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

Moteurs diesel — Filtres à carburant — Méthode d'évaluation de l'efficacité de séparation carburant-eau

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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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).

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

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

This document cancels and replaces the first edition ISO/TS 16332:2006 which has been technically revised. The main changes compared to the previous edition are as follows:

— test fuel definition;

— change of IFT measurement standard and interface age;

— droplet size distribution;

— test duration;

— additional preconditioning cycle; and

— validation of test procedure by conduction of two round robin tests (see Annex G).

Introduction

Modern fuel injection systems, installed in passenger cars, as well as in heavy duty or off-road 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/water separators, 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 can differ widely in different regions of the world and which can also differ when biogenic components are added to the fuel. Additionally the separation efficiency is strongly influenced by fuel composition.

Separation efficiency tests can be applied mainly for two purposes:

— To evaluate the field performance of a fuel/water separator

  To evaluate the performance of a fuel/water separator close to field conditions, the usage of commercially, untreated fuel as test fluid is necessary.

— To compare fuel/water separators under repeatable test conditions

  For a fuel/water separator comparison in the laboratory, fuel conditioning is necessary to achieve constant and repeatable test conditions. Water separation efficiency results obtained with treated fuel can be significantly different from those with commercially available, untreated fuel.

Tests performed with new fuel/water separators can lead to considerably higher water separation efficiencies.

NOTE Ageing of the fuel/water separator due to operational conditions can strongly affect the water separation function of a fuel/water separator. To test a fuel/water separator in an “end of life” state, it can be aged in advance. It is proposed to do this by a standardized ageing procedure, to get comparable “end of life” states. However, it is not a part of this document nor any other ISO standard. This procedure may be explored in future.

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

1 Scope

This document specifies a fuel/water separator comparison test under defined and simplified laboratory conditions.

This test is intended for pressure side fuel/water separators as well as for suction side fuel/water separators. Pressure side fuel/water separators are tested with fine droplets and suction side filters are tested with coarse droplets using the same test rig layout.

The rated flow (in litres per hour) is intended for the range between 50 l/h and 1 500 l/h. By agreement between customer and fuel/water separator manufacturer, and with some modifications, the procedures can be used for fuel/water separators with higher or lower flow rates.

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

ISO 9101, *Surface active agents — Determination of interfacial tension — Drop volume method*

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

ISO 12937, *Petroleum products — Determination of water — Coulometric Karl Fischer titration method*

ISO 13320, *Particle size analysis — Laser diffraction methods*

ASTM D4176–04 (2009), *Standard Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)*

3 Terms and definitions

For the purpose of this document, the following terms and definitions 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 https://www.iso.org/obp

3.1
interfacial tension
IFT
work which is required to increase the interface of the liquid by one surface area unit

Note 1 to entry: In case of additivated liquids, the IFT-value has a significant time dependency. Therefore the default value for the interface age within ISO 16332-usage is defined at 10 s.

Note 2 to entry: The conditions and parameters for determination of IFT by the drop volume method according to ISO 9101 are defined in Annex C.

Note 3 to entry: Interfacial tension is equivalent to the specific interfacial energy and is expressed in Millinewtons per meter (mN/m). Alternative methods to determine the IFT (at 10 s) can be used, as long as the comparability to ISO 9101 is ensured.

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

Note 1 to entry: For further information, see B.3.

3.3
water concentration at the saturation level of dissolved water
c_S
concentration of water in water saturated test fuel with the IFT adjusted by Monoolein

Note 1 to entry: The determination of c_S is defined in Annex E.

3.4
base water concentration
c_B
concentration of water in the test fuel, determined after the preconditioning cycle

Note 1 to entry: See 8.4.3 or 9.1.3.

Note 2 to entry: In case one of the $c_{T,down,i}$-values [determined in 9.1.4 c) and d)] is lower than c_B (determined in 9.1.3) take the lowest value as c_B.

3.5
undissolved water concentration
c_U
concentration of free water, that is concentration above base water concentration

3.6
total water concentration
c_T
summation of base water concentration and undissolved water concentration

Note 1 to entry: $c_T = c_U + c_B$.

