

# INTERNATIONAL STANDARD

# ISO 4020

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## Road vehicles — Fuel filters for diesel engines — Test methods

*Véhicules routiers — Filtres à combustible pour moteurs diesels —  
Méthodes d'essai*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

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

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

International Standard ISO 4020 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 7, *Injection equipment and filters for use on road vehicles*.

This first edition cancels and replaces ISO 4020-1:1979, which has been technically revised. The former Part 2 has been withdrawn.

Annexes A to G form a normative part of this International Standard.

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# Road vehicles — Fuel filters for diesel engines — Test methods

## 1 Scope

This International Standard specifies the types of test for fuel filters in accordance with their application.

This International Standard applies to fuel filters provided for road vehicles with diesel engines and for test installations for fuel injection equipment.

The test described may be used for fuel filters located either on the pressure side or on the suction side of the fuel supply pump.

This International Standard is intended for filters having a rated flow of up to 200 l·h<sup>-1</sup>.

By agreement, the tests, with some modifications, may be used for filters with higher rates of flow.

## 2 Normative references

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

ISO 565:1990, *Test sieves — Metal wire cloth, perforated metal plate and electroformed sheet — Nominal sizes of openings*

ISO 760:1978, *Determination of water — Karl Fischer method (General method)*

ISO 2719:—<sup>1)</sup>, *Determination of flash point — Pensky-Martens closed cup method*

ISO 2942:1994, *Hydraulic fluid power — Filter elements — Verification of fabrication integrity and determination of the first bubble point*

ISO 3016:1994, *Petroleum products — Determination of pour point*

ISO 3104:1994, *Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity*

ISO 3405:2000, *Petroleum products — Determination of distillation characteristics at atmospheric pressure*

ISO 3675:1998, *Crude petroleum and liquid petroleum products — Laboratory determination of density — Hydrometer method*

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1) To be published. (Revision of ISO 2719:1988)

ISO 4548-7:1990, *Methods of test for full-flow lubricating oil filters for internal combustion engines — Part 7: Vibration fatigue test*

ISO 8213:1986, *Chemical products for industrial use — Sampling techniques — Solid chemical products in the form of particles varying from powders to coarse lumps*

ISO 11841-1:2000, *Road vehicles and internal combustion engines — Filter vocabulary — Part 1: Definitions of filters and filter components*

ISO 11841-2:2000, *Road vehicles and internal combustion engines — Filter vocabulary — Part 2: Definitions of characteristics of filters and their components*

ISO 12103-2:1997, *Road vehicles — Test dust for filter evaluation — Part 2: Aluminium oxide test dust*

ASTM-D 971-99a, *Standard Test Method for Interfacial Tension of Oil Against Water by the Ring Method*

ASTM-D 2784-98, *Standard Test Method for Sulfur in Liquefied Petroleum Gases (Oxy-Hydrogen Burner or Lamp)*

### **3 Terms and definitions**

For the purposes of this International Standard the terms and definitions given in ISO 11841-1, ISO 11841-2 and the following apply.

NOTE Pressures are indicated in kPa (instead of bar) or in Pa (instead of mbar); to obtain them in bar or mbar, divide them by  $10^2$ . (100 kPa = 1 bar; 100 Pa = 1 mbar)

#### **3.1 sedimentor**

separator in which contaminant is removed by density difference

#### **3.2 instantaneous filtration efficiency**

$h$   
ratio between the test contaminant retained versus that added, expressed as a percentage

$$\eta = 100 \frac{d_1 - d_2}{d_1}$$

where

$d_1$  is the concentration of test contaminant at filter inlet;

$d_2$  is the concentration of test contaminant at filter outlet.

#### **3.3 filter life**

$t$  or  $V$   
service interval of a filter or filter element until maintenance or replacement, expressed in minutes or until final differential pressure is reached, expressed in litres

#### **3.4 pressure difference**

$P_{\text{stat}}$   
difference in static pressure between upstream and downstream of a filter, expressed in pascals

### 3.5 rated flow

$q_v$

normal operating flow at which liquid is passed through a filter, expressed in litres per hour or litres per minute

NOTE The flow can be that specified by the manufacturer or as agreed between manufacturer and user.

### 3.6 contaminant, organic

suspension of finely divided carbon black in test liquid, formulated to provide similar filter choking characteristics to those of normal diesel fuel

### 3.7 contaminant, inorganic

fused aluminium oxide dust of closely controlled particle size

NOTE It is the incombustible constituent that is added to the organic contaminant for the purpose of revealing the instantaneous filtration efficiency property of a filter.

### 3.8 collapse/burst pressure of filter element

$p_{diff}$

differential pressure at which a choked filter element suffers structural failure, expressed in kilopascals

### 3.9 burst pressure of complete filter

$p$

internal pressure at which the filter housing suffers structural failure, expressed in kilopascals

### 3.10 fabrication integrity test

test to indicate quality standard of filter element by measurement of volume of air escaping through filter medium or joints in unit time, when immersed in liquid at specified depth and internal pressure

NOTE The volume is measured in millilitres per minute and is given the symbol  $V_B$ .

### 3.11 test of cleanliness

test to enable the degree of cleanliness of new filters to be determined and reveal the amount of impurities flushed from the clean side of the filter under specified test conditions

NOTE The amount is measured in milligrams and is given the symbol  $W$ .

### 3.12 test flow rate

$q_t$

rate at which test liquid flows through the filter during a specific test, expressed in litres per hour or litres per minute

NOTE It may be different from the rated flow  $q_v$ .

### 3.13 undissolved water

water dispersed in test liquid

NOTE This means diesel fuel containing water which can be separated by physical means, e. g. by centrifuging.

## 4 Flow rates

The test flow rate shall reflect service conditions and shall be one of the following values:

10 l·h<sup>-1</sup>, 25 l·h<sup>-1</sup>, 50 l·h<sup>-1</sup>, 75 l·h<sup>-1</sup>, 100 l·h<sup>-1</sup>, 125 l·h<sup>-1</sup>, 150 l·h<sup>-1</sup>, 175 l·h<sup>-1</sup>, 200 l·h<sup>-1</sup>

or as agreed between filter manufacturer and user.

## 5 Test materials

### 5.1 Test liquid

The test liquid used for all tests, except the water separation test (see 6.5) and collapse/burst test of the filter element (see 6.6), shall be a straight mineral oil<sup>2)</sup> with properties as shown in annex A.

Except in tests 6.1 and 6.2, this liquid shall be used at such a temperature that the kinematic viscosity of the liquid lies between 4 mm<sup>2</sup>/s and 6 mm<sup>2</sup>/s. Alternatively, the liquid shall be blended with refined spindle oil or premium grade kerosene to give a viscosity that is between these limits at the test temperature. All test liquids shall be free from additives apart from colouring dyes. Provision shall be made to ensure that the test liquid is free from undissolved water. The liquid for each test shall be drawn from its storage container at a point above the zone of sedimentation.

Before use, and if needed, all liquids shall be passed through a highly efficient filter medium, the latter being adequately supported and suitably clamped at the edges; see the following items from B.3 (2nd, 3rd and 4th items under **Other equipment**), e.g.:

- vacuum pump: 85 kPa below atmospheric pressure;
- filtration apparatus: filter paper disc holder;
- filter paper disc or membrane: diameter 140 mm, mean pore size between 0,4 µm and 1,1 µm.

The differential pressure across the filter paper shall not exceed 85 kPa.

Providing the test liquid is suitably cleaned, it may be reused up to a maximum of 20 times.

### 5.2 Test contaminants for tests to determine instantaneous filtration efficiency and filter life

#### 5.2.1 Organic contaminant concentrate

The concentrate (see note) shall consist of a dispersion in a ratio of 1 g of carbon black to a mixture of 90 ml of test liquid and 10 ml of dispersant additive.

For the method of preparation, see annex C.

The specification of the carbon black can be found in annex D.

NOTE This concentrate is difficult to prepare and when prepared requires to be tested for suitability as described in annex C.

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2) Suitable products are available commercially. Details (product list) may be obtained from the Secretariat of Technical Committee ISO/TC 22 or from the ISO Central Secretariat.

### 5.2.2 Inorganic contaminant

The contaminant shall be fused aluminium oxide dust. The particle size distribution shall conform to grades M1 and M2 of ISO 12103-2. Normally, grade M2 dust shall be used, however, for filters manufactured from fine paper the finer M1 grade dust shall be used as an alternative contaminant.

### 5.3 Test installation, general

There shall be no sudden changes in tube or hose bore throughout the test rigs.

## 6 Tests

### 6.1 Test for cleanliness of new filters

#### 6.1.1 Purpose of the test

This test shall be carried out first to ascertain whether the clean side of the filter to be tested is free from dirt and of other loose particles which may result from production, storage and transport.

#### 6.1.2 Test installation

See B.1.

The test liquid temperature shall be  $23\text{ °C} \pm 5\text{ °C}$ .

#### 6.1.3 Other equipment

See B.1.

#### 6.1.4 Procedure

- a) Clean and dry the test sieve for 30 min in a drying cabinet at approximately  $20\text{ °C}$  above the final boiling point of the petroleum ether employed in accordance with 6.1.4 d) and allow to cool for 30 min to ambient temperature.
- b) Weigh the test sieve to the nearest 0,1 mg on a laboratory balance and insert the test sieve in a horizontal position in the measuring device (B.1.7).
- c) Pump the test liquid through the circuit for 1 h at twice the rated flow of the filter under test.
- d) Spray approximately 10 ml of petroleum ether through the cleaning hole on to the inner walls of the measuring device in order to wash down particles from the wall and to gather them on the sieve.
- e) Remove the test sieve with tweezers, place it on filter paper and allow to dry.
- f) Place the test sieve in a clean, dry Petri dish, cover it with a lid, dry and allow to cool as before the first weighing.
- g) Weigh the test sieve to the nearest 0,1 mg. The mass of dirt released by the filter is equal to the difference between the results of the two weighings of the sieve.

#### 6.1.5 Test report

The test report shall indicate at least the following:

- a) the filter make and model;

- b) a description of the filter tested and internal diameter of connections;
- c) the rated flow, in litres per hour;
- d) the type or blend of test liquid.

Indicate the mass, in milligrams, of dirt released.

## 6.2 Fabrication integrity test

This test shows whether the filter element is “tight”; i.e. whether it does not contain pores larger than the unused filter medium. The test shall be conducted in accordance with ISO 2942. However, test liquid in accordance with annex E shall be used instead of isopropanol, as specified in ISO 2942. If this test is made, it should be carried out prior to the other tests specified, but it may be carried out after the cleanliness test.

## 6.3 Test for differential pressure of new filters

### 6.3.1 Purpose and application of the test

The purpose of this test is to measure the differential pressure across the filter at the filter manufacturer’s rated flow. This test shall be carried out prior to the tests for instantaneous filtration efficiency and filter life and for water separation efficiency, but may be carried out after the cleanliness and fabrication integrity tests.

NOTE This method is equally applicable for the measurement of the pressure drop in a filter which has been in use for a determined period, or at a flow rate different from the nominal rate.

### 6.3.2 Test installation

See B.2.

The test liquid temperature shall be  $23\text{ °C} \pm 5\text{ °C}$ .

### 6.3.3 Other equipment

See B.2.

### 6.3.4 Procedure

- a) Connect the filter to be tested to the test rig, start up the system and prime and vent the filter to ensure removal of air from the filter and pressure gauges, inverting the filter if necessary.
- b) Close the control valve (B.2.10) and adjust the pressure by means of the by-pass valve (B.2.12) to that used in practice. Adjust the zero of the differential manometer (B.2.14).
- c) Open the control valve to re-establish the pressure reading on the upstream pressure gauge (B.2.8) to that used in practice, and partially close the by-pass valve. Thus adjust the flow rate, indicated by the flowmeter (B.2.6), to the desired value.
- d) Record the value shown on the differential manometer.

### 6.3.5 Test report

The test report shall indicate at least the following:

- a) the filter make and model;
- b) a description of the filter; whether it is new or used; in the latter case, the approximate period of service;

- c) the rated flow and the test flow rate, in litres per hour;
- d) the type of blend of test liquid;
- e) its viscosity at the test temperature, in square millimetres per second;
- f) the test temperature, in degrees Celsius;
- g) the internal diameter,  $d$ , actually used for the pipes itemized in B.2.

Indicate the differential pressure in Pa.

## 6.4 Test for instantaneous filtration efficiency and filter life

### 6.4.1 Purpose and application of the test

The purpose of this test is to measure the percentage retention of specific particles by a filter under defined test conditions and at the filter manufacturer's rated flow.

It is useful to conduct the test with filters which have already been tested by the cleanliness test, the fabrication integrity test or the differential pressure test.

### 6.4.2 Test installation

See B.3.

The test liquid temperature shall be  $23\text{ °C} \pm 5\text{ °C}$ .

### 6.4.3 Other equipment

See B.3.

### 6.4.4 Procedure

#### 6.4.4.1 Description

The filter test shall be carried out as a continuous process during which the contamination concentration of the test liquid being fed to the filter is constant. The effectiveness of the filter under test (**B.3.8**) is determined by measuring the amount of inorganic test dust remaining in the effluent samples initially and during the process of choking.

