BS ISO 12345:2013

BSI Standards Publication

Diesel engines — Cleanliness assessment of fuel injection equipment

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of ISO 12345:2013. It supersedes BS ISO 12345:2002, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MCE/22, Engines for road vehicles.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Published by BSI Standards Limited 2013.

ISBN 978 0 580 68678 8

ICS 43.060.40

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2013.

Amendments issued since publication

Date	Text affected

BS ISO 12345:2013

INTERNATIONAL STANDARD

ISO 12345

Second edition
2013-03-15

Diesel engines — Cleanliness assessment of fuel injection equipment

Moteurs diesels — Évaluation de propreté pour équipement d'injection de combustible

Reference number
ISO 12345:2013(E)

Contents

Page

Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

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

ISO 12345 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 7, *Injection equipment and filters for use on road vehicles*.

This second edition cancels and replaces the first edition (ISO 12345:2002), which has been technically revised.

Introduction

Modern fuel injection systems contain many closely controlled clearances and rely on the fuel-flowing characteristics of small orifices; thus they require the close control of sources of contamination in order to maintain the operational performance demanded of them throughout their design life. To this end, such systems are designed with integral fuel-filtration equipment, which reduces the amount of potentially damaging debris that could enter the system from external sources.

However, contamination of the fuel injection system can also occur internally, from system use or wear, from equipment servicing, or as a result of the original supplier's manufacturing and assembly processes. The focus of this International Standard is on the latter source of contamination, and is thus concerned with the assessment of the cleanliness of the fuel injection equipment as originally supplied to the engine manufacturer.

Fuel injection systems comprise a number of components. Traditional systems contain low pressure elements (fuel tank, pipe-work, filters, lift pump, etc.), a fuel injection pump, high-pressure pipes and fuel injectors, located within the engine cylinder head.

During the preparation of this International Standard, the importance of care in the handling and measurement of contamination samples was clearly recognized. Moreover, the low levels of contaminant with fuel injection equipment makes this a particularly difficult task. For this International Standard to be used meaningfully - as an indicator of component cleanliness and a driver towards higher quality standards - extreme attention to detail is required of the user. Verification requirements for the test equipment used are therefore emphasized, in detail.

It is not always clear what level and type of cleanliness would be beneficial for improved performance and life on a cost-effective basis. The actual quantitative levels can only be set in relation to other parameters, agreed between the manufacturer, supplier and user. This International Standard provides a set of procedures for evaluating the cleanliness of fuel injection equipment and a framework for a common measurement and reporting.

Diesel engines — Cleanliness assessment of fuel injection equipment

1 Scope

This International Standard specifies cleanliness assessment procedures for evaluating the amount of debris found within the clean side of diesel fuel injection assemblies, which could lead to a reduction in the system's operational effectiveness.

While other International Standards, e.g. the ISO 16232 series, relate to cleanliness of components used in road vehicle fluid circuits, this International Standard is focused on diesel fuel injection assemblies as supplied to diesel engine manufacturers or the service market.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4008-1, *Road vehicles — Fuel injection pump testing — Part 1: Dynamic conditions*

ISO 4113, *Road vehicles — Calibration fluids for diesel injection equipment*

ISO 4788, *Laboratory glassware — Graduated measuring cylinders*

ISO 7440-1, *Road vehicles — Fuel injection equipment testing — Part 1: Calibrating nozzle and holder assemblies*

ISO 8535-1, *Diesel engines — Steel tubes for high-pressure fuel injection pipes — Part 1: Requirements for seamless cold-drawn single-wall tubes*

ISO 8984-1, *Diesel engines — Testing of fuel injectors — Part 1: Hand-lever-operated testing and setting apparatus*

ISO 14644-1, *Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness by particle concentration*

ISO 16232-5, *Road vehicles — Cleanliness of components of fluid circuits — Part 5: Method of extraction of contaminants on functional test bench*

ISO 16232-6, *Road vehicles — Cleanliness of components of fluid circuits — Part 6: Particle mass determination by gravimetric analysis*

ISO 16232-7, *Road vehicles — Cleanliness of components of fluid circuits — Part 7: Particle sizing and counting by microscopic analysis*

ISO 16232-9, *Road vehicles — Cleanliness of components of fluid circuits — Part 9: Particle sizing and counting by automatic light extinction particle counter*

SAE J 1549, *Diesel fuel injection pump — Validation of calibrating nozzle holder assemblies*

3 Terms and definitions

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

3.1
fuel injection equipment cleanliness code
FIECC
alpha-numeric code representing the distribution of particles by size and/or weight

3.2
cleanliness level
CL
amount and/or nature of contaminant present on the controlled surfaces and/or in controlled volumes of a component

Note 1 to entry: The term can apply to the presumed, specified or measured extent of contamination.

