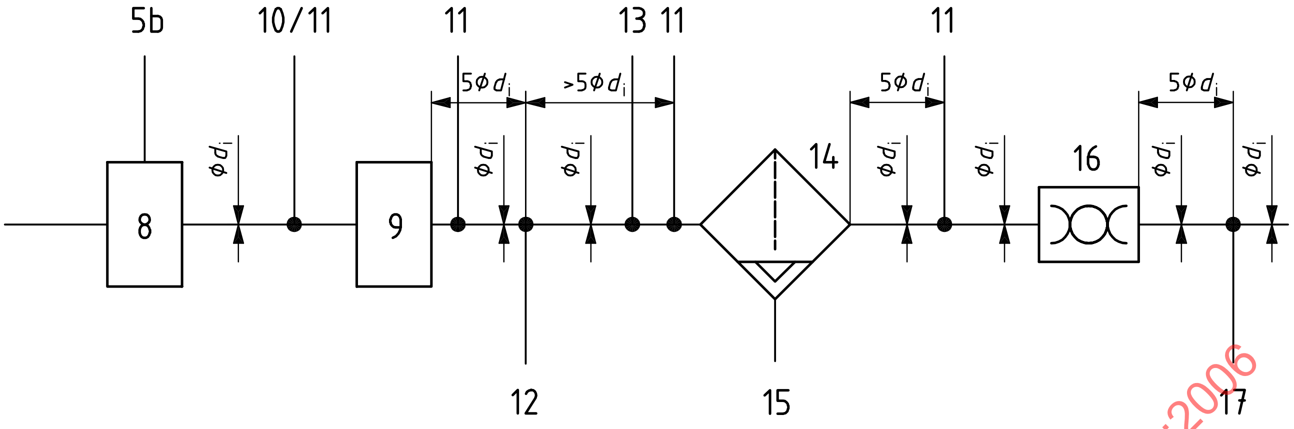


Key

1 fuel sump
2 test pump
3 heat exchanger
4 sampling point (sampling valve)
5a fuel flow meter
5b water flow meter
6 water sump
7 adjustable water injection pump
8 injection device
9 water emulsifying device (orifice plate holder)
10 pressure gauge
11 differential pressure gauges (2)
12 upstream sampling point (upstream sampling device: see Figure 3)
13 temperature indicator
14 test filter (water separator)
15 water drainage system
16 inline static mixer
17 downstream sampling point (downstream sampling device: see Figure 3)
18 three-way ball valve (optional)
19 collecting sump (optional)
20 final water separator assembly
21 back pressure regulating valve

[a] See Figure 2.

Figure 1 — Filter test stand (diagrammatically)

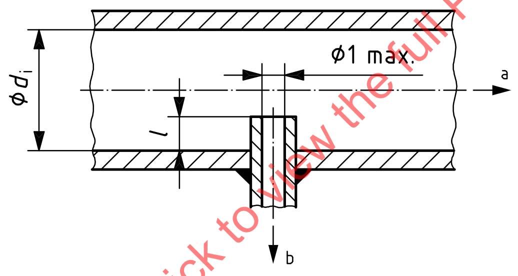


Key

Ød_i inner pipe diameter

Figure 2 — Length and inner diameter d_i of test stand pipes (detail X of Figure 1)

Dimension in millimetres



Key

l $d_i/4 < l < d_i/3$

Ød_i inner pipe diameter

a Flow of test fluid.

b Sampling flow.

Figure 3 — Upstream and downstream sampling device

6 Test conditions

6.1 Volume of fuel

The volume of the fuel [fuel sump (1)] shall be 15 times the test flow rate Q_T per minute.

6.2 Test temperature T

The test shall be conducted at a test temperature T of 23 °C ± 2 °C, measured at the test filter inlet.

Alternatively, the test may be performed at a test temperature T as agreed between customer and filter manufacturer. This shall be recorded in the test report.

6.3 Test flow rate Q_T

The test flow rate Q_T is specified by the customer and is defined as the flow rate of fuel.

6.4 Water concentration (undissolved water)

One of the following two conditions for the undissolved water concentration (see 3.4) shall be used for the test:

- standard condition: 1 500 ppm volume fraction ± 75 ppm volume fraction (approx. 0,15 %);
- optional condition: 2 % volume fraction ± 0,1 % volume fraction.

6.5 Differential pressure Δp_O across water emulsifying device (orifice plate)

The following differential pressure Δp_O measured across the water emulsifying device shall be adjusted in order to achieve the required DSD.

- For coarse water droplets (D_{50} of 300 µm), an orifice plate shall be installed with an orifice which creates a differential pressure Δp_O of 48 hPa ± 5 hPa;
- For fine water droplets (D_{50} of 60 µm), an orifice plate shall be installed with an orifice which creates a differential pressure Δp_O of 260 hPa ± 10 hPa.
- For the definition of D_{50}, see Annex B.
- For the selection of the specified average water droplet size (D_{50}), see Annex D.