Clean test liquid is pumped from the tank (**B.3.1b**) by means of the main delivery pump (**B.3.6**) through the filter under test into the collection tank (**B.3.12**). This enables the filter to be primed and vented. The organic and inorganic contaminants are added as follows:

- a) either as shown in diagram B.3: manually into the tanks (**B.3.1a** and **B.1.3b**) with the contaminants held in suspension with stirrers (**B.3.2**);
- b) or as shown in Figure B.4: with the injection pump (**B.3.21**) the organic contaminant is fed into the tank (**B.3.1a** or **B.3.1b**) and with the injection pump (**B.3.24**) the inorganic contaminant is fed via the injection nozzle (**B.3.25**) before the main delivery pump. The contaminants are held in suspension in the injection tanks by recirculating pumps (**B.3.19** and **B.3.23**).

The main delivery pump transfers this suspension to the filter under test, from which the filtered liquid flows via the flow-measuring device [head tube (**B.3.10**)] and the orifice (**B.3.11**) into the collection tank. Samples of the effluent are taken 2 min after the addition of the contaminants and at 4 min intervals thereafter for the determination of the inorganic concentration. The continuity of the process is ensured by having a second tank (**B.3.1b**) prepared and

ready for use in the event that the whole of the contaminated test liquid contained in the first tank (**B.3.1a**) has been used up.

The test for instantaneous filtration efficiency and filter life ends when the end pressure or any other agreed value is attained.

To determine the instantaneous filtration efficiency of felt filters, terminate the instantaneous filtration efficiency test after 20 min and analyse the samples taken during that time period.

#### 6.4.4.2 Preparation of contaminants

##### 6.4.4.2.1 Organic contaminant

See 5.2.1 and annexes C and D.

Before use ensure that the organic contaminant is thoroughly mixed; an example of the mixing procedure is as follows.

- a) The contaminant shall be supplied in a container which is not more than 75 % full. It shall be agitated by hand shaking for approximately 5 min. To do this, the container shall be turned upside down and back again a number of times.
- b) Immediately following this, the container shall be placed on its side on a laboratory shaker and agitated at a frequency of approximately 250 cycles per minute (approx. 4,2 Hz) at approximately 25 mm amplitude for 2 h.
- c) The container shall then be taken from the shaker and the cap removed. A laboratory stirrer shall be lowered into the container to a position as near as possible to the bottom and stirring shall be maintained for 3 h at a rotational frequency of approximately 1 000 min<sup>-1</sup>.
- d) Immediately after stirring, a sample shall be removed and the solid content determined (see annex F) to ensure that it is within (1 ± 0,1) % mass/volume.

##### 6.4.4.2.2 Inorganic contaminant

See 5.2.2.

- a) To obtain the test dust samples from the bulk supply, the appropriate standard sampling method, e.g. as specified in ISO 8213, shall be used.
- b) Immediately before use, each small quantity of inorganic contaminant shall be dried at a temperature between 110 °C and 150 °C (see B.3, **Other equipment**) for not less than 1 h.
- c) The inorganic contaminant shall be allowed to cool in a desiccator and shall be stored in same.

#### 6.4.4.3 Test rig and contaminants

##### 6.4.4.3.1 Preparation of test rig

- a) Prepare the test liquid as described in 5.1.
- b) Flush the test rig by pouring 5 l of clean test liquid into the main tanks and recirculating for 15 min. This is achieved by attaching a separate flexible hose to the flexible transparent hose and suspending the other end in either of the tanks.
- c) After this flushing operation, pump out and discard the test liquid; refill the rig with 10 l.

- d) Clean the test rig with an arrangement in accordance with Figure B.3 or Figure B.4.

This test shall be carried out prior to the tests for instantaneous filtration efficiency and filter life and for water separation efficiency, but may be carried out after the cleanliness and fabrication integrity tests.

- e) After approximately 30 min and before discarding the test liquid, take a sample at the orifice and determine the level of contamination using the method specified in 6.4.4.5.
- f) If the level of contamination exceeds 0,004 g/l (i.e. 1 % of the inorganic contaminant concentration), the cleaning shall be repeated until this or a lower level is reached.
- g) Prime the system by partially filling the tank (**B.3.1a**) with clean test liquid, and starting the pump to transfer test liquid through the filter under test into the collection tank. During this process, vent air from the filter by opening bleed orifices normally located on the filter head.
- h) When priming is complete, close the bleed orifices and continue pumping test liquid through the filter until the collection tank is almost full but before the level of the test liquid reaches the outlet opening of the main tank (**B.3.1a**).

#### 6.4.4.3.2 Preparation of contaminants

- a) For manual feeding, a mixture of organic contaminant concentrate and clean test liquid shall be produced with a volume ratio of 1:99 in the tanks. The concentrate shall be thoroughly mixed, as described in 6.4.4.2.1. A quantity of inorganic test dust shall be weighed out that will give a concentration of 0,4 g/l in the test liquid contained in the tanks. The inorganic contaminant shall be added to a volume of 500 ml from the contents of the tank, and then stirred for 15 min at about 1 000 min<sup>-1</sup>. The suspension of the inorganic contaminant shall then be added to the whole amount of test liquid which contains the organic contaminant in the tanks. The prepared test liquid, to which the organic and the inorganic contaminants have now been added, shall be stirred for at least 30 min with the stirrer before the start of the test.
- b) For separate contaminant injection, the organic contaminant concentrate – prepared as described in 6.4.4.2.1 – is added to the injection tank (**B.3.22**). The solids are held in suspension with the recirculating pump. The contaminant is injected in the as-delivered state.

A quantity of 80 g of the inorganic contaminant – prepared as described in 6.4.4.2.2 – is weighed out and manually wetted with a rubber scraper in 950 ml of clean test liquid. Then 5 ml of an anti-static agent are added. This is made up to 1 000 ml with clean test liquid and placed in an ultrasonic bath for 3 min to 5 min. The contaminant prepared in this way is placed in the injection tank – always in a quantity of 1 000 ml – and kept in suspension with the recirculating pump.

#### 6.4.4.3.3 Preparation of injection device for separate injection of contaminant

If the injection pumps are not in operation, the intake tubes (**B.3.26**) shall be removed from the injection tanks and the whole injection line shall be flushed with clean test liquid. During this cleaning process the whole test rig is in operation as in 6.4.4.3.1, g) though without a test filter in place; i.e., a connector pipe instead of the test filter. When the effluent entering the collector vessel is visually clean, preparation of the injection device is completed. The test filter is fitted and the test system is evacuated.

#### 6.4.4.3.4 Setting of injected quantity/calibration

Calibration or setting of the quantity injected takes place before the final arrangement of the injection lines.

The volume flow is set with the aid of the orifices [standard graduated tubes (**B.3.20**)].

The contents of the individual injection tanks are circulated during this time and the injected quantities are returned to the relevant injection tanks.

After the target value has been set the injected samples are evaluated gravimetrically; e.g., with a test volume flow rate of  $q_t = 75$  l/h and the appropriately prepared proportions of contaminant – as described in 6.4.4.3.2 and 6.4.4.3.3 – the following target values are obtained for the injected quantities:

- organic contaminant constituent: 12,5 ml/min;
- inorganic contaminant constituent: 6,25 ml/min;
- inorganic solids element: 80 mg/ml.

#### 6.4.4.4 Test procedure

##### 6.4.4.4.1 Feeding of contaminant/oil mixture

- a) Open the stopcock (B.3.4) at the bottom of the main tank (B.3.1a).
- b) Start the main delivery pump (B.3.6) and allow the test liquid to flow through the filter under test (B.3.8) and adjust the flow to the required rate (see clause 4) by controlling the speed of the pump.
- c) Record the differential pressure indicated by the differential pressure gauge (B.3.9).
- d) After 1 min, take a 300 ml sample of test liquid from the sampling pipe (B.3.14).
- e) After 2 min, 4 min and at intervals of 4 min thereafter, take 300 ml samples of effluent at the orifice (B.3.11) and record the differential pressure. Throughout the test the speed of rotation of the stirrer in the main tanks containing test liquid (see B.3) should be carefully controlled to prevent aeration.
- f) When the end pressure or any agreed value is reached, take a final sample from the orifice and a final sample from the sampling pipe.
- g) Shut off the pump and close the stopcock at the bottom of the main tank.
- h) Should the test liquid from main tank become exhausted during the test, open the stopcock at the bottom of the reserve tank (B.3.1b), close the stopcock at the bottom of the main tank and continue the test. Care shall be taken that the test liquid level does not drop so low as to allow air to be entrained.
- i) Care shall be taken that there is no interruption or variation of flow in the course of the test.
- j) Care shall be taken that the filter is not subjected to vibration or shock during the test.
- k) Care shall be taken that pulsation amplitude is less than 1/10 of average inlet pressure.

##### 6.4.4.4.2 Separate contaminant feeding

- a) Replace intake tubes (B.3.26) in the injection tanks (B.3.18) and (B.3.22).
- b) Open the stopcock at the base of either tank.
- c) The pump is switched on and the test liquid is passed through the filter under test; the flow rate is set by regulating the speed of the pump to the required value.
- d) The differential pressure indicated at the differential pressure gauge is noted.
- e) Actuated the injection pumps (B.3.21) and (B.3.24) and operate briefly (max. 15 s) at max. output – to reduce start-up time – and then set the desired flow rate on the standard graduated tubes (20) by means of the pump controller. The start of the test time is determined by the start of discoloration of the test liquid at the outlet into the collection tank (B.3.12).

- f) After 1 min, take a 300 ml sample of test liquid from the sampling pipe.
- g) After 2 min, after 4 min, and subsequently at intervals of 4 min, 300 ml samples of the effluent are to be taken at the orifice and the differential pressure noted.
- h) Either tank shall always be replenished with clean test fluid.
- i) When the end pressure or any agreed value is reached, one final sample shall be taken at the orifice and from the sampling pipe.
- j) The injection pumps and main delivery pump are switched off and the relevant stopcock closed.
- k) The intake pipes shall be removed from the injection tanks and the injection pipes shall be cleaned as in 6.4.4.3.3.
- l) Care shall be taken to ensure that the test liquid level does not fall so much that air is entrained.
- m) Care shall be taken to ensure that no interruption or variation in flow occurs during the test.
- n) Care shall be taken to ensure that the filter is not subjected to vibration or shock during the test.

#### 6.4.4.5 Determination of the mass of incombustible (inorganic) particles in the test liquid samples

##### 6.4.4.5.1 Preparation of the sample

Each sample shall be passed through the filtration apparatus specified in B.3 (2nd, 3rd and 4th items under **Other equipment**) or an equivalent apparatus. After filtration, wash the filter medium and the collected solids and the walls of the filter holder with a suitable solvent, such as petroleum ether of analytical quality, to remove all traces of the test liquid (150 ml to 200 ml is usually sufficient).

##### 6.4.4.5.2 Weighing of the residue

Ignite the filter medium and weigh the residue as specified in 6.4.4.5.3, making a correction for the ash content of the filter medium and any change in mass of the inorganic contaminant due to the incineration.

##### 6.4.4.5.3 Ashing and weighing procedure

- a) Wash a crucible (see B.3) in water to which a little detergent has been added.
- b) Dry the crucible and, using tongs, place it in a muffle furnace controlled at  $800\text{ }^{\circ}\text{C} \pm 50\text{ }^{\circ}\text{C}$  for 1 h. The crucible shall be handled with tongs from this stage onwards.
- c) Remove the crucible and place it in a desiccator until cool (i.e. for at least 1 h); weigh to the nearest 0,1 mg.
- d) Remove the filter medium from the filter holder with care, keeping it horizontal so that no insolubles are lost.
- e) If a membrane is used, roll it into a cylindrical form, holding the lower end of the filter medium above the crucible, and carefully squeeze with thumb and forefinger of both hands to form a "flat tube".

NOTE The membrane may be moistened to avoid cracking. Moistening may be achieved by carefully holding the membrane in contact with the flat surface of a clean sponge dampened with distilled water.

- f) Fold the filter medium in half until small enough to go into the crucible.
- g) Place the crucible and its contents on a hot-plate to incinerate the larger portion of combustible material; care shall be taken to avoid open conflagration of the contents.

- h) When all the filter material has been incinerated on the hotplate, place the crucible in the muffle furnace controlled at  $800\text{ °C} \pm 50\text{ °C}$ .
- i) After 2 h, remove the crucible and place it in a desiccator to cool for at least 1 h before re-weighing to the nearest 0,1 mg.
- j) Subtract the initial mass of the crucible from the final mass to obtain the mass of the residue; i.e. of the incombustible (inorganic) material.
- k) The results shall be corrected by the subtraction of the mass of ash obtained from an unused filter medium.

#### 6.4.4.5.4 Calculation of instantaneous filtration efficiency

The mass of inorganic material in each effluent sample shall be related to the average mass of inorganic material in the initial and final applied influx samples.

The percentage instantaneous filtration efficiency is given by the formula:

$$\frac{m_1 - m_2}{m_1} \times 100$$

where

$m_1$  is the average mass, in grams, of inorganic material in the applied influent;

$m_2$  is the mass, in grams, of inorganic material in the effluent.