3.7
sample index
i
integer from 1 to n, where n equals the number of samples

3.8
instantaneous water separation efficiency
η_i
water separation efficiency, at test time t_i

3.9
average water separation efficiency
η_{av}
average water separation efficiency, calculated based on the average downstream water concentration

Note 1 to entry: Calculation according to 9.2 e).

3.10
calibration flow rate
Q_C
fuel flow rate, which is adjusted for calibration purpose of the emulsifying device

Note 1 to entry: The calibration procedure is defined in B.4.

3.11
sampling point index
< up> reference to the upstream sampling point

3.12
sampling point index
< down> reference to the downstream sampling point

4 Symbols

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

5 Test equipment

5.1 Test fluids

5.1.1 Test fuels

For the validation and for each filter test one of the following three kinds of fuels can be used as test fuel.

— F1 Unmodified service station fuel

— F2 Standard test fuels: Fuels, treated according to Annex A

Test fuel F2.1: High IFT test fuel

— IFT (10 s): 22 ± 2 mN/m, according to ISO 9101, parameterized according to Annex C

  Alternatively IFT (60 s): 20 ± 2 mN/m, according to ISO 9101 or ISO 6889.

— Separability (ASTM D 1401): To be reported

Test fuel F2.2: Low IFT test fuel

— IFT (10 s): 13 ± 2 mN/m, according to ISO 9101

  Alternatively IFT (60 s): 11 ± 2 mN/m, according to ISO 9101 or ISO 6889.

To describe the test fuel used, the following parameters shall be determined:

— IFT(10 s) and IFT(60 s);

— separability (ASTM D 1401);

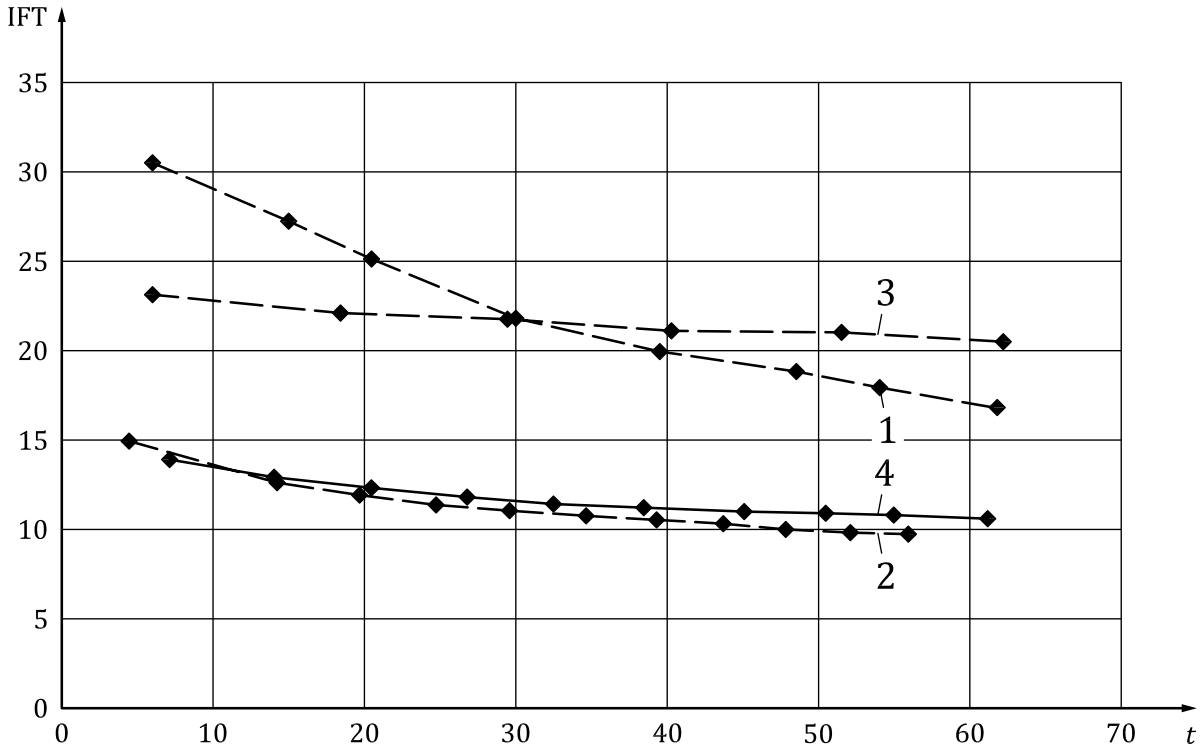
— water saturation level according to Annex E;

— bio diesel content (optional);

— density (optional);

— kinematic viscosity (optional);

— CFPP (optional).