The choice of whether to use coarse or fine water droplets depends on the application and has to be specified by the customer.

NOTE As agreed between customer and filter manufacturer, other D_{50} values may be used. These values shall be reported in the test report as a deviation to the standard operating conditions.

6.6 Total test duration t_{total}

Depending on the concentration of undissolved water (see 6.4) the total test duration shall be

a) t_{total} = 90 min for 1 500 ppm (standard condition), and

b) t_{total} = 60 min for 2 % (optional condition).

7 Accuracy of measuring instruments and test conditions

The measuring instruments shall be capable of measuring to the levels of accuracy given in Table 1. In addition, Table 1 specifies the limits within which the test conditions shall be maintained.

Table 1 — Instrument accuracy and test condition variation

Test condition	Units	Measurement accuracy	Allowed test condition variation
Fuel flow rate (Q, Q_C, Q_T) (fuel flow meter)	l/h	± 1 %	± 2 %
Water flow rate (water flow meter)	ml/min	± 1 %	± 2 % [a]
Pressure (gauge between injection device and water emulsifying device)	hPa	± 2 %	—
Differential pressure Δp_O (gauge at orifice plate)	hPa	± 0,5 %	—
Differential pressure Δp_F (gauge at test filter)	hPa	± 2 %	—
Temperature (temperature indicator)	°C	± 1 °C	± 2 °C
Water concentration [b]	% mass fraction	± 5 ppm	± 5 % [a]

[a] Undissolved water (see 3.4).

[b] Upstream [at sample point (12) of Figure 1].

8 Validation procedure

8.1 Test stand

The validation of the test stand shall be performed at the minimum and maximum test stand design flow rates with a straight pipe in place of the test filter (14).

For each of these two flow rates, perform the following procedure in the order given:

a) commence operation of the final water separator (20);

b) start the test pump (2) and adjust the flow rate to the required value;

c) circulate the test liquid until the temperature reaches the required value;

d) inject water at the required concentration (see 6.4);

e) allow to stabilize for at least 10 min;

f) for a 90 min test, take samples every 10 min according to the sampling procedure described in 8.2,

   1) at the sampling point (4),

      [validation of final water separator assembly (20) and determination of base water concentration]

   2) at the upstream sampling point (12), and

      [validation of the injection system (6), (7), (5b) and (8) and the water emulsifying device (9)]

   3) at the downstream sampling point (17);

      [validation of the inline static mixer (16)]

g) measure the water content of each sample.

The validation shall be accepted only if

- at the sampling point (4), the variation between the total water concentration of each sample is less than 30 ppm by volume, and
- at the sampling points (12) and (17), the actual concentration of water of each sample, reduced by the base water concentration, is equal to the injected water concentration, within the limits defined in Table 1.

NOTE Many water in oil analytical devices will determine the water concentration in terms of micrograms. To convert micrograms to parts per million (ppm) by volume, use the following equation:

Titration reading, in ppm volume fraction = titration reading, in ppm mass fraction × fuel/water densities correlation factor

where the fuel/water densities correlation factor is (fuel density, in grams per litre) / (water density, in grams per litre).

8.2 Sampling procedure

8.2.1 Primary sampling procedure

The following procedure shall be executed for the upstream and downstream sampling points:

a) open the sampling valves at sampling points (12) and (17);

b) flush the volume between the sampling points (12) and (17) and discard in an appropriate repository;

c) immediately open the sampling bottles (prepared as described in 5.2.2) and fill approximately 50 ml;

d) close the sampling bottles directly after filling and identify the sample.

If an automatic codistillation unit is used for Karl-Fisher titration, insert the bottles directly in the distillation unit.

If an automatic sampling unit is used, flushing of the sampling pipes and exclusion of humidity inflow into the sample volume shall be assured, until final analysis in titration cells is completed.

8.2.2 Secondary sampling procedure

If a manually served cell is used, homogenize the sample using the same mixer (see 5.2.6) to assure that the water is completely and uniformly dispersed. Use a hypodermic syringe and extract an adequate sample volume as described in 5.2.3.

This secondary sampling procedure shall be validated according to 8.2.3.

8.2.3 Secondary sampling procedure validation

a) Take 51 g ± 0,05 g sample of test fuel;

b) take 1 g ± 0,01 g secondary sample by using a micro-syringe;

c) measure the water content c_1;

d) add 0,075 g ± 0,005 g water into remaining 50 g sample and mix by using an ULTRA-TURRAX mixer;

e) take another 1 g ± 0,01 g sample using a micro-syringe;

f) measure the water content c_2;

g) $c_2 - c_1$ shall be 1 500 ppm ± 75 ppm.

