TECHNICAL REPORT

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Diesel fuel and petrol filters for internal combustion engines — Initial efficiency by particle counting, retention capacity and gravimetric efficiency

Filtres à carburant pour moteurs à combustion interne à essence ou diesel — Efficacité initiale par comptage des particules, capacité de rétention et efficacité gravimétrique

TECHNICAL ISO

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Contents

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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 main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 13353, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 7, *Injection equipment and filters for use on road vehicles*.

This document is being issued in the type 2 Technical Report series of publications (according to subclause G.4.2.2. of part 1 of the ISO/IEC Directives, 1992) as a "prospective standard for provisional application" in the field of filters for road vehicles because there is an urgent need for guidance on how standards in this field should be used to meet an identified need.

This document is not to be regarded as an "International Standard". It is proposed for provisional application so that information and experience of its use in practice may be gathered. Comments on the content of this document should be sent to the ISO Central Secretariat.

A review of this type 2 Technical Report will be carried out not later than two years after its publication with the options of: extension for another two years; conversion into an International Standard; or withdrawal.

Annexes A, B, C, D, E and F form an integral part of this Technical Report. Annex G is for information only.

Diesel fuel and petrol filters for internal combustion engines — Initial efficiency by particle counting, retention capacity and gravimetric efficiency

1 Scope

This Technical Report specifies a test procedure for evaluation of the initial efficiency, the efficiency evolution during clogging and the retention capacity of a fuel filter for internal combustion engines submitted to a constant flowrate of test liquid. It applies to filters having a rated flow from 50 l/h to 250 l/h. By agreement between filter manufacturer and customer, the procedure, with some modification, may be used for fuel filters with higher flowrates.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

ISO 3722:1976, *Hydraulic fluid power — Fluid sample containers — Qualifying and controlling cleaning methods.*

ISO 3968:1981, *Hydraulic fluid power — Filters — Evaluation of pressure drop versus flow characteristics.*

ISO 4021:1992, *Hydraulic fluid power — Particulate contamination analysis — Extraction of fluid samples from lines of an operating system.*

ISO 4402:1991, *Hydraulic fluid power — Calibration of automatic-count instruments for particles suspended in liquids — Method using classified AC Fine Test Dust contaminant.*

ISO 4405:1991, *Hydraulic fluid power — Fluid contamination — Determination of particulate contamination by the gravimetric method.*

3 Principle

The first step of the procedure uses a test fluid with a low concentration of contaminant. The initial efficiency of the filter is evaluated by particle counting upstream and downstream of the filter, allowing on-line particle counting without any dilution. The second step consists of an injection of a high concentration of contaminant to clog the filter and to evaluate its efficiency by the gravimetric method.

4 Test equipment

4.1 Test fluid

4.1.1 Hydraulic fluid according to MIL H 5606[1] or equivalent with a viscosity of 10 mm^2/s minimum at 40 °C.

1) MIL H 5606, *Hydraulic fluid petroleum base, aircraft, missile and ordnance.*

4.1.2 Antistatic agent at 0,02 ml/l[2] added to each new batch of clean test fluid and to each batch of used fluid after cleaning. Antistatic agent is to be discarded one year after opening of the canister.

4.2 Test contaminant

Test contaminant is silica powder called ACFTD (Air Cleaner Fine Test Dust) whose particle size distribution in mass is given in table 1.

Table 1 — Contaminant particle size distribution

Size µm	Percentage of total mass % min.	mean	max.
5,5	35	38	41
11	51	54	57
22	68	71	74
44	85	89	92
88	94	97	100
176	—	100	—

NOTE — Work is progressing towards an ISO standardized test dust.

4.3 Laboratory equipment

4.3.1 Automatic particle counter calibrated in accordance with ISO 4402 or equivalent.[3]

4.3.2 Sampling bottles and glassware prepared in accordance with ISO 3722.

4.4 Test stand

A typical test stand is shown in figure 1, where some of the reference numbers are amplified in 4.4.1 and 4.4.2. It is composed of the test circuit and an injection system.

4.4.1 Filter test circuit

4.4.1.1 The main reservoir **4** shall have a conical bottom with an included angle of not more than 90° and the fluid entering below the fluid surface. The total volume (V_F) of test fluid in the circuit is 6 l.