This formula applies to each test; i.e. with and without water saturation of the element.

#### 6.4.5 Test to determine the effect of water (optional)

Immerse an unused filter element in the test liquid for 10 min, remove and drain for 10 min. Then immerse it in water for 30 min, after which remove it and allow it to drain for 10 min before installation in the test rig. Then carry out the test for instantaneous filtration efficiency and filter life in accordance with the procedure specified in 6.4.4.

#### 6.4.6 Test report

The test report shall indicate at least the following:

- a) procedure used (6.4.4.4.1 or 6.4.4.4.2);
- b) the filter make and model;
- c) a description of the filter; whether it is new or used; in the latter case, the approximate period of service;
- d) the rated flow and the test flow rate, in litres per hour;
- e) the type or blend of test liquid;
- f) its viscosity at the test temperature, in square millimetres per second;
- g) the test temperature, in degrees Celsius;
- h) the organic contaminant (see 5.2.1):
  - supplier;
  - batch No.;

- volume,  $V_9$ , in millilitres, of test liquid to choke reference paper 633/9, should be near to the standard volume  $V_0$  of 25 ml.

NOTE A choking volume range of 25 ml is permitted for reference paper 633/9 as a check on quality.

i) inorganic contaminant (see 5.2.2):

- supplier;
- grade;
- batch No.;
- 50 % mean particle size, in micrometres.

## 6.4.7 Test results

### 6.4.7.1 Presentation of test results

#### 6.4.7.1.1 Instantaneous filtration efficiency

Stage	Efficiency %	$\Delta p$ kPa
Initial (2 min)		
4 min		
8 min		
12 min and at 4 min intervals until the end pressure is reached		

Figure 1 — Presentation of filtration efficiencies

#### 6.4.7.1.2 Filter life

In terms of time:

measured time ( $t_1$ ) to choke test filter to 70 kPa or any other agreed value: ..... min;

The measured time ( $t_1$ ) shall be corrected to make allowances for variations in the choking ratios of different batches of organic contaminants, using the equation:

$$t_2 = t_1 \frac{V_0}{V_9}$$

where

$t_2$  is the corrected time;

$V_0$  is the standard volume (25 ml) to choke the reference paper 633/9;

$V_9$  is the average volume to choke the reference paper 633/9 with the batch of contaminant used in the test.

NOTE This correction to the measured time enables more accurate comparisons to be made between filter tests, using different batches of contaminant, over a period of time. See also C.3 when changes have been made to the reference papers used to determine  $V_0$ .

### 6.4.7.1.3 Diagram

The diagram showing instantaneous filtration efficiency and differential pressure versus choking time is shown in annex G.

## 6.5 Test for water separation efficiency

### 6.5.1 Purpose and application of the test

With this test, it is possible to determine the quantity of water separated by the filter from a water-oil dispersion. This test only applies to filters which are claimed to separate water. The test may be conducted with new or used filters.

NOTE The main pump (B.4.8), as specified in B.4, limits the use of the test to filters with rated flows up to 50 l/h. Filters with higher rated flows require the use of two or more pumps operating in parallel. If two or more pumps are used, the rated flow value is to be multiplied by the number of pumps.

### 6.5.2 Test installation

See B.4 and annex E.

The test liquid temperature shall be  $23\text{ °C} \pm 5\text{ °C}$ .

NOTE 1 The test installation is designed for filters downstream of the fuel supply pump (pressure side), but it is suitable for filters upstream of the fuel supply pump (suction side) as well.

For this test, ordinary diesel fuel oil, free from anti-smoke additives and undissolved water shall be used.

The test liquid shall be treated with Fuller's Earth (see B.5), followed by the addition of cetane number improver.

NOTE 2 This treatment of test liquid will tend to eliminate differences in testing fuel/water separators at different laboratories in different geographic locations.

### 6.5.3 Other equipment

See B.4.

### 6.5.4 Procedure

#### 6.5.4.1 Preparation and calibration

- a) All equipment shall be clean and free from water. Fit a new element in the absorbent filter (B.4.24), if necessary.
- b) Fill the main tank (B.4.1) with test liquid free from undissolved water. Open by-pass valve (B.4.11) and check that the stopcock (B.4.13) is shut. Start the main pump(s) (B.4.8) and adjust by-pass valve, so that the flow through the pump is 50 l/h. If two or more pumps are used, this value shall be multiplied by their number.
- c) If a recirculation system is used, allow the collection tank (B.4.20) to fill partly and refill the main tank. Start the transfer pump (B.4.21), flush the coalescer (B.4.23) and absorbent filter (B.4.24) then adjust valve (B.4.25) to balance the main flow.
- d) Fill the water tank (B.4.3) with distilled or deionized water. Open valve (B.4.6) and adjust it to give a flow of 1 l/h. If two or more pumps are used, this value shall be multiplied by their number. The percentage water content in the test liquid will then be approximately 2 % and the water will be dispersed by the action of the

main pump(s). It is essential to keep the level in the water tank reasonably constant, otherwise frequent adjustment of valve (B.4.6) will be necessary. For this purpose, it is recommended that a constant-level device (B.4.4) be fitted.

- e) Stop the water feed by shutting valve (B.4.6).

NOTE The overflow valve should be made non-operative during these operations.

#### 6.5.4.2 Test to determine the separation of undissolved water

- a) Fit the filter to be tested (B.4.15) into the circuit. Open valve (B.4.17) [plus, if necessary, valve (B.4.19)] and the stopcock. Flush the filter under test to remove air locks. Set the flow to the rated value of the filter under test or to any other required value by adjusting valves (B.4.17) and (B.4.19) and at the same time adjusting the by-pass valve so that the flow through the main pump is  $50 \text{ l/h} \pm 2,5 \text{ l/h}$  (see note). If two or more pumps are used, this value shall be multiplied by their number. Note and maintain constant the level in the head tube (B.4.18).

NOTE The reason for maintaining this flow through the main pump, regardless of the rated flow of the filter under test, is to maintain a standard condition with regard to water droplet size.

- b) Open valve (B.4.6) and adjust to give a flow of  $1 \text{ l/h} \pm 0,05 \text{ l/h}$ . If two or more pumps are used, this value shall be multiplied by their number. The filter under test will now receive test liquid having a water concentration of approximately 2 %. Note the differential pressure in the manometer (B.4.16).
- c) Continue the flow for a period of 60 min, taking 100 ml samples at the outlet (B.4.19) after 5 min, and then at 5 min intervals. As the test proceeds, water will collect in the bowl of the filter under test. This water shall be drained off whenever the bowl is 50 % full. Water shall not be drained off when a sample is being taken. If the bowl is not transparent, measure its volume and calculate the draining time interval, assuming 100 % water separation. After the final sample has been taken, again note the differential pressure on the manometer.
- d) Analyse the samples of effluent taken as described in 6.5.4.2 c) for undissolved water content in accordance with the method specified in E.2, or by the Karl Fischer method (ISO 760).

#### 6.5.5 Test report and test results

6.5.5.1 The test report shall indicate at least the following:

- a) the filter make and model;
- b) a description of the filter, whether it is new or used; in the latter case, the approximate period of service;
- c) the rated flow and the test flow rate, in litres per hour;
- d) the type or blend of test liquid;
- e) its viscosity at the test temperature, in square millimetres per second;
- f) the test temperature, in degrees Celsius.

6.5.5.2 The test results shall be presented as follows:

- a) in graphical form, as shown in annex E;
- b) initial differential pressure across filter under test, in kilopascals or pascals;
- c) final differential pressure across filter under test, in kilopascals or pascals.

## 6.6 Collapse/burst test of the filter element

### 6.6.1 Purpose of the test

The purpose of this test is to determine the resistance of the filter element to rupture under applied differential pressure.

It is useful to conduct the test with filters which have already been tested by the fabrication integrity test.

### 6.6.2 Test installation

See B.6.

For this test, an engine lubricating oil in the ISO VG 46 to ISO VG 150 (SAE 20 to SAE 40) range shall be used.

The test liquid temperature shall be  $23_{-10}^{+15}$  °C. Other temperatures may be used as agreed between the filter manufacturer and the engine manufacturer.

### 6.6.3 Other equipment

See B.6.

### 6.6.4 Procedure

Use any surface contaminant or pulverized vinsol resin (P.V. resin), the particle size distribution shall be:

- 100 % to pass 850 µm
- 85 % to pass 180 µm
- 50 % to pass 75 µm (see ISO 565)

Prepare a concentrate containing 100 g of contaminant per litre of test liquid. Pour into the tank 5 l of test liquid. Start the pump and adjust the flow to the rated flow of the filter under test, then start the stirrer. Every 5 min, add 25 ml of the concentrate to the tank.

Plot a graph of differential pressure against time. Failure of the filter element is indicated by a permanent fall in differential pressure, or by a marked drop in the rate of pressure rise. Continue the test until failure or until a differential pressure of 300 kPa or any value agreed upon between filter manufacturer and customer, is reached — whichever occurs first.

### 6.6.5 Test to determine the effect of water (optional)

Immerse an unused filter element in the test liquid for 10 min, remove and drain for 10 min. Then immerse it in water for 30 min, after which remove it and allow it to drain for 10 min before installation in the test rig. Carry out the collapse/burst test in accordance with the procedure specified in 6.6.4.

### 6.6.6 Test report

The test report shall indicate at least the following:

- a) the filter make and model;
- b) a description of the filter; whether it is new or used; in the latter case, the approximate period of service;
- c) the rated flow, in litres per hour;
- d) the collapse/burst pressure, in kilopascals.

## 6.7 Burst test of complete filters

### 6.7.1 Purpose of the test

The purpose of this test is to determine the mechanical resistance of the complete filter to internal pressure.

### 6.7.2 Test installation

- Laboratory hydraulic hand pump, with suitable connections or adaptors to attach to the filter under test.
- Pressure gauge.
- Test liquid, the properties of which are shown in annex A, suitably coloured for visual observation of leakage.

The test liquid temperature shall be  $23 \pm_{10}^{15}$  °C. Other temperatures may be used as agreed upon between the filter manufacturer and the engine manufacturer.

### 6.7.3 Test procedure

- a) Install the detachable filter housing on an appropriate head, applying the recommended average tightening torque. Connect to the pump by means of a suitable adaptor. Install spin-on filters on an appropriate adaptor, applying the recommended tightening torque for the filter under test.
- b) Connect the pump outlet pipe to the inlet of the filter or adaptor and ensure that the outlet from the filter is open.
- c) Position the filter so that the outlet is at the highest point relative to the remainder of the filter.
- d) Introduce test liquid into the filter by operating the hydraulic pump until test liquid is seen to emerge from the outlet connector of the filter. This indicates that all the air has been excluded from the system.
- e) Close the filter outlet using a suitable plug and clean off all surplus test liquid.
- f) Raise the internal pressure to 100 kPa, and maintain for 30 s, checking the filter for leaks and other adverse effects during the raising and maintenance periods of pressure.
- g) Reduce the pressure to zero by opening the venting cock on the pump, wait 30 s and check for permanent distortion or other visual defects. Attempt to rotate the housing by hand to ensure that pressure has not caused loosening. Relative movement of one half to the other of the housing assembly should be checked.
- h) Close the venting cock and repeat the above procedure, increasing the pressure in steps of 100 kPa.
- i) Continue until ultimate failure (i.e. bursting or leaking) occurs or until a pressure of 1 000 kPa or any value agreed upon between filter manufacturer and customer, is reached.

### 6.7.4 Test report

The test report shall indicate at least the following:

- a) the filter make and model;
- b) a description of the filter, whether it is new or used; in the latter case, the approximate period of service;
- c) the rated flow, in litres per hour;
- d) the failure pressure, in kilopascals or no failure at 1 000 kPa;

- e) the mode of failure and its location;
- f) the torque applied in accordance with 6.7.3 a).

## 6.8 Pulsating pressure fatigue test

### 6.8.1 Purpose of the test

The purpose of this test is to determine the mechanical resistance of the complete filter to pulsating pressure such as would occur under service conditions.

### 6.8.2 Test installation

See B.7.

**6.8.2.1 Pulse rig**, as shown in Figure B.9, capable of producing – in accordance with the values given in Table 1 – the pressure waveform indicated in 6.8.5, Figure 2, with suitable adaptors to attach the filter under test to the rig. An alternative rig is permissible provided that the pressure waveform is as indicated in 6.8.5, Figure 2.

### 6.8.2.2 Suitable torque wrench and adaptors.

**6.8.2.3 Test liquid**, the properties of which are given in annex A. It shall be suitably coloured for visual observation of leakage. The test liquid temperature shall be  $60\text{ °C} \pm 20\text{ °C}$ . Other temperatures may be used as agreed upon between the filter manufacturer and the engine manufacturer.