9 Test procedure

9.1 Pre-test preparation

Perform the pre-test preparation procedure in the following order:

a) install the test filter (14) and water drainage system (15) for testing;

b) choose an orifice plate with a suitable orifice for the required DSD (D_{50} = 60 µm or D_{50} = 300 µm) and fuel flow rate Q_C according to Annex B;

c) install the orifice plate into the holder [water emulsifying device (9)];

d) start circulation at the specified test flow rate Q_T (see 6.3) and test temperature T (see 6.2). Bleed air from the system including water drainage system (15). Record an initial pressure drop reading at the orifice (9) and at the test filter (14) immediately after the start;

e) record the resulting DSD as described in Annex B;

f) circulate the clean test fluid at the specified test flow rate Q_T (see 6.3) through the test filter (14) for at least 30 min.

9.2 Efficiency measurement

Perform the following procedure in the order given:

a) commence water injection at the specified test flow rate Q_T (see 6.3) and start the timing clock at the same time water begins to flow. This point is test time $t = 0$. Record the differential pressure Δp_O across the orifice (9) and test filter (water separator) (14);

b) after 10 min:

  1) take an initial sample at sampling point (4) and measure the water content; this is to determine the base water concentration of the fuel;

  2) take an initial upstream sample according to the sampling procedure described in 8.2; analyse the sample immediately to confirm that the specified water concentration is being injected into the fuel stream;

  3) take an initial downstream sample according to the sampling procedure described in 8.2; repeat this sampling procedure every 10 min thereafter until termination of the test;

The volume of the samples analysed shall be sufficient to dose at least 50 µg of water into the titration cell.

c) record the differential pressure Δp_O (11) across the orifice (9) and the test filter (14) at each downstream sampling interval;

d) terminate the test if one or more of the following conditions are met:

  1) the undissolved water concentration in the downstream sample is above the acceptable level specified by customer or filter manufacturer, or

  2) an equilibrium pressure drop across the test filter (14) has been reached and a minimum of 90 min of total test duration t_{total} has been attained, or

  3) the differential pressure Δp_F across the test filter (14) exceeds an upper limit specified by customer or filter manufacturer;

e) take a final sample at sampling point (4) to verify that the base water concentration did not change [i.e. check of the final water separator (20)];

f) if the base water concentration has not changed, record the volume of water drained from the test filter (14);

g) if the base water concentration has changed by more than 30 ppm, cancel the test; check the final water separator (20) and repeat the steps a) to e).

10 Calculation and reporting of test results

10.1 Calculation of water separation efficiency

Perform the following procedures in the order given:

a) determine and record the concentration of undissolved water of the downstream samples with respect to test time t:

undissolved water = total water – base water

b) plot the concentration of undissolved water in the downstream samples (ppm by volume) versus test time t, in min;

NOTE All following water concentrations (c , c_i , c_{av}) refer to undissolved water.

c) calculate, report and plot (see Figure C.1) the instantaneous water separation efficiency η_{i}, in %, versus test time t, in min, by the following equation:

$$\eta_{\text{i}} = \frac{\left(c - c_i\right)}{c} \times 100$$

where

c is the specified test water concentration, in ppm by volume;

c_i is the downstream water concentration, in ppm by volume, of sample i ;

d) calculate and report the average downstream water concentration c_{av} , in ppm by volume, by the following equation:

$$c_{\text{av}} = \frac{\sum c_i}{n}$$

where

c_i is the downstream water concentration, in ppm by volume, of the sample i ;

n is the number of samples (see 9.2);

e) calculate and report the average water separation efficiency η_{av}, in %, by the following equation:

$$\eta_{\text{av}} = \frac{\left(c - c_{\text{av}}\right)}{c} \times 100$$

where

c is the specified test water concentration, in ppm by volume;

c_{av} is the average downstream water concentration, in ppm by volume.

10.2 Test report

The test report shall include:

a) test fluid(s) characteristics;

b) test flow rate Q_{T};

c) water concentration (undissolved water);

d) calibrated orifice diameter d;

e) differential pressure Δp_{O} at orifice plate and corresponding average droplet size D_{50};

f) differential pressure Δp_{F} at test filter;

g) test temperature T;

h) total test duration t_{total};

i) base water concentration of the fuel at test temperature T;

j) total volume of water drained from the test filter;

k) a graph showing the water separation efficiency versus test time t as shown in Figure C.1; and

l) an explanation of reason(s) for test termination.

See Annex C for a typical filter test report.