4.4.1.2 The main pump with a variable rotational frequency **10** is insensitive to contaminant and does not alter the particle size distribution of the contaminant. The pump shall not induce excessive flow pulsations. A diaphragm-type dosing pump with two pistons and a damper as described in annex A is suitable and guarantees pressure pulsations of less than 1 % of mean pressure.

4.4.1.3 Clean-up filters **5a** and **5b** shall be capable of providing an initial contamination level of less than 30 particles greater than 3 µm/ml. The clean-up filter **5b** is on-line during the initial efficiency test and off-line during the retention capacity test.

4.4.1.4 Upstream and downstream samplers (see **8a** and **8b**) shall be provided in accordance with ISO 4021. On-line particle counting is the recommended method. Bottle sampling may be used as an alternative but this shall be clearly indicated in the report.

4.4.1.5 The double-headed peristaltic pump **8** allows flow control of both upstream and downstream sampling.

NOTE 1 Sampling flowrate is stated to be 50 ml/min. It is recommended that the sensor be calibrated at 50 ml/min. Where the calibrating flow is different, the sampling flowrate will be different and the injection flowrate will be twice this flow.

Continuous sampling is not shown in figure 1.

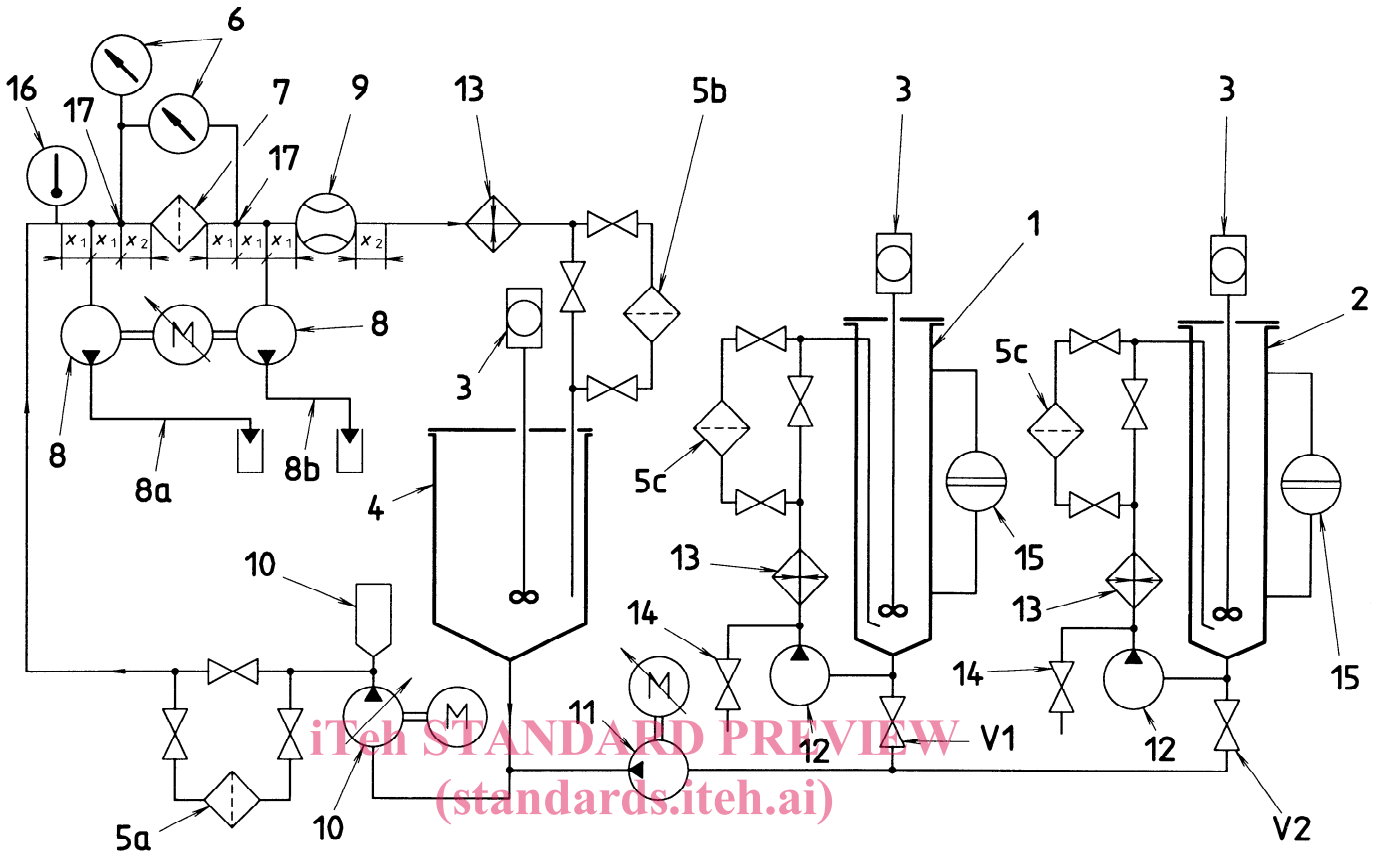
4.4.1.6 All pipes and the reservoir are chosen so as to avoid particle settling or segregation. For test flowrates specified in clause 1, pipes of 6 mm inside diameter are recommended. The reservoir height should be 1,5 to 3 times its diameter.