### 6.8.3 Test procedure

- a) Install the filter on an appropriate adaptor, applying the recommended tightening torque for the filter to be tested.
- b) Connect the test adaptor into the pipework system of the pulse test rig.
- c) Start the pump, ensuring that the valve (**B.7.4**) is fully open before commencing the test, by operating the solenoid valve control switch and the main switch.
- d) Allow the rig to run under the above conditions until all air has been excluded from the system, shut the solenoid valves, adjust the valve until the test pressure, as agreed with the engine manufacturer, is attained. Switch on the solenoid valves to obtain a pressure waveform as indicated in 6.8.5, Figure 2. Any further adjustments during the test should be made as necessary during the periods when the solenoid valves are closed in order to avoid the filter being overloaded.
- e) Set the counter to zero.
- f) When using the test rig illustrated, open the inlet and return valves of the water cooling system and adjust the water flow to regulate the reservoir oil temperature (preferred maximum:  $80\text{ °C}$ ). Ensure that the thermostat situated in the rig oil reservoir is set at  $80\text{ °C}$  as this is fitted as a safety device to switch off the rig, should the temperature rise to this level.
- g) Allow the test to continue, making visual checks for signs of failure at frequent intervals, until failure occurs or until the required number of pulses, as agreed with the engine manufacturer, has been applied.
- h) To stop the test, fully open the valve and switch off the pump and solenoid valve control switch.
- i) Check and record the tightening torque (i.e. turn in the tightening direction).
- j) Remove the filter, allow to drain, and visually examine the filter to determine the failure point and type of failure.

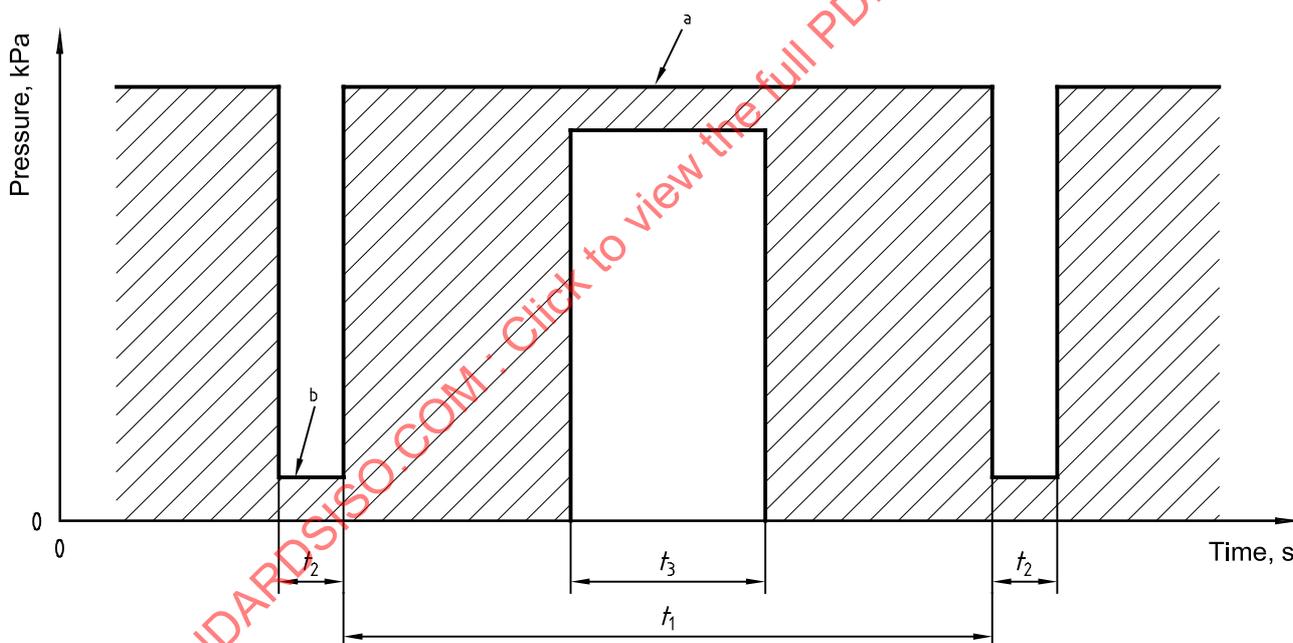
#### 6.8.4 Test report

The test report shall indicate at least the following:

- the filter make and model;
- a description of the filter, whether it is new or used; in the latter case, the approximate period of service;
- the rated flow, in litres per hour;
- the test pressure, in kilopascals;
- the mode of failure and its location;
- the torque applied initially and at the end of the test [see 6.8.3 a) and 6.8.3 i)];
- the number of cycles to failure or the number of cycles completed, as agreed [see 6.8.3 g)].

#### 6.8.5 Hydraulic pulse

The diagrammatic waveform is shown in Figure 2.



<sup>a</sup> Maximum pressure.

<sup>b</sup> < 10 % maximum pressure.

**Figure 2 — Diagrammatic waveform of the hydraulic pulse ( $t_1$  to  $t_3$  see Table 1)**

#### 6.8.6 Test procedure (if no agreement)

In the absence of an agreement between the engine manufacturer and the filter manufacturer the test values, given in Table 1, shall be used for the pulsating pressure fatigue test.

**Table 1 — Values to be used for tests (if no agreement)**

Type of fuel injection pump	Hydraulic pulse					
	Number of cycles	Pressure pulse waveform (see Figure 2)				
		max. pressure kPa	frequency Hz	$t_1 + t_2$ s	$t_2$ s	$t_3$ s
in-line	$10^5$	$500 \pm 20$	$< 5^a$	$> 0,2^a$	$\geq 0,02^a$	$\geq 0,05$
rotary distributor	$4 \times 10^4$	$200 \pm 20$				

<sup>a</sup> Ensure that less than 10 % of the maximum pressure is reached between the pulses.

**6.9 Vibration resistance fatigue test**

The purpose of such a test is to determine the mechanical resistance to vibration under normal service conditions.

Depending on the application and location of the filter on the road vehicle, the vibration fatigue test parameters shall be as agreed between engine manufacturer and filter manufacturer.

If the filter is directly mounted to the engine and if there is no such agreement the test method specified in ISO 4548-7 may be applied.

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## Annex A (normative)

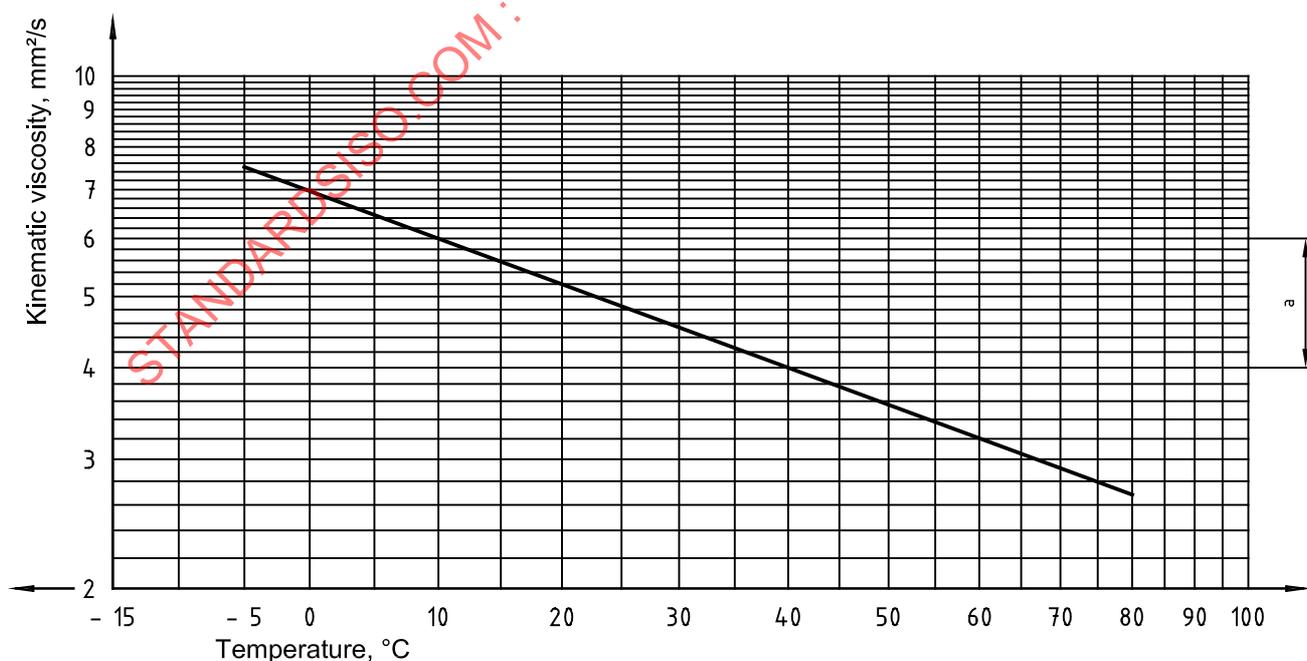
### Test liquid for fuel filter test

<b>Kinematic viscosity</b> (see ISO 3104)	6 mm <sup>2</sup> /s to 4 mm <sup>2</sup> /s at an ambient temperature of between 10 °C and 40 °C
<b>Density at 15 °C</b>	0,816 g/ml to 0,850 g/ml (see ISO 3675)
<b>Flash point</b>	99 °C to 127 °C (see ISO 2719)
<b>Pour point</b>	-10 °C max. (see ISO 3016)
<b>Additives</b>	none
<b>Sulfur content</b>	0,1 % ( <i>m/m</i> ) max. (see ASTM D 2784)
<b>Surface tension</b>	(29 ± 1) · 10 <sup>-3</sup> N/m (see ASTM D 971)

#### Distillation:

Initial boiling point	252 °C (see ISO 3405)
50 % reclaimed boiling point	275 °C (see ISO 3405)
Final boiling point	320 °C (see ISO 3405)

The test liquid shall not contain components in such a concentration that irritation of a normal skin could be caused.



<sup>a</sup> Viscosity limits for test liquid.

Figure A.1 — Typical viscosity/temperature curve for test liquid

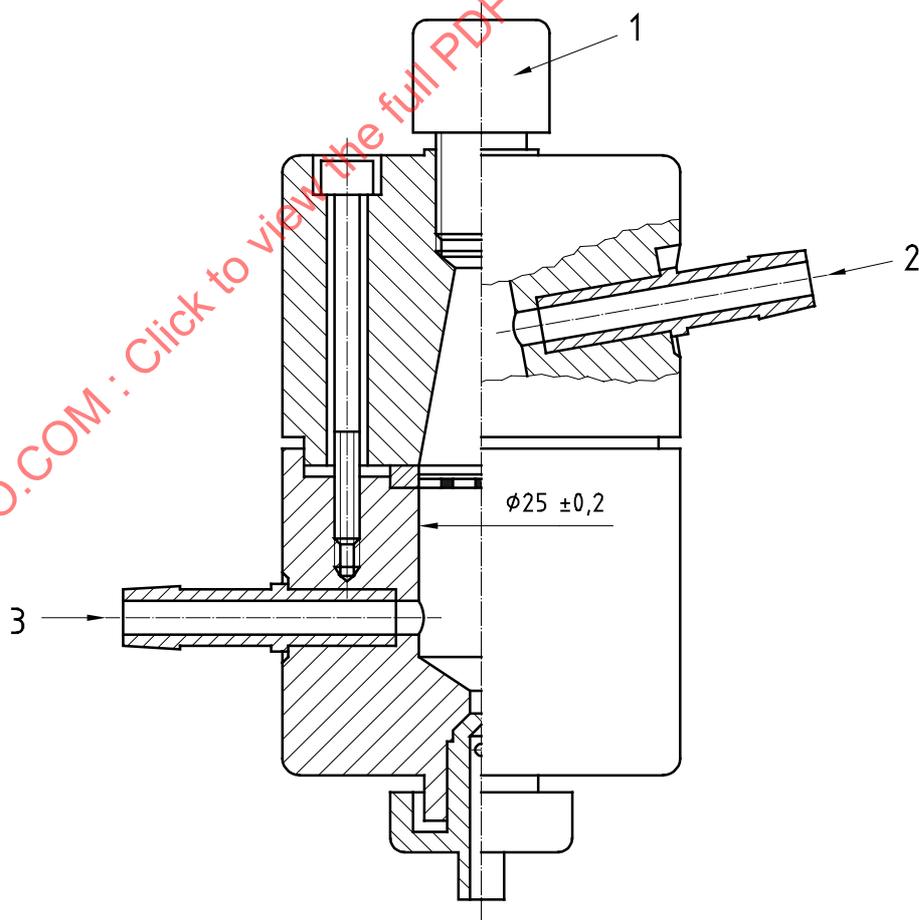
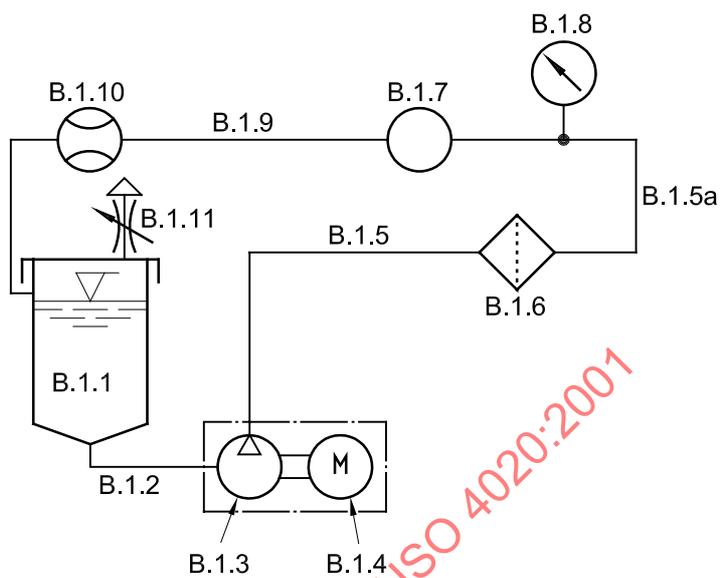
**Annex B**  
(normative)

**Test installations**

**B.1 Test for cleanliness of new filters** (see 6.1)

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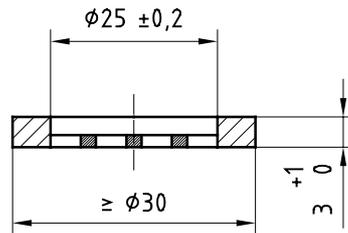
Dimensions in millimetres



**Key**

- 1 Cleaning plug
- 2 Inlet
- 3 Outlet

**Figure B.1 — Test rig for cleanliness of new filters**



NOTE 1 Test sieve of polyamide, fabric basket or twill weave; size of aperture width, 28  $\mu\text{m}$ ; wire diameter 25  $\mu\text{m} \pm 1 \mu\text{m}$ ; open area of sieve 28 %.