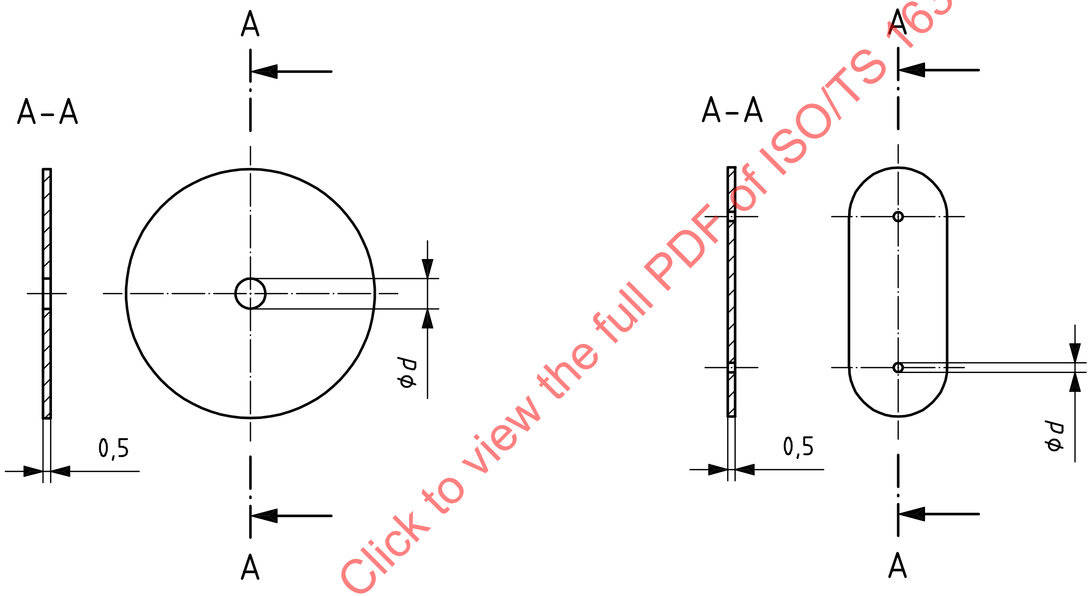
Annex A
(normative)

Water emulsifying device

Details of the water emulsifying device (9) are shown in Figures A.1 to A.4.

The orifice itself (calibrated diameter d) shall be produced by laser cutting and shall be free from any burrs.

Dimensions in millimetres

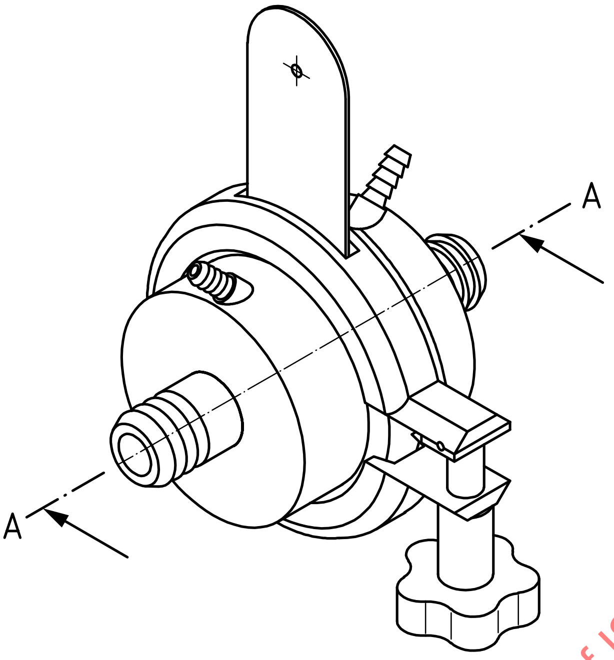


a) Simple orifice plate **b) Double orifice plate**

Key

Ød calibrated orifice diameter d of orifice plate

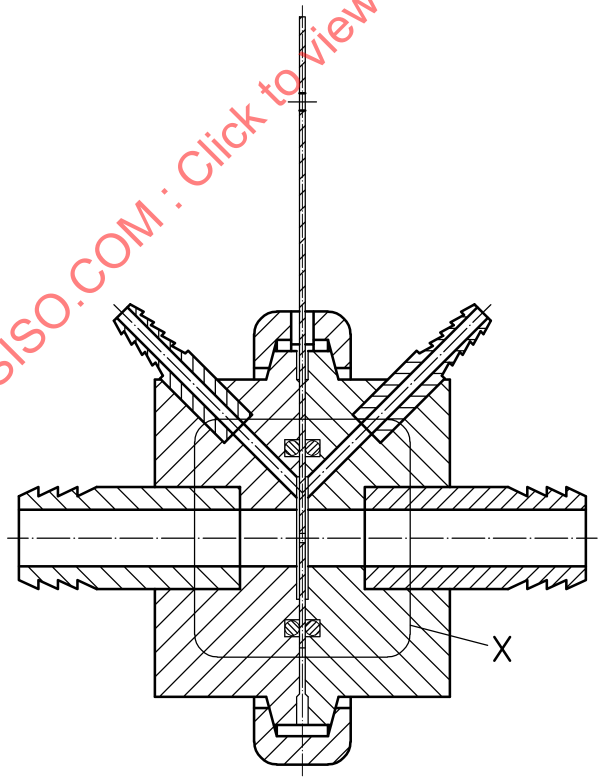
Figure A.1 — Orifice plates with calibrated orifice diameters d