3.3
cleanliness specification
CS
document that specifies the cleanliness level CL required for a given component along with the agreed inspection method

3.4
reynolds number
Re
dimensionless parameter expressing the ratio between the inertia and viscous forces in a flowing fluid, given by the formula

$$\mathrm{Re} = \frac{U \times l}{v}$$

where

U is the mean axial fluid velocity across the defined area, expressed in millimetres per seconds

l is the characteristic dimension of the system over which the flow occurs, expressed in millimetres

[for pipes l = d (pipe bore diameter)]

v is the kinematic viscosity of the fluid, expressed in square millimetres per second (centistokes).

3.5
blank test
analysis carried out with the same operating conditions as on the test component but without the component or the component being a “clean” master sample used only for this purpose

Note 1 to entry: The blank test allows quantification of the contamination brought in from the environment, process or materials used.

3.6
blank value/ level
result obtained from the blank test

4 Test apparatus

4.1 General

Typical test equipment recommended for measuring fuel-injection equipment cleanliness are described in Annex A. Following are details of specific apparatus that shall be used, unless a suitable alternative can be demonstrated.

4.2 Pressure source

4.2.1 General

The pressure source is test dependent as described in the following subclauses.

4.2.2 Fuel injection pump test bench

A single cylinder inline pump as specified in SAE J1549 and a test bench as specified in ISO 4008-1.

4.2.3 Hand-lever-operated testing and setting apparatus

A testing apparatus as described in ISO 8984-1.

4.2.4 High-pressure pulsating flow rig

A pressure source capable of achieving

a) a flow rate which will generate a turbulent flow in the pipes (Re > 4000) for a period of 30 s ± 1 s, while pulsating the flow between zero and this value at a frequency of 0,2 Hz to 1 Hz, followed by

b) a flush at 1,4 MPa ± 0,1 MPa constant pressure for 15 s ± 1 s.

4.2.5 Verification low pressure pump

A plunger or diaphragm-type pump having a flow rate of approximately twice the rated value for the component under test at a pressure of at least 2 MPa.

The verification low-pressure pump shall be cleaned to the cleanliness level CL in accordance with Annex C and carefully stored with proper cover in a clean environment.

4.2.6 Verification high pressure delivery pump

For testing of high-pressure pipes with open ends, having a flow rate capable of generating a Reynolds number in the pipes of Re > 4000. A pressure capability of 3 MPa ± 0,1 MPa is considered suitable.

The verification high-pressure delivery pump shall be cleaned to the cleanliness level CL in accordance with Annex C and carefully stored with proper cover in a clean environment.

4.2.7 Pressure vessel

Used as pressure source, shall be able to supply a testing pressure of at least 0,5 Mpa (= 5 bar) and to produce a turbulent flow inside the rail (recommended flow rate at least 2,5 l/min).

4.2.8 Flushing pump

For testing of rails with open ends, having a flow rate of at least 0,1 l/min. For this pump a pressure capability of up to 0,1 MPa ± 0,01 MPa is considered suitable.

4.3 Verification high-pressure pipe assembly

600 mm long, of tube ISO 8535-1 S-2-6-2 1 P 0, as specified in ISO 8535-1[1)], and suitable for the component under test.

Stainless steel tubing should be used because of its resistance to rust and corrosion contamination. The verification high-pressure pipe assembly shall be cleaned to the cleanliness level CL in accordance with Annex C and carefully stored with proper cover in a clean environment.

4.4 Verification test injector

In accordance with ISO 7440-1, fitted with an orifice plate of orifice diameter 2,5 mm.

The inlet edge filter shall be removed, while the pintle end may be removed to improve the particle passage. The nozzle opening pressure shall be set to $20{,}7\ ^{+0{,}3}_{-0}$ MPa.

4.5 Collecting vessel

Which may be necessary for collecting test fluid downstream from the tested equipment at a flow rate different from that passing through the particle counter, the contamination monitor or the membrane filter.