NOTE 2 This drawing is only an example. However, dimensions specified and specifications given for the test sieve are to be complied with.

**Figure B.1a — Enlargement of measuring device B.1.7**

**Test rig components:**

**B.1.1 Tank with test liquid**, minimum capacity 10 l, overlapping cover.

**B.1.2 Suction pipe**.

**B.1.3 Feed pump**, only pumps of plunger or diaphragm shall be used. The flow rate of the pump shall be approximately twice the rated flow of the filter under test at a differential pressure of 20 kPa.

**B.1.4 Electric motor**.

**B.1.5 Pressure pipe**.

**B.1.5a Flexible hose**.

**B.1.6 Filter under test**.

**B.1.7 Measuring device** (see Figure B.1a).

**B.1.8 Pressure gauge**, measuring range 0 kPa to 150 kPa (above atmospheric pressure).

**B.1.9 Return pipe**.

**B.1.10 Flowmeter**, adapted to normal test flow.

**B.1.11 Air vent**.

**Other equipment:**

**Drying cabinet**.

**Laboratory balance**, with an accuracy of  $\pm 0,1 \text{ mg}$ .

**Two Peri dishes**, with lids.

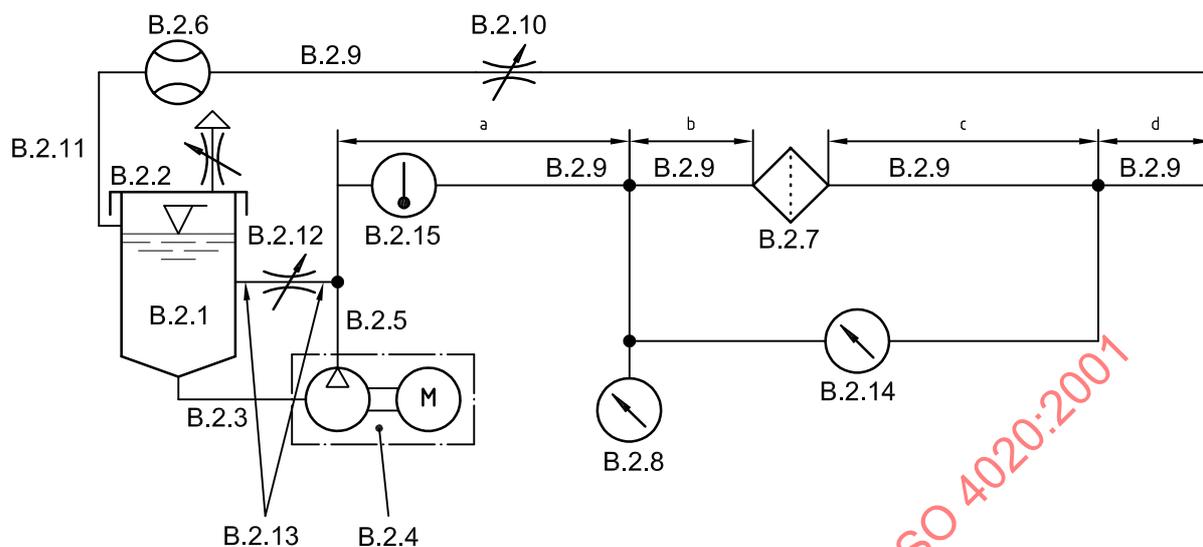
**Tweezers**.

**Soft hair brush**.

**Wash bottle**, 100 ml, filled with petroleum ether.

**Filter paper**.

## B.2 Test for differential pressure of new filters (see 6.3)



- a >  $12d$   
 b =  $8d \pm d/2$   
 c =  $12d \pm d/2$   
 d >  $8d$

where  $d$  is the internal diameter of the pipes.

Figure B.2 — Test rig for differential pressure of new filters

### Test rig components:

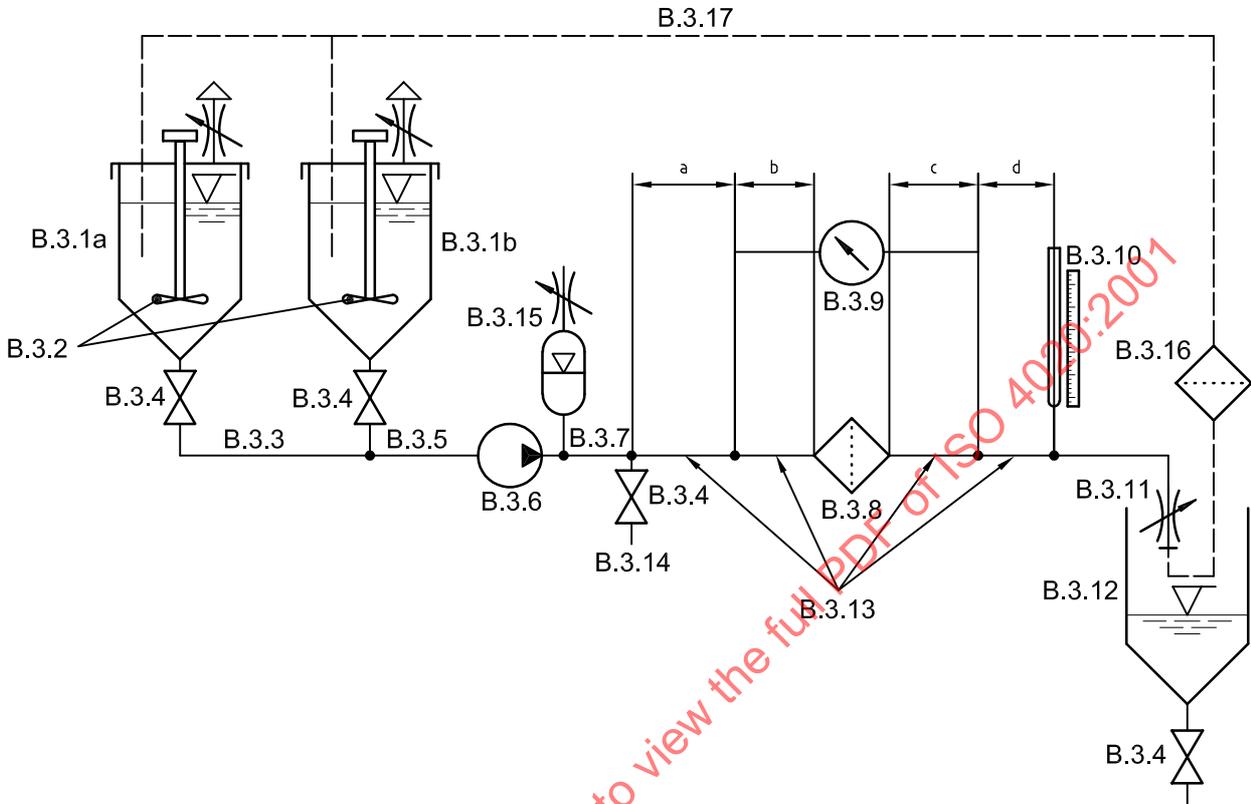
- B.2.1** Tank with test liquid, minimum capacity 10 l.
- B.2.2** Cover of the tank, with air vent.
- B.2.3** Suction pipe.
- B.2.4** Variable-speed motor-pump set, capable of non-pulsating delivery of the nominal flow at the pressure used in normal practice.
- B.2.5** Pressure pipe.
- B.2.6** Suitable flowmeter.
- B.2.7** Filter under test.
- B.2.8** Pressure gauge, with a measuring range of 0 kPa to 150 kPa (above atmospheric pressure).
- B.2.9** Filter connecting pipes, internal diameter,  $d$ , identical to filter inlet and outlet bores.
- B.2.10** Control valve.
- B.2.11** Return pipe.
- B.2.12** By-pass valve.
- B.2.13** By-pass pipes.
- B.2.14** Differential manometer, adapted to the measuring range.
- B.2.15** Thermometer.

### Other equipment:

Stop-watch.

**B.3 Test for instantaneous filtration efficiency and filter life (see 6.4)**

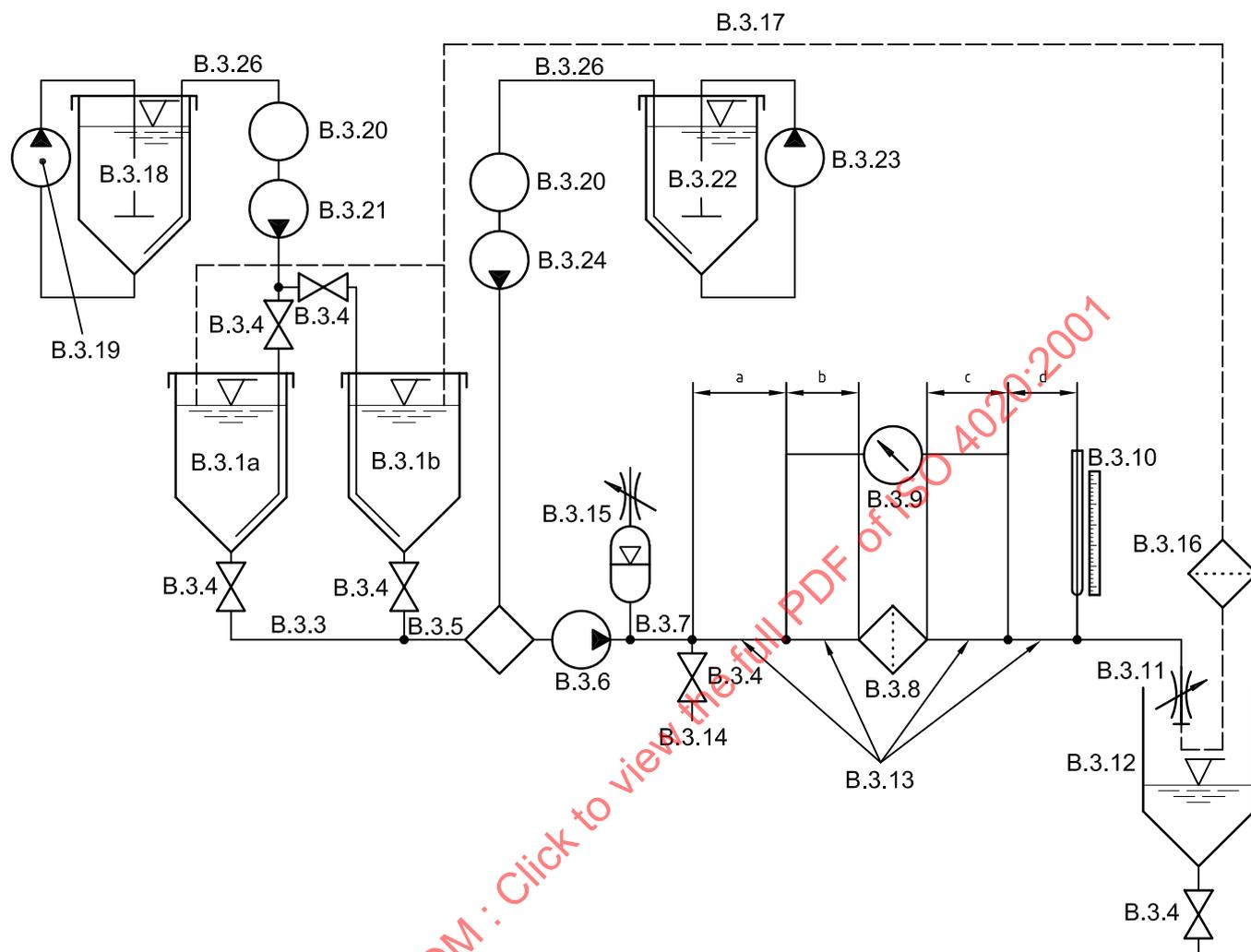
**B.3.1 Feeding of contaminant/test liquid mixture (manually)**



a, b, c, d See Figure B.2.