Key

t	interface age (s)
IFT	interfacial tension (mN/m)
1	F1 (B0 Premium field fuel)
2	F1 (B7 Premium field fuel)
3	F 2.1
4	F 2.2

Figure 1 — Time dependency of interfacial tension [IFT(*t*)] for F1 fuels, F2.1 and F2.2 fuel

Figure 1 is showing two typical IFT(*t*)-curves for commercially available F1 fuels and for F 2.1 and F 2.2 fuel.

Depending on the F1-quality, the brand/product specific slope in IFT(*t*) does not allow to deduct the F1 IFT(10 s) value based on the measured F1 IFT(60 s) value.

The Monoolein specific slope in IFT(*t*) of F2 fuel is stable and reproducible, therefore the deduction of the F2 IFT(10 s)value - based on the measured F2 IFT(60 s) value - is valid and proven.

The test fuel shall be stored in a sealed container, protected from humidity, dust and light.

For each filter test fresh fuel shall be used. In the case of F2 fuel, fresh fuel can be achieved by retreating used fuel according to Annex A.

5.1.2 Test water

Clean, distilled or deionised water, with a surface tension of 70 mN/m -72 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 12937.

5.2.2 Sampling bottles and glassware

100 ml sampling bottles carefully cleaned and dried, free of any residuals from the cleaning process.

5.2.3 Water detection system

5.2.3.1 Karl Fischer (KF) titrator

As commercially available.

For biodiesel and biodiesel containing fuels the direct Karl Fischer method is recommended.

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

5.2.3.2 Centrifuge

For higher water concentration as specified in 6.4.1, 20 000 ppm water concentration, a centrifuge according to D.2 can be used. The measurement accuracy according to Table 1 shall be confirmed.

5.2.4 Equipment for determination of IFT

The equipment for determination of the interfacial tension shall be according to ISO 9101.

5.3 Test stand

5.3.1 General

The test stand, shown diagrammatically in Figure 2, shall comprise a fuel/water separator test circuit as described in 5.3.2.

All parts in contact with fuel, should be made of stainless steel.

5.3.2 Fuel/water separator test circuit

5.3.2.1 Fuel sump (1)

The container with a conical bottom should be made of stainless steel. The fuel outlet shall be located at the lowest point of bottom. The container shall be able to contain the volume as specified in 6.1. The fuel sump shall be covered with a non-transparent cover to protect the fuel from light. The fuel sump shall contain a suitable device to maintain homogeneity of its content.

5.3.2.2 Water sump (6)

The container should be made of stainless steel or corrosion resistant material with appropriate volume.

NOTE Instead of the container, a continuous water supply unit can be used.

5.3.2.3 Heat exchanger (3)

The heat exchanger shall be able to maintain the test fuel temperature T within the tolerances given in Table 1.

Alternative to the position of the heat exchanger depicted in Figure 2, the heat exchanger can as well be positioned downstream the back pressure gauge (16).

5.3.2.4 Test pump (2)

A pump type shall be chosen, which does not exhibit pressure pulsation with an amplitude greater than 10 % of the average pressure at the inlet of the water emulsifying device.

5.3.2.5 Water injection pump (7)

The pump type shall be adjustable to enable a water concentration in the test circuit between 1 500 ppm and 20 000 ppm over the complete flow rate of test fluid.

5.3.2.6 Fuel flow meter (5a)

The equipment shall be suitable for the complete range of the flow rate of test fluid with an accuracy as specified in Table 1.

5.3.2.7 Water flow meter (5b)

The equipment shall be suitable for the complete range of the required injection range with an accuracy as specified in Table 1.

5.3.2.8 Injection device (8)

The concept shall allow a continuous water injection. The resulting DSD at the injection point shall be validated. The validation criterion is defined by:

$d_{3,50}$ shall be greater or equal to the $d_{3,50}$ value chosen according to 6.7

5.3.2.9 Water emulsifying device (9)

The concept shall be able to generate a DSD as specified according to 6.7. Jet emulsification - as described in Annex B is recommended to be applied.