4.4.1.7 Pressure taps shall be in accordance with ISO 3968 and annex B.

4.4.1.8 Pressure gauges, temperature indicator, flowmeters and controllers shall ensure the accuracy stated in 4.5.

2) Dupont de Nemours Stadis 450 is an example of a suitable product available commercially. This information is given for the convenience of users of this Technical Report and does not constitute an endorsement by ISO of this product.

3) A new calibration procedure using latex spheres in oil is being prepared by ISO TC 131/SC8/WG9.



x = straight length of pipe
$x_1 = 10d$
$x_2 = 5d$
(d = pipe i.d., in millimetres)

1 First injection tank (10 l to 15 l)
2 Second injection tank (10 l to 30 l)
3 Mechanical mixer (1 000 r/min to 1 500 r/min, 50 mm diameter stirrer)
4 Main reservoir (8 l)
5a Main clean-up filter with high capacity
5b Return clean-up filter with high efficiency
5c Injection clean-up filter
6 Pressure indicator
7 Test filter
8 Double-headed peristaltic pumps (50 ml/min each)
8a Upstream sampling line
8b Downstream sampling line
9 Flowmeter
10 Diaphragm-type dosing pump with damper (volume 2 l) (see annex A)
11 Contaminant injection pump (100 ml/min) (e.g. three-roller peristaltic type)
12 Recirculation injection pump (centrifugal type)
13 Heat control system
14 Injection sampling taps (outlets)
15 Level indicator
16 Temperature indicator
17 Flush-type static pressure tap (see annex B)
V1 Valve to isolate first injection pump
V2 Valve to isolate second injection pump

Figure 1 — Typical test stand

4.4.2 Injection system

4.4.2.1 The two injection tanks 1 and 2 shall have a conical bottom with an included angle of not more than 90° and the fluid entering below the fluid surface. The volume of the tank should be appropriate to the most probable test duration and calculated on the basis of an injection flowrate of 100 ml/min.

4.4.2.2 Each injection tank shall be equipped with a recirculation pump of centrifugal type **12** and with a stirrer **3**. The recirculation flowrate in l/min should be at least twice the injection fluid volume in litres.

4.4.2.3 All pipes and the tanks should be chosen so as to avoid particle settling or segregation. Pipe lengths should be minimized.

4.4.2.4 The contaminant injection pump **11** is of the three-roller peristaltic type with a variable rotational frequency. The injection flowrate is kept at 100 ml/min ± 2 ml/min.

4.4.2.5 Temperature and level of injection fluids **15** are continuously indicated.

4.5 Test condition accuracy

Set up and maintain test condition accuracy within the limits given in table 2.

Table 2 — Test condition accuracy

Test condition	Allowable deviation from actual value
Flow	± 2 %
Pressure	± 2 %
Temperature	± 2 °C
Volume	± 2 %

5 Validation procedure

The validation test is conducted at the minimum flowrate to verify that the contaminant is not altered by the components of the circuit, to prove the ability of the main clean-up filter **5a** to clean the system, and to verify that the contamination level is kept constant at the specified value.