**Figure B.3 — Test rig for manual feeding**

### B.3.2 Separate contaminant feeding (with injection pumps)



a, b, c, d See Figure B.2.

Figure B.4 — Test rig for injection pump feeding

#### Test rig components:

**B.3.1a Main tank with test liquid**, this is round tank with smooth sides, minimum capacity 50 l, diameter approximately 380 mm, conical bottom with 90° included angle, central outlet, overlapping cover.

**B.3.1b Reserve main tank with test liquid** (description as for B.3.1a).

**B.3.2 Stirrer**, with a rotational speed of approximately  $200^{-1}$ , positioned as close to the bottom as possible. See Figure B.5a.

**B.3.3 Pipe**, with a minimum internal diameter of 12mm.

**B.3.4 Stopcock**, on/off, straight-through bore type.

**B.3.5 Hose**, with a minimum internal diameter of 12 mm.

**B.3.6 Pump (main delivery pump)**, peristaltic, with two rollers and a nominal hose bore diameter of 8 mm; continuously-variable speed control. The material of the tube shall be neoprene.

- B.3.7 Pipe**, with a minimum internal diameter of 12 mm.
- B.3.8 Filter under test**.
- B.3.9 Differential pressure gauge**, with a measuring range of 0 kPa to 70 kPa.
- B.3.10 Head tube**, made of glass and with an arbitrary scale to check flow rate in conjunction with B.3.11.
- B.3.11 Orifice**, to provide pressure for B.3.10.
- B.3.12 Collection tank**, minimum capacity 50 l, same as B.3.1a but without the cover.
- B.3.13 Filter connecting pipes**, inlet diameter,  $d$ , identical to the filter inlet and outlet bores.
- B.3.14 Samplig pipe**, metal of nominal internal diameter 6 mm.
- B.3.15 Pulse damper**, suitable for reducing amplitude of pulses to not more than 1/10 of the actual average inlet pressure.
- B.3.16 Membrane clean-up filter** (see Figure B.5b).
- B.3.17 Separate hose**, of minimum internal diameter 12 mm.

**Supplementary test rig components for separate contaminant feeding (optional) (Figure B.4 only):**

The test rig equipment of Figure B.3 shall comply with Figure B.4 apart from the stirrers (**B.3.2**) which are not required.

- B.3.18 Injection tank**, this is a round tank with smooth sides, diameter 170 mm, a cylindrical height of 220 mm, conical bottom with less than 90° included angle, central outlet, overlapping cover, capacity (cylindrical part of the vessel) approximately 5 l;
- B.3.19 Recirculating pump**, for the organic contaminant. This shall be a hose pump producing at least 5 l/min or 15 kPa; the tubes shall have 4 mm maximum internal diameter; the pump outlet shall be designed so that the flow can be clearly seen on the liquid surface.
- B.3.20 Standard graduated tubes**, for monitoring injected quantities. All injection lines and injection hoses shall have 1,6 m maximum internal diameter, as otherwise there is a danger of contaminant deposits forming.

Size and capacity of the standard graduated tubes with float:

- diameter, internal: 3,9 mm; external: 10,5 mm;
- length of graduated scale: 210 mm;
- for the float material mu-metal should be used; i.e. metal with magnetic characteristics;
- for the inorganic contaminant component:
  - flow capacity for water:  $q_v = 1,3$  ml/min to 27 ml/min (max. 1,6 l/h);
- for the organic contaminant component:
  - flow capacity for water:  $q_v = 2,1$  ml/min to 42 ml/min (max. 2,5 l/h).

These throughputs are sufficient for test flow rates up to  $q_t = 75$  l/h; for larger flow rates it is necessary to have larger standard graduated tubes, or – even better – two tubes arranged in parallel.

The quantity of organic contaminant is monitored with a ring initiator, which determines the float position in a non-contacting manner, as a limit switch function. The limit switching point should be checked manually at regular intervals by means of the controller of the injection pump (B.3.21).

**B.3.21 Injection pump**, these shall be hose pumps with a maximum input of 150 W. The following data are proposed:

- hose diameter: 0,5 mm to 8,0 mm;
- delivery, depending on hose diameter: 2 ml/min to 200 ml/min;
- tachometer generator, accuracy  $\pm 1$  %, temperature stabilized;
- operation: forward and reverse;
- number of rollers: 4.

To reduce pulsation, pump heads with double hoses and with offset, spring-loaded roller guides are recommended.

Injection hose material: Viton.

**B.3.22 Injection tank** (see B.3.18).

**B.3.23 Recirculating pump for inorganic contaminant** (see B.3.19).

**B.3.24 Injection pump** (see B.3.21).

**B.3.25 Injection nozzle for inorganic contaminant**, The nozzle tube (internal diameter 1,6 mm, external diameter 3,2 mm) shall be inserted in the middle of the delivery line [pipe (B.3.7)] (internal diameter 12 mm); the end of the nozzle tube has an outlet diameter of 1,0 mm. The injection direction is in the direction of the flow.

**B.3.26 Flexible intake tube**, these shall be arranged so that they can deliver clean test liquid from a separate tank to clean the whole injection line.

#### Other equipment:

**Laboratory balance**, with an accuracy of  $\pm 0,1$  mg.

**Vacuum pump**, operating at a maximum of 85 kPa below atmospheric pressure.

**Filtration apparatus**, filter paper disc holder (see Figure B.6).

**Filter paper disc or membrane**, with a mean pore size between 0,4  $\mu\text{m}$  and 1,1  $\mu\text{m}$  and a diameter of 140 mm (see Figure B.6).

**Drying oven**, capable of being controlled at  $130\text{ }^{\circ}\text{C} \pm 20\text{ }^{\circ}\text{C}$ , for drying inorganic contaminant (for drying filter paper disc/membrane see annex C).

**Desiccator**.

**Muffle furnace**, capable of being controlled at  $800\text{ }^{\circ}\text{C} \pm 50\text{ }^{\circ}\text{C}$ .

**Hotplate**, for preliminary combustion of filter disc, capable of being controlled at approximately  $500\text{ }^{\circ}\text{C}$ .

**Crucibles**, of porcelain or quartz, diameter approximately 40 mm and depth 36 mm.

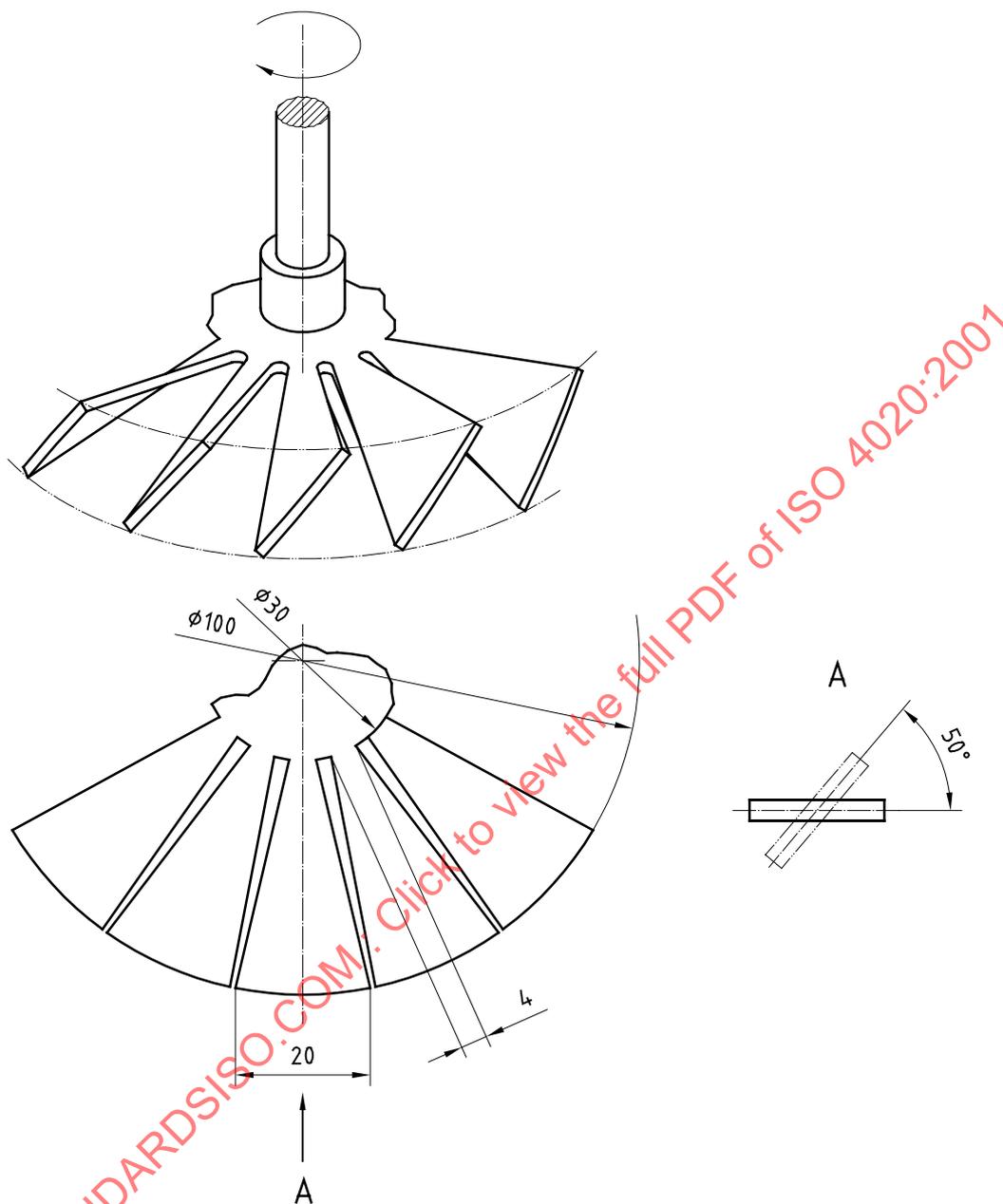
**Stop-watch**.

**Petri dishes with lid**, of glass and with a diameter of 65 mm, for storage of used filter papers.

**Beakers**, of glass and with a capacity of 400 ml.

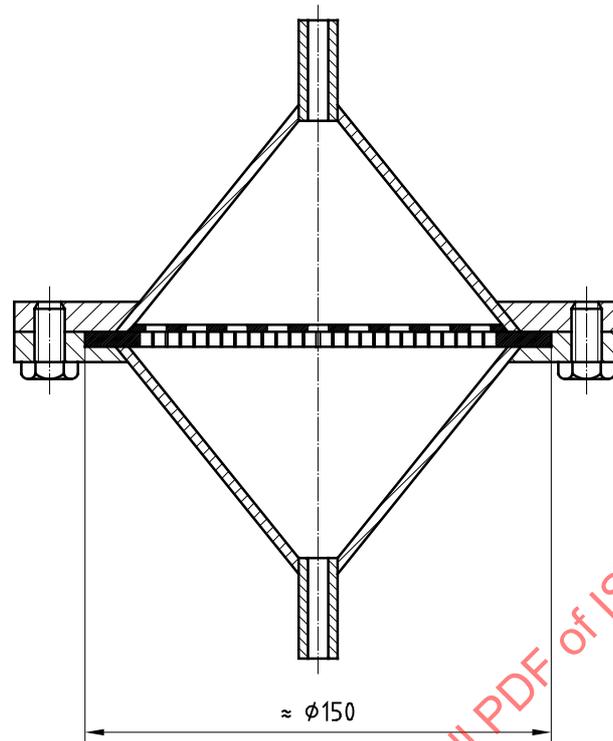
**Measuring cylinder**, of glass and with a capacity of 2 l.