The collecting vessel may be used for storing test fluid before transfer fluid samples to laboratory for analysis. A cylindrical stainless steel or glass reservoir with a conical bottom should be used for facilitating further particle collection.

4.6 Verification rail

Needed to establish the cleanliness level CL for the whole rail cleanliness test apparatus.

For the verification the verification rail shall be cleaned to the blank value in accordance with Annex C and carefully stored with proper cover in a clean environment.

4.7 Equipment for contamination measurement

4.7.1 General

Involving the application of two specific techniques for evaluating the level of contamination:

— gravimetric analysis;

— microscopic examination.

Each requires the specific laboratory apparatus as given in 4.7.2 to 4.7.3.

4.7.2 Gravimetric analysis apparatus

NOTE For gravimetric analysis see ISO 16232-6.

4.7.2.1 Non-ventilated drying oven

Capable of maintaining a temperature of 80 °C ± 2 °C.

1) Use of stainless steel tubing is recommended to resist rust and corrosion contamination.

4.7.2.2 Filter holder

Comprising

— glass funnel of at least 300 ml capacity with suitably calibrated volumetric graduations (e.g. 25 ml ± 2 ml),

— suitable cover for the funnel (e.g. petri dish),

— clamping device,

— suitable base to support the membrane filter, and

— a means of dissipating any static electricity generated during the filtering process.

4.7.2.3 Vacuum flask

Suitable for the filter holder and of capacity enabling it to hold the entire volume of sample liquid without refilling.

4.7.2.4 Vacuum device

Able to generate a vacuum of 86,6 kPa (gauge).

4.7.2.5 Solvent dispenser (syringe)

A pressurized vessel that discharges solvent through an in-line filter membrane with a pore size of not greater than 1 µm.

4.7.2.6 Tweezers

Flat-bladed (non-serrated, blunt tips), and of stainless steel.

4.7.2.7 Graduated cylinders

For measuring out the volume of test liquid, the accuracy of which shall be in accordance with ISO 4788, unless a suitable alternative can be demonstrated (with a minimum accuracy of ± 2%).

4.7.2.8 Sample bottles

Of 250 ml nominal capacity, preferably flat-bottomed and wide-mouthed, with a screw cap containing a suitable internal polymeric seal.

4.7.2.9 Plastic film

0,05 mm thick x 50 mm x 50 mm, placed between the sample bottle cap and neck if the cap does not have an internal seal. The film shall be compatible with both the cleaning and sample liquids.

4.7.2.10 Filter membranes

Preferred 25 or 47 mm in diameter, white, without grids, and compatible with the fluid to be analysed and with the rinsing chemicals. Reference membranes shall have a recommended pore size of between 5 and 8 µm. The pore size used shall be stated.

4.7.2.11 Petri dishes

Of glass and 150 mm diameter.

4.7.2.12 Analytical balance

Of at least 0,05 mg accuracy.

4.7.2.13 Alpha-ray ionizer

To be used to prevent collection of dust during the weighing operation placed under the balance scale incorporating the filter and projecting from beneath it.

4.7.2.14 Air dryer

4.7.2.15 Collecting vessel

A vessel with a vacuum device connecting, to be used to collect test fluid.

4.7.3 Microscopic analysis apparatus

NOTE For microscopic analysis see ISO 16232-7.

4.7.3.1 Filter membrane

Compatible with the sample liquid and any solvents or chemicals used in the processes. Normally, the membrane shall be of 25 or 47 mm diameter, white, with grids (each grid square width side 3,08 mm ± 0,05 mm and equal to 1 % of the effective filtration area), and with a pore size < 8 μm, used for manual counting down to 2 μm. A 47 mm diameter white, membrane without grids and with a pore size of < 8 μm should be used for image analysis. Membranes of different diameters may be used.

4.8 Test fluid

4.8.1 General

Test fluids are described in the following clauses, depending on the test being conducted.

(see 5.2.2.1, 5.3.2, 5.4.2, 5.5.2.1, 5.5.3.1, 5.6.2.1, 5.7.2.1, 5.7.3.1, 5.7.4.1, 5.8.1, 5.8.3.1, 5.8.4.2, 5.9.2)

4.8.2 Calibration fluid

Test oil in accordance with ISO 4113, pre-filtered on a maximum of 1,0 μm cartridge filter, unless otherwise specified.