5.1 Validation of test circuit

5.1.1 Fit a straight pipe in place of the test filter.

5.1.2 Adjust the fluid volume, V, in litres, to the recommended value of 6 l and the flowrate to the minimum flow at which the test system will operate. Introduce into the main reservoir **4** a quantity of dried test dust, m, in milligrams, so the theoretical gravimetric level is 5 mg/l.[4] Use the mixing procedure in annex C.

EXAMPLE

$$m = V \times 5$$

If $V = 6$ l, then $m = 30$ mg.

5.1.3 Circulate the fluid in the test system for 1 h while counting particles every 5 min at the downstream sampling point **8b**.

5.1.4 Record three differential counts for each period of 5 min and for a minimum sampling volume of 25 ml at the following particle size ranges, in micrometres:

3 to 5; 5 to 10; 10 to 15; 15 to 20; 20 to 30 and > 30

5.1.5 Accept the validation test only if

a) the average of all particle counts obtained for a given size from each bottle or on-line count does not deviate by more than x % from the average particle counts for that size, x being determined by the curve in annex E;

b) the average for all particle counts per millilitre for particle sizes larger than 5 µm is not less than 2 400 nor more than 2 800 (see annex F);

c) the average for all particle counts per millilitre for particle sizes larger than 20 µm is not less than 110 nor more than 150 (see annex F).

5.2 Validation of main clean-up filter

5.2.1 At the end of the validation of the test circuit in 5.1, when the last sample has been taken, switch the valves so that the main clean-up filter **5a** is in service.

5.2.2 Circulate the fluid in the test system for 1 h while counting particles every 5 min at the downstream sampling point **8b**.

4) This contamination level is below the saturation limitations of most automatic particle counters.

5.2.3 Record three cumulative counts for each period of 5 min and for a minimum sampling volume of 25 ml at the particle size ranges specified in 5.1.4.

5.2.4 Fit the curve of the number of particles for each particle size as a function of time and determine the time to reach the acceptable cleanness level specified in 4.4.1.3. This time period should then be used as a minimum time to clean the test circuit each time it is necessary. If excessive time is necessary (more than 1 h), change the clean-up filter **5a** to a finer one.

5.3 Validation of injection system

5.3.1 Prepare in the injection reservoir a quantity of suspension to simulate a test duration of 120 min to provide a base upstream gravimetric level, C_{e2}, of 50 mg/l at the minimum flowrate, q_{Ve}, of the test stand. Use the mixing procedure described in annex C.

Calculate the volume of fluid, V_i, in litres, by

$$V_i = 120 \times q_{Vi}$$

where q_{Vi} = 100 ml/min (injection flowrate).

Calculate the amount of test dust, m, in milligrams, by

$$m = 120 \times C_{e2} \times q_{Ve}$$

where q_{Ve} is the minimum flowrate, in litres per minute, and C_{e2} is expressed in milligrams per litre.

5.3.2 Orient the outlet **14** of the injection piping into an auxiliary reservoir (not shown in figure 1).

5.3.3 Switch on the injection pump **12** at the specified flowrate and take 50 ml samples at the outlet **14** every 15 min during 120 min.

5.3.4 Analyse the samples by the gravimetric method according to ISO 4405.

5.3.5 Accept the validation if

a) the average of all measurements does not deviate by more than 10 % from the theoretical concentration;

b) the maximum and minimum values do not deviate by more than 10 % from the average value.

5.4 Validation of complete system

5.4.1 Fit a straight pipe in place of the test filter.

5.4.2 The validation of the complete system should be conducted by particle counting to confirm the ability of the contaminant injection system to deliver a constant number of particles to the test circuit during 120 min and the ability of the return clean-up filter **5b** to retain particles not retained by the test filter **7**.

5.4.3 Introduce into the injection tank a quantity of suspension to simulate a test duration of 120 min, to provide a base upstream gravimetric level (C_{e1}) of 5 mg/l at the minimum flowrate, q_{Ve}, of the test stand. For test dust and fluid mixing, see annex C.