**Tongs**, for holding the crucibles.



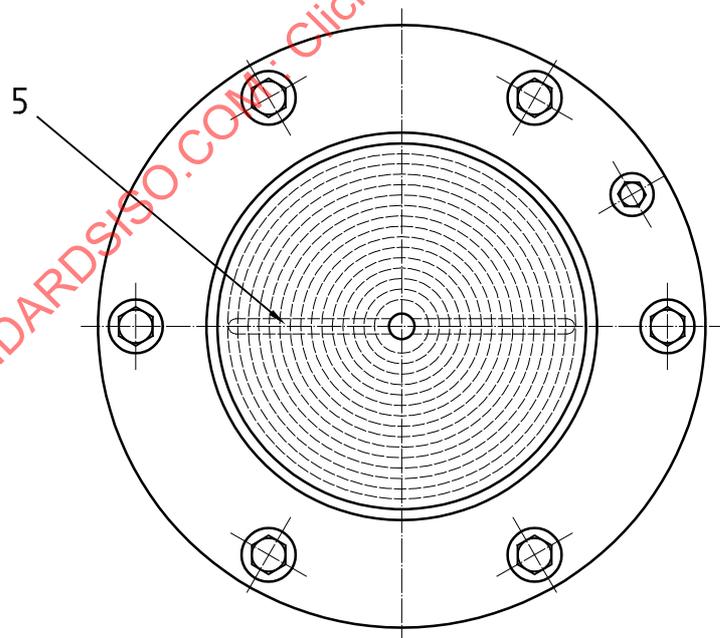
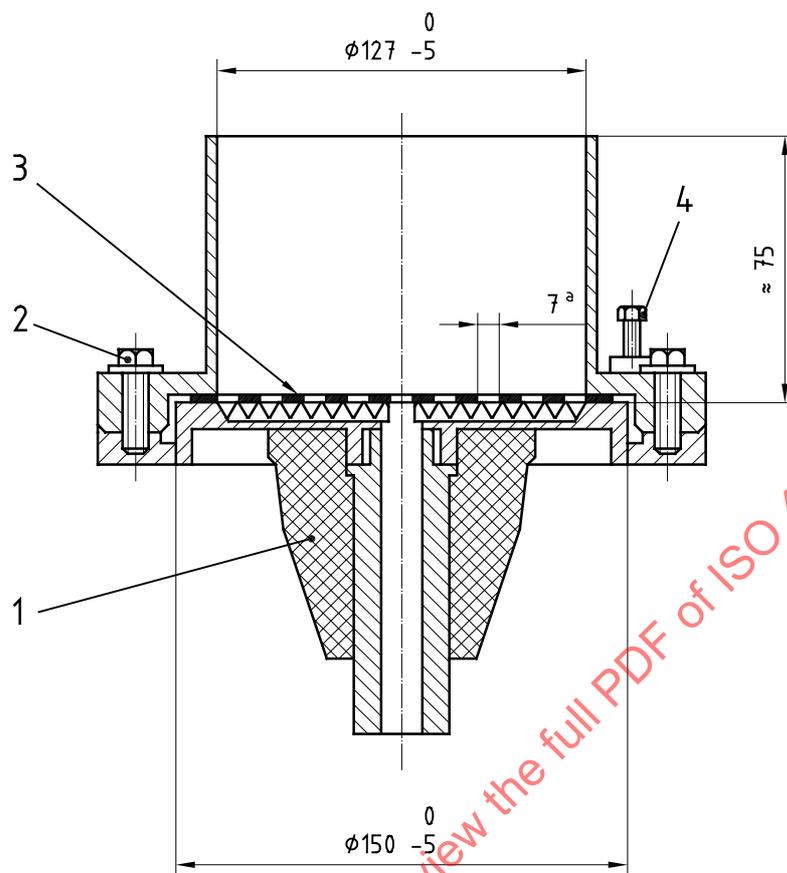
a There are 15 blades at  $50^\circ$  to the horizontal.

**a) Detail of stirrer (B.3.2)**



b) Detail of membrane clean-up filter (B.3.16)

Figure B.5 — Details of stirrer and membrane clean-up filter as used in the feeding test rigs



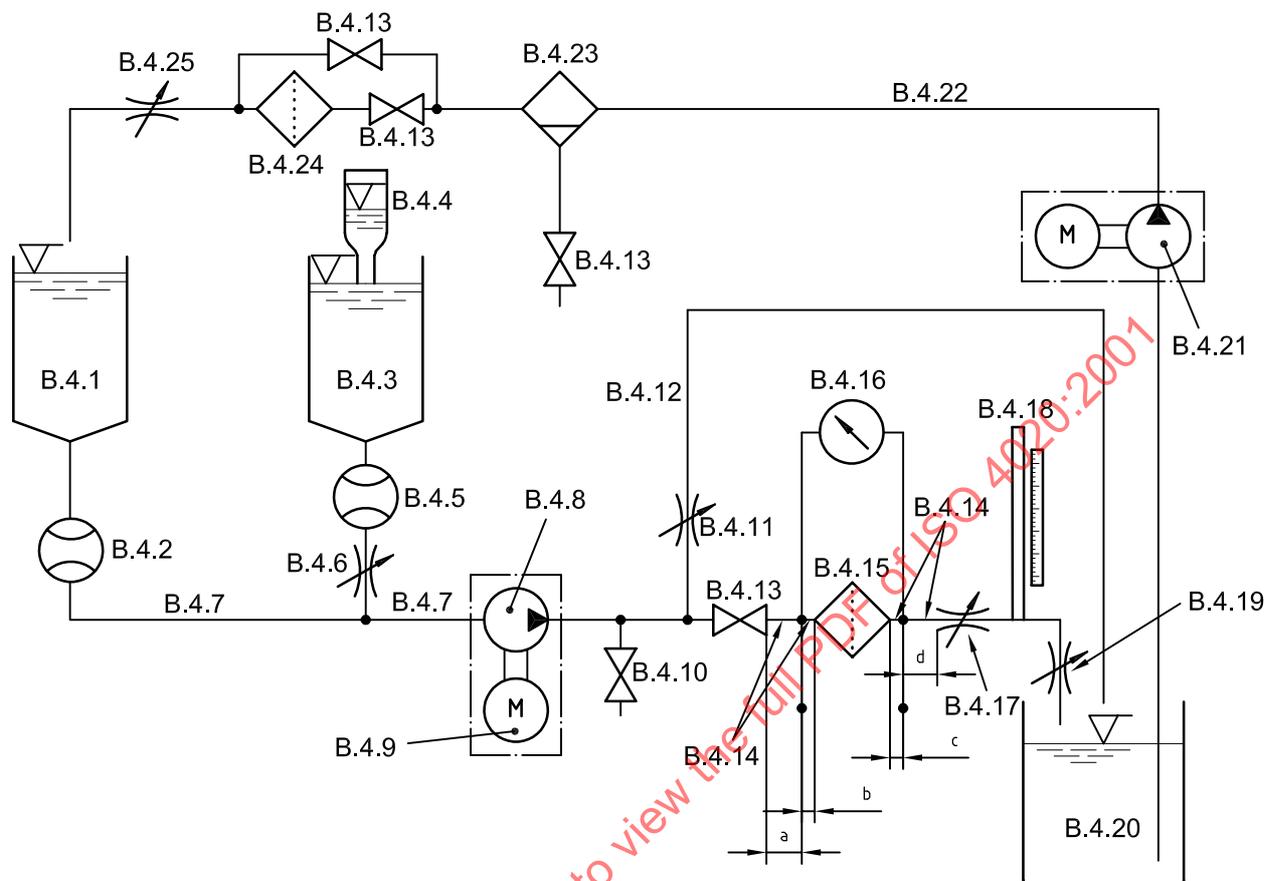
**Key**

- |   |                                      |   |                   |
|---|--------------------------------------|---|-------------------|
| 1 | Rubber bung (size to suit flask)     | 4 | Earth terminal    |
| 2 | Clamp bolts (6)                      | 5 | Drainage channels |
| 3 | Filter paper disc of diameter 140 mm |   |                   |

<sup>a</sup> Concentric rings at 7 mm pitch.

**Figure B.6 — Filtration apparatus**

## B.4 Test for water separation efficiency (see 6.5)



a, b, c, d See Figure B.2.

Figure B.7 — Test rig for water separation efficiency

### Test rig components:

**B.4.1 Main tank with test liquid**, minimum capacity 50 l.

**B.4.2 Flow meter**, with a measuring range of 0 l/h to 200 l/h.

**B.4.3 Water tank with distilled water**, minimum capacity, 1 l.

**B.4.4 Constant-level device**, minimum capacity 4 l (optional).

**B.4.5 Flow meter**, with a measuring range of 0 l/h to 4 l/h.

**B.4.6 Valve**, adjustable.

**B.4.7 Main pipe**, minimum internal diameter 12 mm.

**B.4.8 Main pump**, diaphragm type, capable of generating consistent water droplet size distribution (see also E.1).

**B.4.9 Electric motor**.

**B.4.10 Stopcock for sampling**, mounted at a distance of approximately  $8d$  from the outlet of B.4.8, on/off, straight-through bore type with a 56 mm length of 1,2 mm bore pipe at the outlet.

**B.4.11 By-pass valve**, adjustable.

**B.4.12 By-pass pipes**, minimum internal diameter 12 mm.

**B.4.13 Stopcock**, on/off, straight-through bore type.

**B.4.14 Filter connecting pipes**, internal diameter,  $d$ , identical to filter inlet and outlet bores and straight for the lengths specified in the diagram.

**B.4.15 Filter under test**.

**B.4.16 Differential pressure measuring device** (manometer), with a measuring range of 0 kPa to 40 kPa.

**B.4.17 Valve**, adjustable.

**B.4.18 Head tube with scale**, with a measuring range of 0 mm to 300 mm.

**B.4.19 Orifice or adjustable valve**.

**B.4.20 Collection tank**, <sup>3)</sup> minimum capacity 10 l.

**B.4.21 Transfer pump**, <sup>3)</sup> minimum flow rate 200 l/h.

**B.4.22 Transfer pipes**, <sup>3)</sup> minimum internal diameter 12 mm.

**B.4.23 Coalescer**, <sup>3)</sup> capable of reducing free water content to less than 300 mg/l.

**B.4.24 Absorbent filter**, <sup>3)</sup> minimum flow rate 200 l/h, capable of removing any undissolved water after B.4.23 and the additives from the fuel (see Fuller's Earth under **Other equipment**).

**B.4.25 Valve**, <sup>3)</sup> adjustable.

**Other equipment:**

**Sample bottle**, capacity 100 ml.

**Ultrasonic bath**, frequency 30 kHz to 50 kHz.

**Laboratory centrifuge**, capable of producing a centrifugal force of approximately 1 500  $g$

**Centrifuge tubes**, capable of reading down to 0,04 % of tube volume.

**Methylene blue powder**.

**Surfactant**, water-miscible, surface tension-reducing agent.

**Acetone**.

**Fuller's Earth** (see B.4.24).

**Microlitre syringe**.

**B.5 Fuel treatment to obtain test liquid as specified in 6.5.1** (treatment with Fuller's Earth)

**B.5.1** Take the required volume of ordinary diesel fuel in the fuel sump and continuously recirculate the fuel by filtering it through commercially available Fuller's Earth or clay cartridge filters in place of the clean-up filter.

**B.5.2** Periodically (about every 4 h) take a sample of the fuel in a beaker. Filter the sample through a 0,45 mm membrane and measure the interfacial tension with distilled water at  $20\text{ °C} \pm 1,5\text{ °C}$ . The platinum ring detachment method (ASTM-D 971) is recommended, although other correlatable methods may be used. Stop the fuel treatment when the interfacial tension is between  $25$  and  $30 \times 10^{-3}$  N/m.

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3) Optional item. If these items are omitted, B.4.1 and B.4.3 shall have minimum capacity of 200 l.

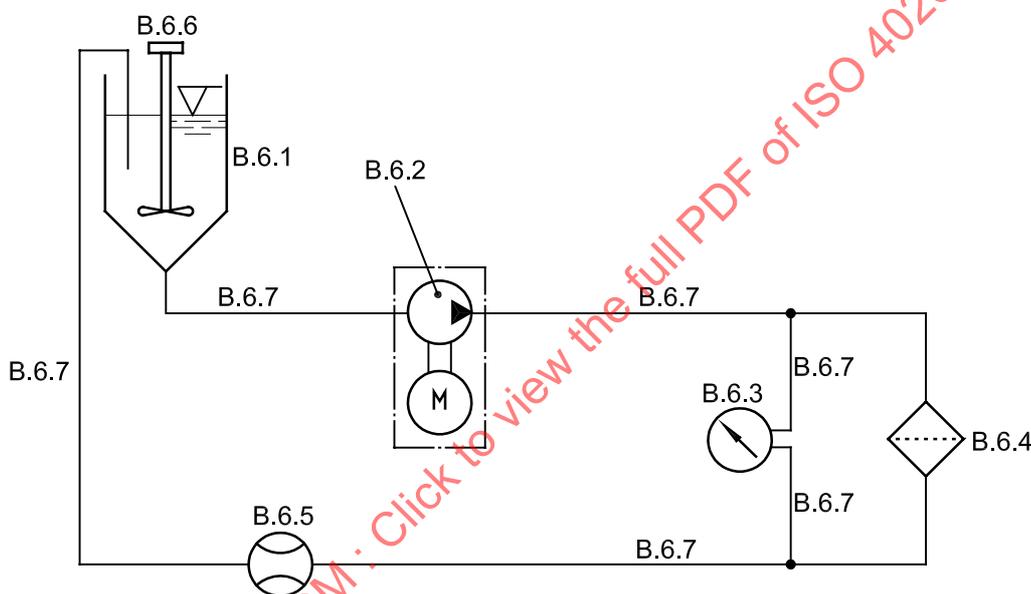
**B.5.3** Remove the Fuller's Earth filters from the test loop or adjust valve positions such that the Fuller's Earth filter is isolated from the test loop.

**B.5.4** Add to the Fuller's Earth-treated fuel 0,1 % (1 000 ppm) of a cetane number improver.

**NOTE** Since cetane number improvers are commercially available additives and since they may have a finite shelf life, it is advisable to check the interfacial tension of this treated fuel (with a cetane number improver against distilled water (ASTM-D 971). If the fuel treatment is successful and the cetane number improver additive is acceptable, the interfacial tension within 1 h of cetane number improver addition should be between  $23 \times 10^{-3}$  N/m and  $28 \times 10^{-3}$  N/m.