Key

A–A see Figure A.3

Figure A.2 — Water emulsifying device (orifice plate holder) with double orifice plate and pressure taps (measurement of differential pressure Δp_{O})

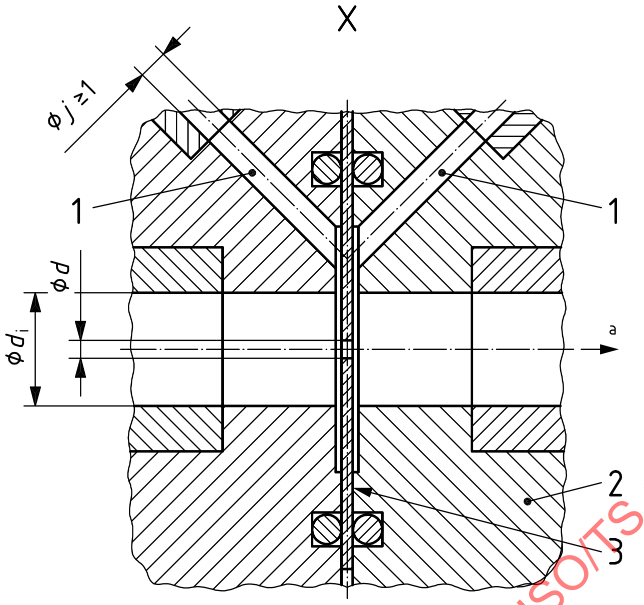


Key

X see Figure A.4

Figure A.3 — Water emulsifying device (orifice plate holder) (cut A – A of Figure A.2)

Dimensions in millimetres



Key

1 pressure transmitting bores (to pressure tap connections for differential pressure Δp_O measurement)
2 orifice plate holder
3 orifice plate
$Ød$ calibrated orifice diameter of orifice plate
$Ød_i$ inner pipe diameter
$Øj$ diameter of pressure transmitting bores and of pressure tap bores

[a] Flow of fuel/water mixture.

Figure A.4 — Detail X of Figure A.3:
Measurement of differential pressure Δp_O at the orifice plate

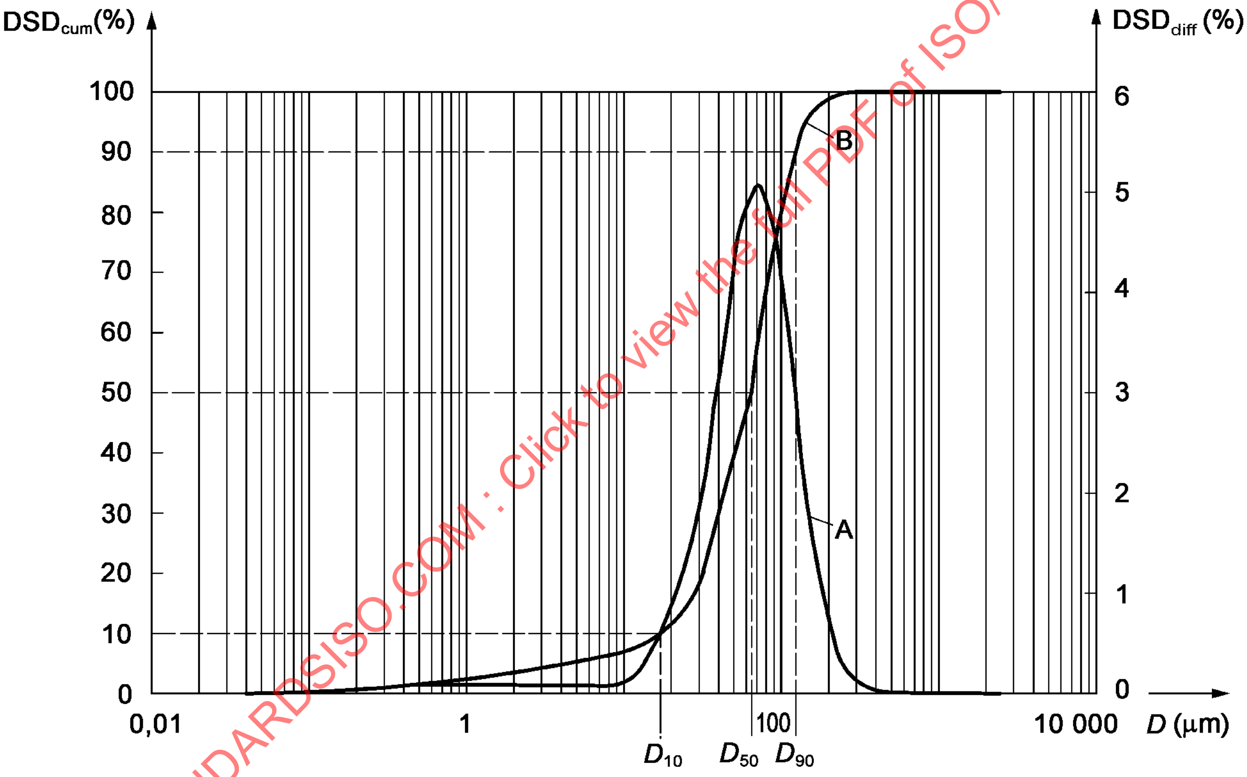
Annex B
(normative)