4.8.3 Solvent, aliphatic hydrocarbon

Pre-filtered using a maximum of 1,0 μm, single-membrane nylon filter, which shall

— not leave any residue when vaporized, as residuals can influence the weighing results,

— have a minimum flash point of 38 °C, in order to fulfil normal working environment safety aspects,

— not have any aromatic components that could enter the atmosphere when vaporized, and

— have a boiling point not higher than 200 °C.

4.8.4 Water, de-mineralised

With surface tension reduction additives (e.g. Tensides) and pre-filtered on a maximum of 1,0 μm filter.

4.9 Clean-up filter

Cartridge filter with a filtration rating suited to the cleanliness level CL required for the test (see Annex C).

4.10 Pressure gauge

Capable of measuring the system operating pressure, which is dependent on the system under test (see 5.3, 5.4, 5.5, 5.6 and 5.7).

5 Procedure

5.1 General

All tests should be carried out in a clean laboratory environment. Failure to achieve a satisfactory blank test level of contamination could indicate unsuitable control of test conditions (see C.2). Clean room conditions according to ISO 14644-1, class 8, shall be employed as a minimum for these procedures, unless a suitable alternative can be demonstrated.

Before starting the test procedure the outer surface of the component or assembly should be thoroughly cleaned by using a solvent such as detailed in 4.8.3.

This International Standard covers the following components of the fuel injection equipment:

a) Pumps:

   1) high-pressure supply pumps (common rail fuel injection system) (see 5.2);

   2) unit injectors (see 5.3);

   3) fuel injection pumps (see 5.4);

b) Injectors:

   1) CR fuel injectors (see 5.5);

   2) fuel injectors (nozzle holder assemblies) (see 5.6);

c) Pipes and rails:

   1) high-pressure fuel injection pipes (see 5.7);

   2) rails (see 5.8);

d) Low pressure systems (see 5.9).

Each of these, in turn, is treated with respect to two procedural areas:

— equipment set-up and verification (the verification corresponds to the blank tests requested in ISO 16232);

— testing procedure.

In cases where more than one test procedure for a component is specified, the experience has shown that for removal of typical particles produced in the manufacture of these components, the test procedure with a turbulent flow and with pulsating pressure (simulation method) is preferred, simulating actual operating conditions.

When the simulation method is impractical, then the second test procedure should to be used as a more pragmatic means for removal of contaminants.

If neither the simulation method nor the second test procedure prove practical to the supplier or customer, by agreement a "flushing" test procedure (syringe or solvent dispenser method) may be used as an alternative.

The determination of

— the test procedure to be used,

— as well as of the number of components to be tested,

— shall be by agreement between the fuel injection equipment supplier and customer.

5.2 High-pressure supply pumps (common rail fuel injection system)

5.2.1 General

This subclause describes two test procedures for checking the cleanliness of high-pressure supply pumps:

— preferred test is a dynamic test with the test pump running;

— if the dynamic test is not practical, a flushing test at low speed with the test pump running by hand should be used.

5.2.2 Dynamic test with the test pump running

5.2.2.1 Equipment set up and verification (blank test) of cleanliness

a) Set up the equipment for verifying the system as shown in Figure A.1 (see A.2.2, NOTE 3), using a clean high-pressure supply pump of the same type as to be tested; the test bench shall have a separate test reservoir for the calibration fluid. Instead of a clean pump a clean dummy or a hydraulic short cut may be used.

b) The calibration fluid used should be as described in 4.8.2, pre-filtered using a filter as described in 4.9, permanently fixed in the system and replaced regularly.

c) Verify the system according to Annex C.

5.2.2.2 Test procedure

a) Replace the clean high-pressure supply pump by the pump to be tested; the pump shall be fully open (any flow regulating devices or throttling devices are not active).

b) Connect a tube to the high-pressure outlet(s) and another one to the low-pressure return flow outlet(s), both without any pressure regulation devices. Only if the pump needs a minimum system pressure for its safe operation, a pressure regulation device may be applied.

c) Run pump on test at ≥ 500 min^{-1} and similarly but separately collect 1 l of test fluid at the high pressure outlet (s) and 1 l at the low pressure outlet.

d) Separately and similarly measure and count the contaminant output (particles) from every outlet according to Clause 6.

e) Report the results according to Clause 7.