**B.5.5** Circulate the fuel with additive through the pump for at least two complete turnovers of the fuel volume in the sump. The fuel treatment is now complete.

## B.6 Collapse/burst test of the filter element (see 6.6)



**Figure B.8 — Test rig for the collapse/burst test**

### Test rig components:

**B.6.1** Tank with test liquid, minimum capacity 5 l.

**B.6.2** Pump, gear type driven by an electric motor with continuously-variable speed control and capable of supplying a flow of 200 l/h or a pressure of up to 2 000 kPa above atmospheric pressure.

**B.6.3** Differential pressure gauge.

**B.6.4** Filter under test.

**B.6.5** Flowmeter, with a measuring range of 0 l/h to 200 l/h.

**B.6.6** Stirrer.

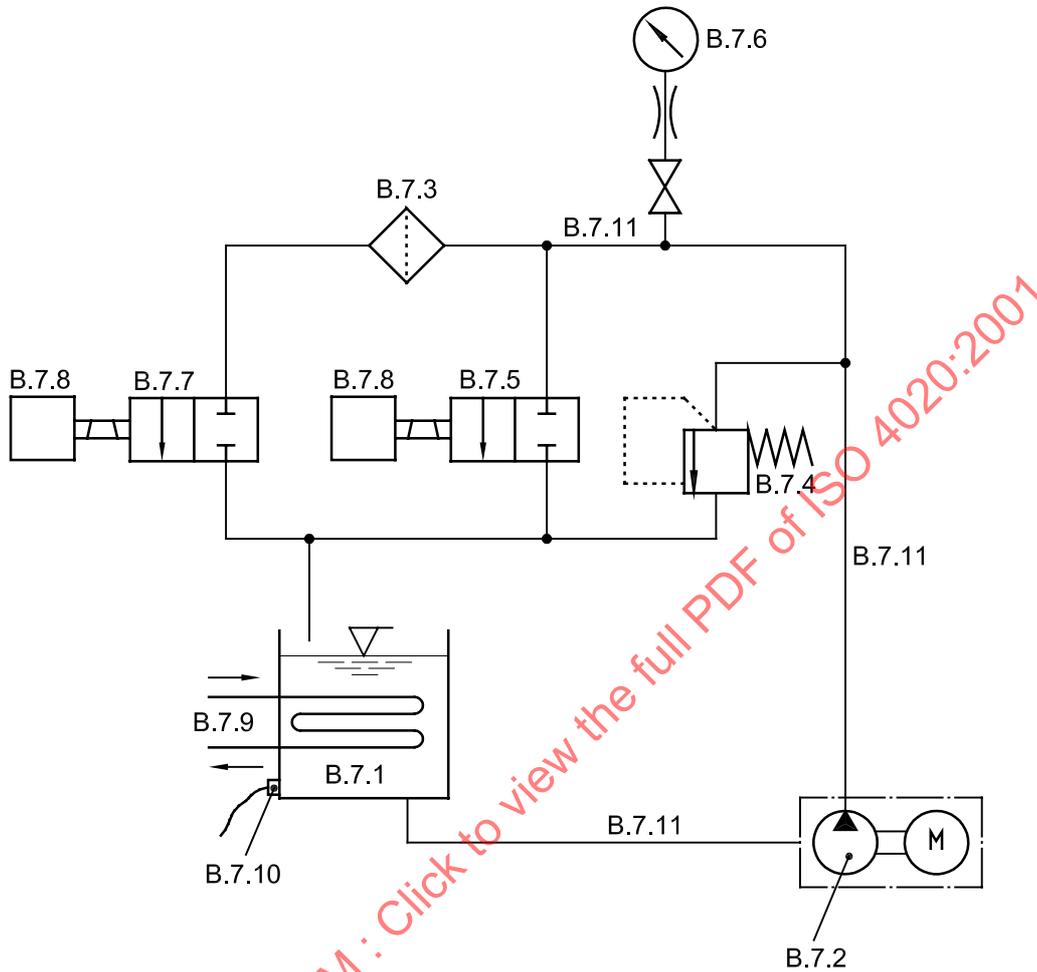
**B.6.7** Pipes, minimum internal diameter 12 mm.

### Other equipment:

Glass jar, capacity 1 l.

Laboratory stirrer.

**B.7 Pulsating pressure fatigue test (see 6.8)**



**Figure B.9 — Test rig for pulsating pressure fatigue test**

**Test rig components:**

- B.7.1** Oil reservoir.
- B.7.2** Pump assembly.
- B.7.3** Filter under test.
- B.7.4** Inlet pressure control valve.
- B.7.5** Solenoid valve.
- B.7.6** Pressure gauge.
- B.7.7** Solenoid valve.
- B.7.8** Solenoid sequence timer and counter, to operate B7.5 and B.7.7.
- B.7.9** Cooling coils (heat exchanger).
- B.7.10** Thermostat.
- B.7.11** Metal pipes, internal diameter 12 mm.

## Annex C (normative)

### Organic contaminant

#### C.1 Apparatus

All apparatus employed in the preparation of the contaminant shall be thoroughly cleaned by washing in detergent solution, rinsing in clean water and dried.

#### C.2 Preparation

- a) Place a 250 ml beaker containing a quantity of carbon black powder (see also annex D) in an air oven, controlled at  $120\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$  for 16 h. Remove the beaker and allow to cool in a desiccator. Filter about 2 l of the test liquid through a cellulose acetate membrane into a 3 l beaker, measure 1 980 ml of the filtrate and add 220 ml of ashless dispersant additive, measured in a measuring cylinder. Stir the mixture with a laboratory-type stirrer, running at a speed of approximately  $250\text{ min}^{-1}$ , for a period of 1 h.
- b) Weigh  $22\text{ g} \pm 0,1\text{ g}$  of dried carbon black into a beaker, and then carefully transfer to a mortar, washing out the beaker with some of the oil/additive mixture with a squeeze-type wash bottle. By means of the pestle and mortar, wet the carbon black and gradually "cream" in with further additions of the oil/additive mixture. As the preparation proceeds, pour some of the carbon black/oil mixture into a 3 l beaker, and with further additions of the filtrate to the mortar, continue the "creaming" process until the carbon black/oil mixture is a smooth, thin paste. Transfer the contents of the mortar to the beaker and carry out the final washing of the pestle and mortar with the remaining quantity of the oil/additive mixture. (The time spent on this stage of "creaming" is about 1 h 30 min.)
- c) Stir the contents of the 3 l beaker thoroughly for approximately 1 h using the laboratory-type stirrer, running at approximately  $250\text{ min}^{-1}$ . Transfer the mixture to a ball mill porcelain pot containing a charge of carbon steel balls and, after sealing, rotate the pot horizontally on rollers at a rotational frequency of approximately  $50\text{ min}^{-1}$  for 24 h.

The internal dimensions of the porcelain pot shall be approximately 175 mm diameter, 200 mm deep.

The number and diameters of the carbon steel balls shall be:

- 162 of 13 mm  $\emptyset$
- 60 of 19 mm  $\emptyset$
- 26 of 25 mm  $\emptyset$

- d) At the end of the ball milling period, remove the pot from the rollers, transfer its contents to a clean 3 l beaker and allow the pot to drain.
- e) Stir the concentrate with a glass rod. Remove a suitable sample volume in order to determine the concentration of insolubles in the dispersion. Carry out the analysis according to the procedure given in annex F, to ensure that the solids concentration is within  $1\% \pm 0,1\%$  ( $m/V$ ). Immediately transfer 200 ml of the concentrate to a clean 3 l beaker and dilute with filtered test liquid to a total volume of 2 l, washing out the measuring cylinder with filtered test liquid. Stir the mixture for approximately 1 h with the laboratory-type stirrer, running at approximately  $250\text{ min}^{-1}$ . Then carry out choking tests with reference filter papers of two grades, eight of each grade being tested. The contaminant shall be fed by means of an appropriate pump at a flow rate

of 5 ml/min. The filter test area for each test paper shall be 25 cm<sup>2</sup>. Measure the volumes to choke the filter papers when the end pressure is reached.

For details of the filter holder assembly for choking tests, see Figure C.1.

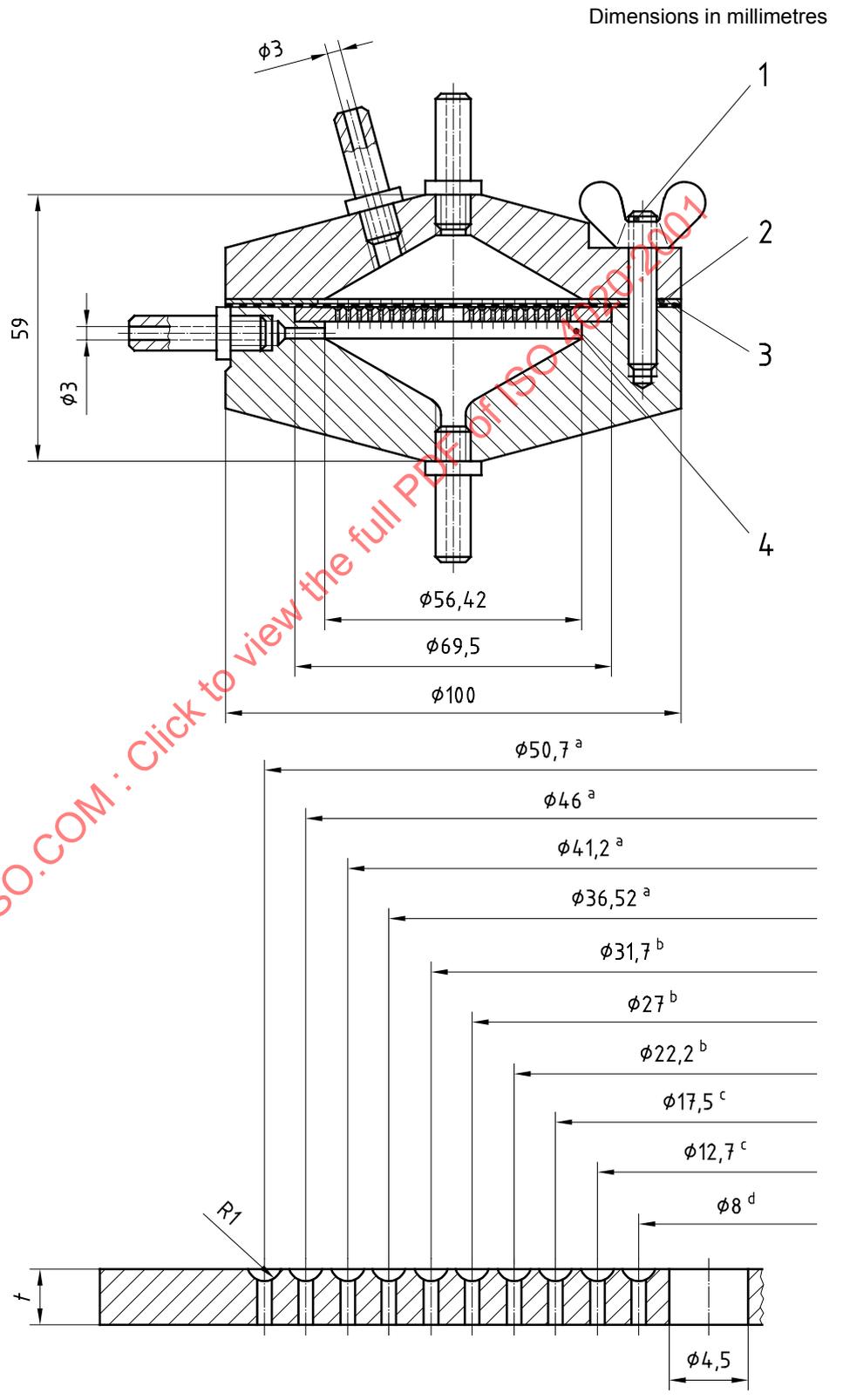


Figure C.1 — Filter holder assembly for choking tests

### C.3 Correlation test

When changing from one set of reference papers to a new one, it is necessary to carry out a correlation test in accordance with C.2 e). Since the choking volume of the reference papers is used for correction of filter life test results, this correlation test enables filter life results to be compared, whenever they were obtained.

The new standard volume  $V'_0$  (see 6.4.7.1.2) is then given by the formula

$$V'_0 = V_0 \frac{V_y}{V_x}$$

where

$V_0$  is the old standard volume;

$V_x$  is the choking volume of the old reference paper;

$V_y$  is the choking volume of the new reference paper.

It is essential that the choking volumes of the two reference papers be determined in parallel, i.e. at the same time and with the contaminant from the same tank. Since the choking times are different, this can be done with a separate pump for each paper. However, it is more convenient to use a single pump with two hoses, both set for a higher rate of flow than the 5 ml/min required, using by-pass arrangements so that the flow through the papers can be controlled independently.

Measures shall be taken to keep pressure fluctuations low; i.e. it is better to use a smaller bore hose and run the pump fast than vice versa. The choking pressure is taken to be the maximum of the fluctuations. However, towards the end of the test, the differential pressure increases rapidly, as is usual when filters approach their choked conditions, so that the effect of pressure fluctuations on the time to reach the choking pressure is insignificant.

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