Procedure to determine the water droplet size distribution (DSD)

B.1 Water droplet size distribution (DSD) — Definition

The water droplets are generated by dissipating a known energy within the fuel/water mixture by flowing it through a calibrated orifice diameter d (see Figure B.2).

Droplet sizes D are polydispersed, generally according to the model shown in Figure B.1, when measured using the laser diffraction technique according to ISO 13320-1.



Key

D	droplet size, in micrometres (µm)
DSD_{diff}	differential droplet size distribution (curve A), in percent (%)
DSD_{cum}	cumulative droplet size distribution (curve B), in percent (%)
A	typical size distribution curve of water droplets after passing through an orifice (DSD_{diff})
B	typical droplet size distribution curve for the determination of D_{10}, D_{50} and D_{90} (DSD_{cum})

Figure B.1 — Typical distribution curves of polydispersed droplet sizes D

Curve A represents the differential distribution of droplet sizes DSD_{diff} (i.e. percentage of droplets within a size range) and curve B the cumulative one DSD_{cum} (i.e. percentage of droplets smaller than the indicated droplet size D). The cumulative distribution DSD_{cum} can be represented by three droplet sizes:

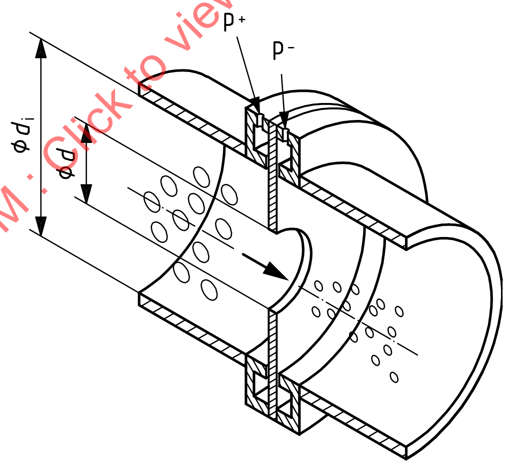
- D_{10} is the droplet size D that only 10 % of the droplets underpass.
- D_{50} is the droplet size D which separates the droplets in two identical populations, 50 % larger and 50 % smaller; i.e., D_{50} is the average diameter of the droplet size distribution DSD.
- D_{90} is the droplet size D that only 10 % of the droplet population overpass (90 % underpass).

Since it has been shown by studies performed to develop this Technical Specification that water droplets in fuel have similar Gaussian distributions whatever their average sizes, it has been agreed to characterize this distribution by the D_{50} figure, only.

B.2 Calibrated orifices

Because of their simplicity, orifice plates with calibrated orifice diameters d have been used to mix, under known and repeatable conditions, the water with fuel to generate droplets of known size D. The orifice plates are made of 0,5 mm thick stainless steel discs with a central hole of variable inside diameter d (orifice diameter). Typical stainless steel orifice plates with calibrated orifice diameters d (simple and double orifice plates) are shown in Figure A.1.

The energy dissipated by a liquid flowing through the calibrated orifice diameter d is quantified by its pressure drop (or differential pressure Δp_{O} measured across the orifice plate) provided measured adequately, e.g. as shown on Figure B.2.