Calculate the volume of fluid, V_i, in litres, by

$$V_i = 120 \times q_{Vi}$$

where q_{Vi} = 0,1 l/min (injection flowrate).

Calculate the mass of test dust m, in milligrams, to be introduced into the injection fluid to prepare the sump:

$$m = V_i \times \frac{q_{Ve} \times C_{e1}}{q_{Vi}}$$

where

V_i is the volume of injection fluid, in litres;

q_{Ve} is the minimum flowrate, in litres per minute;

C_{e1} is the upstream gravimetric level, in milligrams per litre;

q_{Vi} is the injection flowrate, in litres per minute.

In this case, V_i = 12 l and $m = 600 \times q_{Ve}$

5.4.4 Switch on the main pump **10** at q_{Ve} and the injection pump **11** at q_{Vi} and count particles every 5 min for 1 h.

5.4.5 Record three cumulative counts for each period of 5 min and for a minimum sampling volume of 25 ml at the particle size ranges specified in 5.1.4.

5.4.6 The test rig is validated if the number of particles in each size range is within the limits given in annex D when bottle sampling and in annex E when on-line sampling.

6 Test procedure

6.1 Preparation of injection systems

6.1.1 Preparation for initial efficiency

6.1.1.1 Calculate the volume, V_{i1}, in litres, of fluid to introduce in the first injection tank to allow a test duration, t, of 60 min at the injection flowrate, q_{Vi1}, of 100 ml/min with a safety factor, F_s, of 1,2.

$$V_{i1} = F_s \times q_{Vi1} \times t \times 10^{-3}$$

In this case

$$V_{i1} = 1{,}2 \times 100 \times 60 \times 10^{-3}$$

$$= 7{,}2 \text{ l}$$

6.1.1.2 Calculate the mass, m_{i1}, in milligrams, of dried contaminant to be added to the first injection tank to allow a gravimetric level of the first injection fluid, C_{e1}, of 5 mg/l upstream of the test filter:

$$m_{i1} = \frac{q_{Ve1}}{q_{Vi1}} \times C_{e1} \times V_{i1}$$

where

q_{Ve1} is the test flowrate, in litres per minute;

q_{Vi1} = 0,1 l/min (initial injection flowrate);

V_{i1} is as defined in 6.1.1.

In this case,

$$m_{i1} = \frac{q_{Ve1}}{0{,}1} \times 5 \times 7{,}2$$

$$= 360 \times q_{Ve1}$$

Use the mixing procedure described in annex C.

6.1.2 Preparation for retention capacity and gravimetric efficiency

6.1.2.1 If the retention capacity of the test filter is unknown, a preliminary test should be conducted to determine it.

6.1.2.2 Calculate the test duration, t, in minutes, assuming a base upstream gravimetric level, C_{e2}, of 50 mg/l:

$$t = \frac{m'_{ir}}{C_{e2} \times q_{Ve2}}$$

where

$q_{Ve2} = q_{Ve1}$ (test flowrate), in litres per minute;

m'_{ir} is the total dust addition in the capacity test, in grams.

6.1.2.3 Calculate the injection volume, V_{i2}, in litres, necessary to perform the test with a safety factor, F_s, of 1,2:

$$V_{i2} = F_s \times t \times q_{Vi} \times 10^{-3}$$

where q_{Vi} and t are as specified above.

In this case

$$V_{i2} = 1{,}2 \times t \times 0{,}1 = 0{,}12 \times t$$

6.1.2.4 Calculate the gravimetric level, C_{i2}, in milligrams per litre, of the second injection fluid (tank 2):

$$C_{i2} = \frac{C_{e2} \times q_{Ve}}{q_{Vi2}}$$

where

C_{e2} is the gravimetric level for retention capacity measurement (50 mg/l);

q_{Ve} is the test flowrate, in litres per minute;

q_{Vi2} is the injection flowrate (0,1 l/min).

In this case,

$$C_{i2} = \frac{50 \times q_{Ve}}{0{,}1}$$

$$C_{i2} = 500 \times q_{Ve}$$

6.1.2.5 Calculate the amount of test dust, m_{i2}, in grams, to mix in the predetermined volume V_{i2}:

$$m_{i2} = \frac{C_{i2} \times V_i}{1\,000}$$

$$m_{i2} = 0{,}5 \times q_{Ve2} \times V_i$$

where C_{i2}, V_i and q_{Ve2} are as specified above.