5.2.3 Flushing test at low speed with the test pump running by hand

5.2.3.1 Equipment set up and verification of cleanliness

a) Set up the equipment for verifying the system as shown in Figure A.3, using a clean high-pressure supply pump of the same type as to be tested; the test bench shall have suction side valve between the test fluid tank and the inlet port of high-pressure pump, a drain side valve between the high-pressure outlet port and the vacuum pump.

NOTE 1 Rails and CR fuel injectors are not required for this test.

NOTE 2 For the actual test this pump will be replaced by the pump to be tested.

b) Use a test fluid as described in 4.8.3 as prefiltered in 4.7.3.1.

c) Close the suction side valve and the drain side valve.

d) Throttling devices at the pump shall be fully open and not active.

e) Operate vacuum pump up to - 66,6kPa (gauge) negative pressure and open the suction side valve and then the drain side valve.

f) Run the pump of approximately 120 min $^{-1}$ by hand delivering at least 500 ml of the test fluid and collect the fluid in the collecting vessel.

g) Close the suction side valve and disconnect the pipe on the side of suction side valve from the high-pressure pump (leaving it open to the air), and run the pump 10 times with hand.

h) Collect the test fluid in the collecting vessel and the stainless steel can separately.

i) Measure the system cleanliness according to Clause 6.

j) Verify the system according to Annex C.

5.2.3.2 Test procedure

a) Replace the clean high-pressure supply pump for the system verification with the pump to be tested.

b) Run the system under the conditions described in 5.2.3.1.

c) Count the contamination collected in the collecting vessel and the stainless steel can.

d) Report the results according to Clause 7.

5.3 Unit injectors

5.3.1 General

This subclause describes a dynamic test procedure for checking the cleanliness of unit injectors operating close to service conditions.

5.3.2 Equipment set up and verification of cleanliness

a) Set up the equipment for verifying the system as shown in A.1 (see A.2.2, NOTE 2).

b) Use a test bench able to operate the unit injector under normal running conditions.

c) Fit a clean unit injector assembly for verification purposes.

d) Retain the verification assembly for verification of the system.

e) Use a test fluid as specified in 4.8.2, pre-filtered using a filter as specified in 4.9, permanently fixed in the system.

f) Verify the system according to Annex C.

5.3.3 Test procedure

a) Carefully remove the verification unit injector from the test bench then cap nozzle, inlet and return ports.

b) Fit the first unit injector to be tested while avoiding any possible sources of contamination.

c) Run the unit injector at full load and speed for 10 min, collecting the contaminant output (particles) from the nozzle; separately and similarly collect the contaminant output from the unit injector return outlet.

d) Remove the test unit injectors, strip and wash out all internal high-pressure areas and collect contaminant along with the amount collected from the nozzles in 5.3.3 c).

e) Similarly wash out all low pressure areas and collect contaminants along with those collected from the unit injector return flow outlet (see 5.3.3 c)).

f) Separately and similarly measure and count the contaminant output (particles) from each outlet according to Clause 6.

g) Report the results according to Clause 7.

5.4 Fuel injection pumps

5.4.1 General

The test procedure is a dynamic test. It is similar for rotary, distributor and inline diesel fuel injection pumps and consists of a dynamic test procedure with the test pump running under conditions close to normal operation.

5.4.2 Equipment set up and verification of cleanliness

a) Set up the equipment for verifying the system, shown in Figure A.1, using a pressure source as specified in 4.2.2.

NOTE This pressure source is replaced by the verification pump during testing.

b) For multi-cylinder test pumps, use either the pressure source as specified in 4.2.2 to validate every line or choose a suitable, clean, multi-cylinder pressure source to validate all lines simultaneously. If the pressure source has not been previously verified as “clean”, it may be necessary to run the pump for a period prior to verifying the system in order to ensure a high base level of cleanliness.

c) Use verification high-pressure pipe assemblies in accordance with 4.3 and a verification injector(s) in accordance with 4.4.

d) Use a test fluid in accordance with 4.8.2, pre-filtered using a filter in accordance with 4.7.3.1, permanently fixed in the system and replaced regularly.

e) Verify the system according to Annex C.

5.4.3 Test procedure

a) Ensure the pump return outlet is unrestricted by valves or orifices. If not unrestricted, remove and replace it with a plain outlet.

b) Run the pump on test for a period of 90 min on full fuel delivery and at a pump speed of 200 min^{-1} below the maximum quoted full load speed.

c) Collect the contaminant output from all high-pressure outlets.

d) Separately and similarly collect the contaminant output from the pump return.

e) Measure the contaminant according to Clause 6.

f) Report the results according to Clause 7.