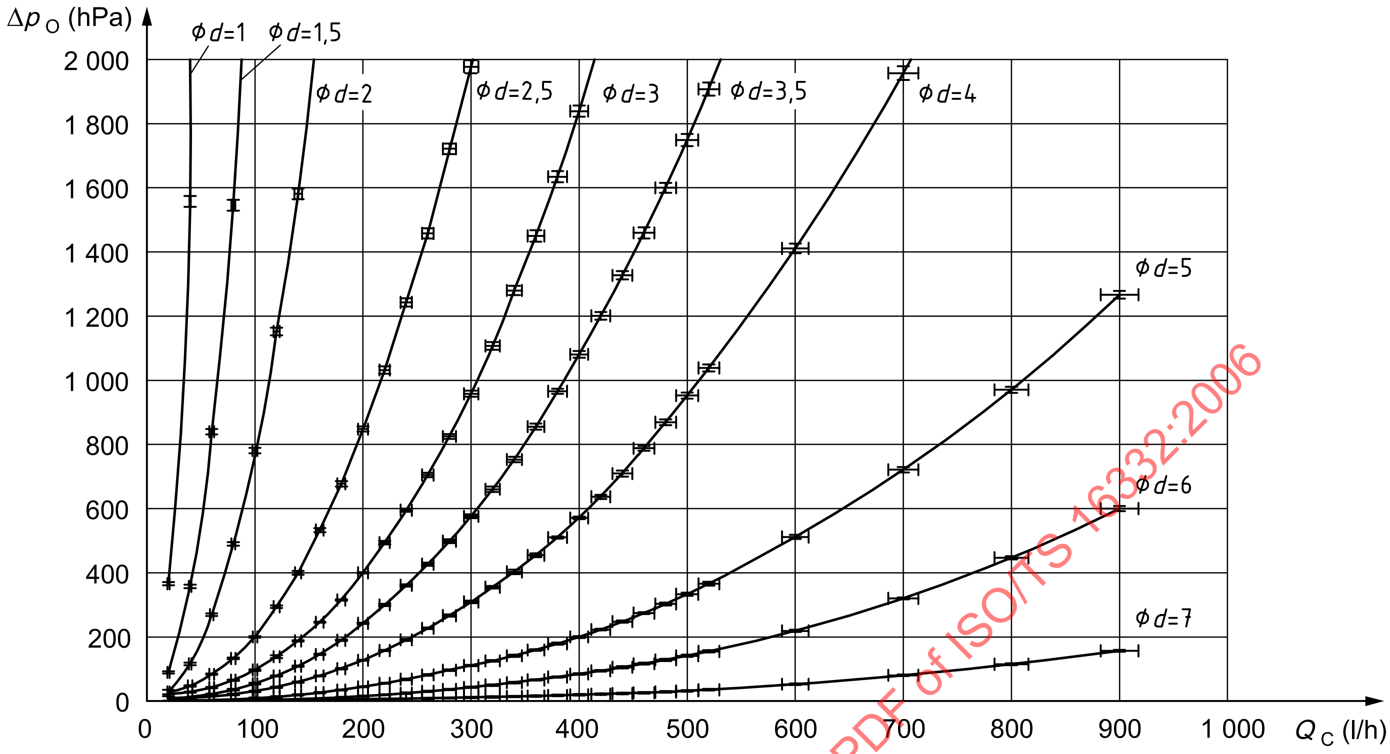


Key

p+, p–	differential pressure Δp_{O} measuring points at the orifice plate (see Figure A.4, detail X)
Ød_{i}	inner pipe diameter
Ød	calibrated orifice diameter of orifice plate

Figure B.2 — Energy dissipated by a liquid flowing through the calibrated orifice diameter d of an orifice plate

Typical curves representing differential pressure Δp_{O} versus fuel flow rate Q_{C} have been measured on calibrated orifices of various diameters d with a given fuel (CEC RF-06-99; ν = 7 mm^2/s at 24 °C). These curves are shown in Figure B.3.



Key

Q_C	fuel flow rate (for calibration of orifice plates), in litres per hour (l/h)
Δp_O	orifice differential pressure, in hectoPascals (hPa)
$Ød$	calibrated orifice diameter of orifice plate, in millimetres (mm)

NOTE The curves of Figure B.3 are given for information only, since they strongly depend on the actual characteristics of the test fuel used.

Figure B.3 — Typical curves of differential pressure Δp_O through calibrated orifice diameter d

B.3 DSD generated by orifices

It has been shown with various fuel/water mixtures in a number of conditions that the average droplet size D_{50}, in µm, of the DSD was linked to the differential pressure Δp_O, in hPa, across an orifice plate by the following equation:

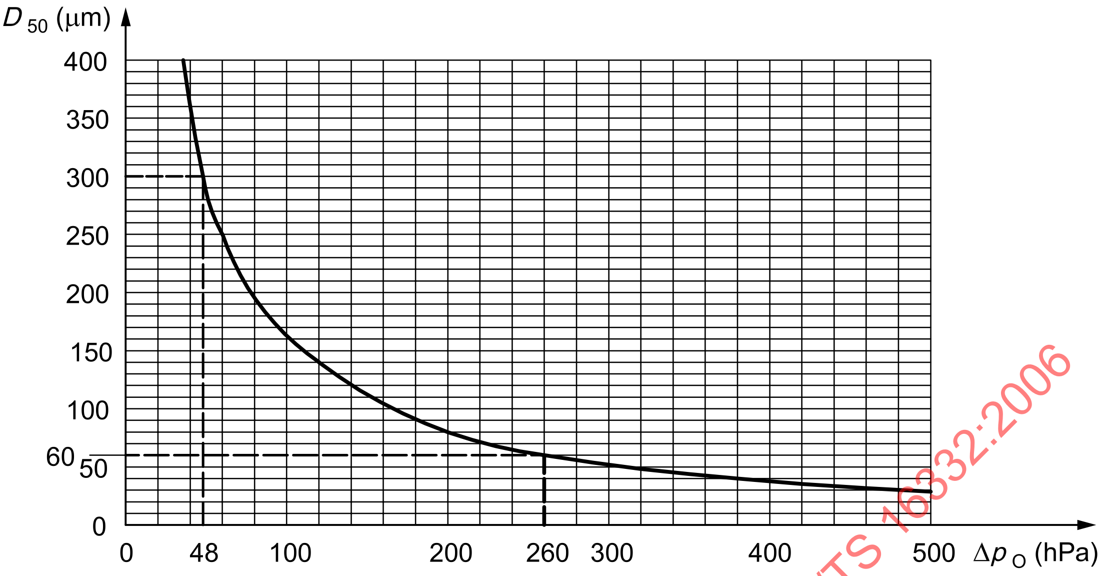
$$D_{50} = 1339 \times e^{-\frac{(\ln \Delta p_O)^2}{10}} \qquad \text{where } r^2 = 0,96 \qquad \text{(B.1)}$$

As a reciprocal, the equation used to determine the differential pressure Δp_O, in hPa, across an orifice plate to generate a known average droplet size D_{50}, in µm, is:

$$\Delta p_O = e^{\sqrt{-10 \times \ln\left(\frac{D_{50}}{1339}\right)}} \qquad \text{where } r^2 = 0,96 \qquad \text{(B.2)}$$

NOTE r^2 is the linear regression coefficient for fitting the equation to actual experimental data measured on 92 points.

These equations lead to the curve shown on Figure B.4.



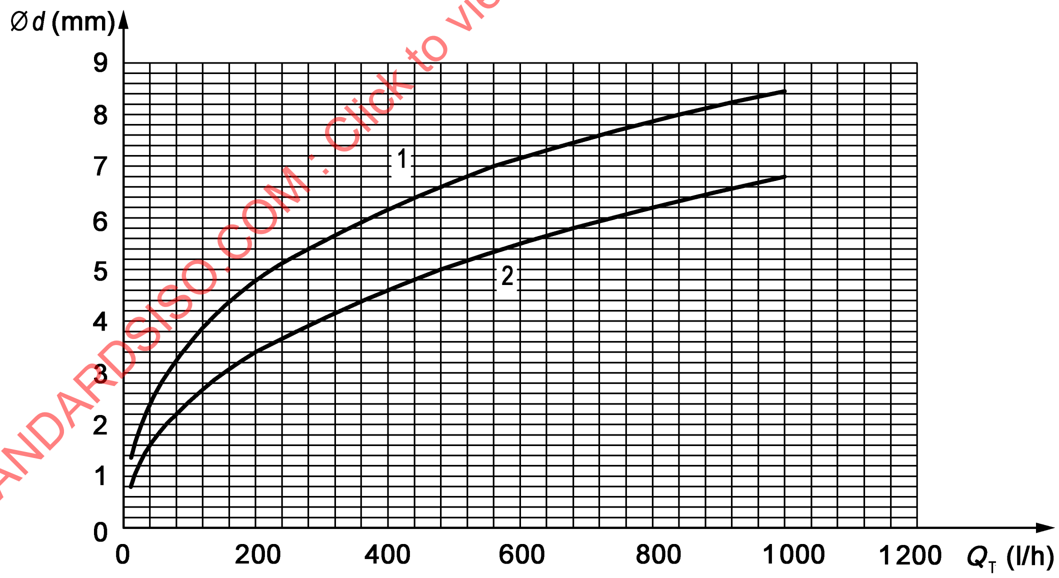
Key

Δp_O orifice differential pressure, in hectoPascals (hPa)

D_{50} average droplet size, in micrometres (µm)

Figure B.4 — Standard curve of average droplet size D_{50} vs orifice differential pressure Δp_O

Figure B.5 can be used as a help in choosing the appropriate calibrated orifice diameter d from the type of filter to be tested (i.e. pressure or suction system) and the test flow rate Q_T.



Key

Q_T test flow rate, in litres per hour (l/h)

Ød calibrated orifice diameter of orifice plate, in millimetres (mm)

1 suction system (D_{50} = 300 µm)

2 pressure system (D_{50} = 60 µm)

NOTE The curves of Figure B.5 are given for information only, since they strongly depend on actual fuel characteristics.

Figure B.5 — Curves relating diameter d of calibrated orifices and fuel test flow rate Q_T for filters of pressure and suction systems