6.1.2.6 Using the previous calculations, prepare the injection system in accordance with annex C.

6.1.2.7 Agitate the suspension for at least 5 min with the recirculation pump before starting the injection. The stirrer shall operate continuously during the test.

6.2 Initial efficiency measurement

6.2.1 If possible, check the test filter integrity in accordance with ISO 2942. If the element is not readily accessible, as in a spin-on configuration, check after testing the filter and disqualify the element if it fails to meet the designated fabrication integrity value.

6.2.2 Fit a straight pipe in place of the test filter **7**, circulate 6 l of fluid in the test system at the rated flow, and maintain the temperature at 40 °C ± 2 °C, with the return clean-up filter **5b** in service. Add anti-static agent at 0,02 ml/l.

6.2.3 Adjust the sample flowrate with the peristaltic pump **8** in each sampling line **8a** and **8b**. Flows from the sampling lines should not be interrupted throughout the entire test. At this stage of the test (before the real beginning of the efficiency test), return the sampling lines to the main reservoir **4**.

6.2.4 Check the cleanness through the upstream sampling point **8a** and continue to filter the system until the cleanness is in accordance with the specification in 4.4.1.3.

6.2.5 Fit the test filter **7** on the test rig in the specified position (horizontally or vertically). If the element can be removed, fit only the empty housing first for the determination of the pressure drop of the housing, then fit the element into the housing for the determination of the total pressure drop. The pressure drop of the element is then equal to the total pressure drop minus the pressure drop of the housing.

6.2.6 Record the pressure drop for 25 %, 50 %, 75 %, 100 % and 125 % of the rated flow of the filter.

6.2.7 Adjust the flow to the test flowrate. Check the cleanness through the upstream sampling point **8a** and continue to filter the system until the cleanness is in accordance with the specification in 4.4.1.3.

6.2.8 Remove the sampling lines from the circuit and initiate the test by starting the contaminant injection pump **11**.

6.2.9 Record three cumulative counts for each period of 5 min and for a minimum sampling volume of 25 ml at the particle size ranges specified in 5.1.4.

6.2.10 At 10 min and 50 min, take a sample from the injection tank **1** and measure the initial and end gravimetric level.

6.2.11 Record the injection fluid volume at 0 min and 10 min (V_0, V_{10}) and at 50 min and 60 min (V_{50}, V_{60}).

6.3 Retention capacity and gravimetric efficiency

6.3.1 After 60 min, by-pass the return clean-up filter **5b**.

6.3.2 Close valve V1 and open valve V2 to allow injection of high concentrated slurry. Ensure that the injection flowrate remains constant at 100 ml/min ± 2 ml/min.

6.3.3 At 70 min, take a sample from the injection tank **2** and measure the initial gravimetric level. Note the injection fluid volume after 65 min and 75 min test time (V_{65}, V_{75}).

6.3.4 Conduct the test until the pressure drop reaches 0,7 bar or any value determined in agreement with the manufacturer. Extract upstream and downstream samples continuously at flowrates of 50 ml/min.

6.3.5 At 70 min and 80 min, then, if necessary, every 20 min, extract 150 ml samples upstream **8a** and downstream **8b** of the test filter **7** for gravimetric analysis. Record times corresponding to pressure drops of 10 kPa, 20 kPa, 30 kPa, 40 kPa and 50 kPa.

6.3.6 When the pressure drop reaches 0,5 bar,

— record the corresponding time, $t_{0,5}$;

— record the injection fluid volume, $V_{0,5}$.

6.3.7 When the pressure drop reaches 70 kPa or the agreed termination point,

— stop the injection pump **11**;

— record the corresponding time, $t_{0,7}$;

— record the injection fluid volume, $V_{0,7}$;

— take a sample from the injection tank for gravimetric analysis;

— take samples upstream **8a** and downstream **8b** of the test filter **7** for gravimetric analysis. The final upstream gravimetric level is C_F, in milligrams per litre.