For each combination of emulsifying device, test fuel, flow rate and temperature a calibration curve is mandatory

In case the jet emulsification concept in accordance with Annex B is used, the calibration procedure is described in B.4.

5.3.2.10 Operating pressure gauge (10)

The operating pressure is defined at the up-stream side of the test fuel water separator (14). The required accuracy is specified in Table 1.

5.3.2.11 Differential pressure gauges (11)

The required accuracy is specified in Table 1.

5.3.2.12 Upstream sampling point (12)

The upstream sampling point shall be designed as illustrated in Figure 4.

5.3.2.13 Temperature indicator (13)

The required accuracy is specified in Table 1.

5.3.2.14 Water drainage system (15)

Realized as a graduated and transparent collector (e.g. laboratory measuring cylinder), located directly below the test fuel/water separator (14). The internal diameter of the connecting pipe between the test fuel/water separator (14) and the graduated water drainage system (15) shall be of at least 10 mm an unconstrained removal of water. It shall be realized with pressure-tight fittings. The collector volume shall be drainable at its lowest point.

The collector volume shall be adjusted to the total amount of water injected, with a maximum of 5 % of the volume of test fuel V_T (according to 6.1).

In case the collected amount of water is reaching 80 % of the collector volume, the water shall be drained out of the collector within approx. 1 min. The collector outlet valve shall be adjusted adequately. Care should be taken, not to take samples during or immediately after the water draining.

5.3.2.15 Back pressure gauge (16)

For determination of back pressure with an accuracy as specified in Table 1.

5.3.2.16 Back pressure control valve (17) (optional equipment)

The backpressure control valve is to ease test fuel/water separator venting, to adjust the back pressure and allow sufficient sampling at the upstream sampling point. When adjusting the back pressure, the test fuel/water separator design pressure shall be taken into consideration.

5.3.2.17 Downstream sampling point (18)

For manual sampling the operating conditions at sampling point 18 shall fulfil the requirements defined in D.1.1. Proper sampling can be reached by adjustment of a suitable back pressure value.

The downstream sampling point shall be designed as illustrated in Figure 4.

5.3.2.18 Clean-up system (19)

A suitable fuel water clean-up system with the capability to separate the water – such that not more than 50 ppm by volume of undissolved water is recycled on an average basis under test conditions – shall be installed.

5.3.2.19 Droplet size distribution measurement device (20)

Laser diffraction measurement device according to ISO 13320.

The measurement device shall not influence the droplet size distribution. This is especially valid for an inline measurement cell, which is designed as a full flow concept.

In case no droplet size measurement device is used and the jet emulsification concept according to Annex B is applied, for each combination of orifice, batch of test fuel (independent of it being F1 or F2 fuel), flow rate and temperature, a calibration curve shall be used (further explanation is given in B.4).

5.3.2.20 Bypass line (21)

The total length of the bypass line shall be as short as possible.

5.3.2.21 Inline water concentration measurement device (22) (Optional equipment)

Suitable inline water concentration measurement devices can be used. The measurement accuracy according Table 1 shall be confirmed.

The inline water concentration measurement device shall be placed into the pipe in the full flow at the position of the up- and/or downstream sampling points (optional installation) as defined in Figure 2.

5.3.2.22 General requirements on the hydraulic piping system

The test stand piping shall be designed to enable the drainage of the total test fuel volume out of the test stand. This is to ensure the correct adjustment of the test fuel volume within the limits specified in Table 1.

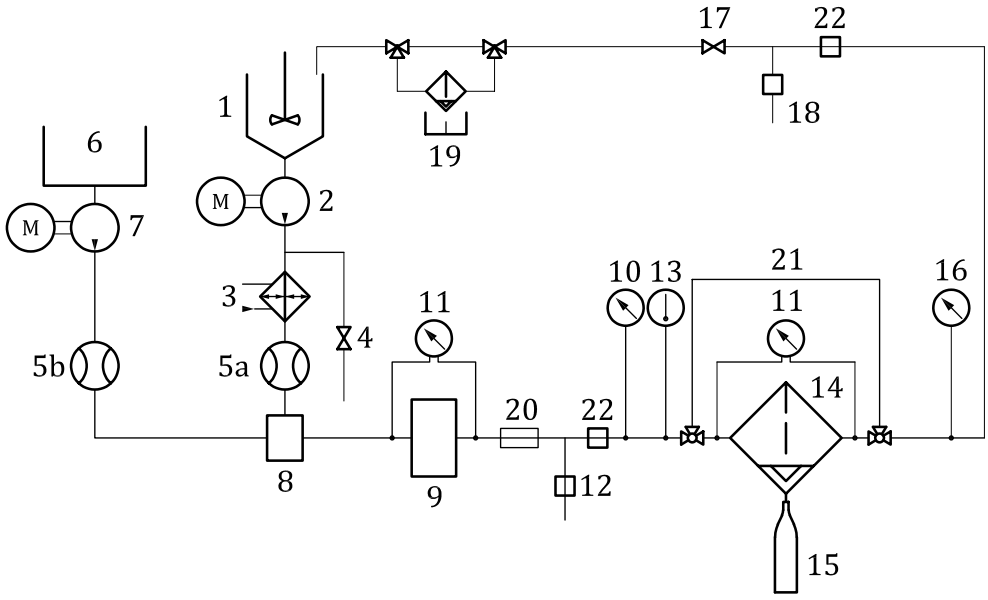
The test stand pipes shall be made of stainless steel; painted or coated pipes are not allowed.

For the adaptation of the test fuel/water separator (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 fuel/water separator (potential difference <10 V between each point).

The test stand section line inner diameter d_i between water injection device (8) and downstream sampling point (18) shall allow a flow velocity ≥0,75 m/s. The overall pipe length between the water emulsifying device (9) and test fuel/water separator (14) shall not to exceed 1 m. (Figure 3).

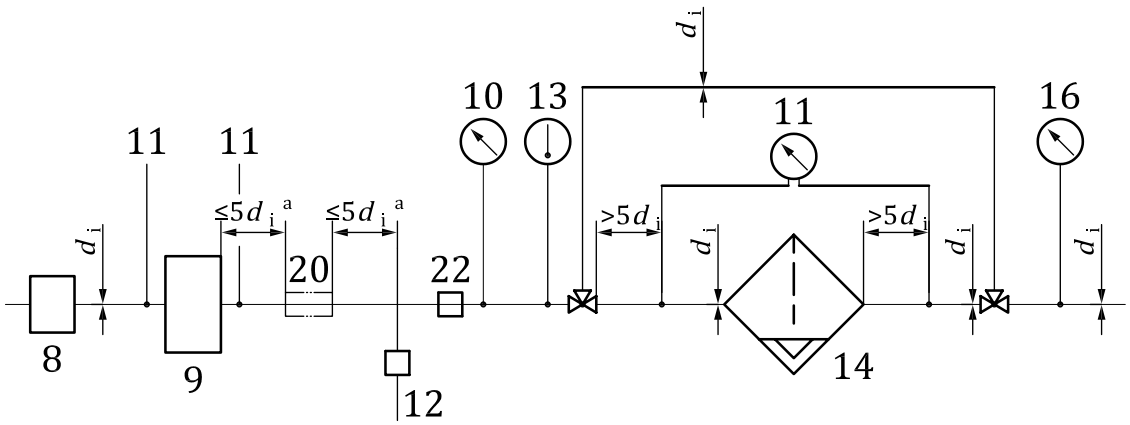
The pipes, outside of Figure 3, shall be as short as possible.



Key

1 fuel sump including homogenizing device
2 test pump
3 heat exchanger
4 sampling point
5a fuel flow meter
5b water flow meter
6 water sump
7 adjustable water injection pump
8 injection device
9 water emulsifying device (orifice)
10 operating pressure gauge
11 differential pressure gauges (2)
12 upstream sampling point
13 temperature indicator
14 test fuel/water separator
15 graduated water drainage system
16 back pressure gauge
17 back pressure control valve (optional)
18 downstream sampling point
19 clean-up system
20 DSD measurement device
21 bypass line
22 inline water concentration measurement devices (optional)

Figure 2 — Fuel/water separator test stand (diagrammatically)



Key

d_i inner pipe diameter
a for $d_i < 10$ mm: $\leq 10\ d_i$

Figure 3 — Distances of components and inner diameter d_i of test stand pipes