5.5 CR fuel injectors

5.5.1 General

This subclause describes two test procedures for checking the cleanliness of CR fuel injectors:

— Preferred test is a dynamic test, where the CR fuel injectors operate close to as they would in service.

— If the dynamic test is not practical, a test procedure using a continuous high-pressure flow to flush the CR fuel injectors should be used.

5.5.2 Dynamic test

5.5.2.1 Equipment set up and verification (blank test) of cleanliness

a) Set up the equipment for verifying, using a function test as shown in Figure A.1 (see A.2.2, NOTE 1), in order to simulate the operating conditions of the CR fuel injectors. As concerns pressure, the lower range of the usual operating pressures may be applied. For the blind test a dummy without injection function may be used.

b) The test rig shall, among others, consist of

  1) a high-pressure supply,

  2) a rail or a pipe from high pressure supply to the injector,

  3) a pressure control valve, and

  4) an electronic control unit for operating the CR fuel injector under service conditions.

c) Fit a clean CR fuel injector (or a dummy) for the verification purpose.

d) Use a fluid as specified in 4.8.2, 4.8.3, or 4.8.4.

e) Collect an appropriate amount (see C.3) of the test fluid from the high pressure outlet and the low pressure outlet in two separate containers.

f) Measure the contaminant according to Clause 6.

g) Verify the system according to Annex C.

5.5.2.2 Test procedure

a) Remove the system verification CR fuel injector and cap the nozzle tip, the inlet port and the return flow outlet with clean caps.

b) Carefully fit the first CR fuel injector under test in place of the calibration CR fuel injector, avoiding any possible sources of contaminant.

c) Run the high pressure supply and operate the injector via the electronic control unit.

d) Collect an appropriate amount (see C.3, NOTE) of the test fluid from high pressure outlet and from the low pressure outlet in two suitably cleaned containers (see 4.5 and ISO 3722).

e) Repeat procedure for the number of sample tests required as agreed between supplier and customer.

f) Measure the contaminant according to Clause 6.

g) Report the results according to Clause 7.

5.5.3 Continuous high-pressure flow test

5.5.3.1 Equipment set up and verification (blank test) of cleanliness

a) Set up the equipment as shown in Figure A.1 (see A.2.2, NOTE 1), for verifying the system, using

   1) a suitable pressure source (high-pressure supply pump) operating of at least 25 MPa,

   2) a high-pressure control valve,

   3) and - optionally – a filter with a pore size 1 µm max. and capable to withstand the pressure supplied by the pressure source;

b) Fit a clean CR fuel injector or a dummy for verification (blank test);

c) Use as test fluids, either

   1) calibration fluid as specified in 4.8.2, or

   2) de-mineralised, pre-filtered water as specified in 4.8.4;

   NOTE The reason for the use of water is the easier handling compared with the handling of the calibration fluid.

d) Operate the system by the high pressure supply pump at a pressure of at least 25 MPa;

e) Collect an appropriate amount (see NOTE) of the test fluid from high pressure outlet and the low pressure outlet in two separate containers;

f) Measure the contaminant according to Clause 6;

g) Verify the system according to Annex C.

5.5.3.2 Test procedure

a) Remove the system verification CR fuel injector and cap the nozzle tip, the inlet port and the return flow outlet with clean caps.

b) Carefully fit the first CR fuel injector under test in place of the calibration CR fuel injector, avoiding any possible sources of contaminant.

c) According to injector type it may be necessary to unscrew (several turns) the nut of the armature group of the CR fuel injector so far that the test fluid can flow through the nozzle and the return flow outlet, by-passing the internal valves.

d) Operate the system by the high pressure supply pump at the specified pressure.

e) Collect an appropriate amount of the test fluid from the high pressure outlet and the low pressure outlet in two separate containers (see 4.5 and ISO 3722).

f) Repeat procedure for the number of sample tests required as agreed between supplier and customer.

g) Measure the contaminant according to Clause 6.

h) Report the results according to Clause 7.

5.6 Fuel injectors (Nozzle holder assemblies)

5.6.1 General

This subclause describes two test procedures for checking the cleanliness of fuel injectors:

— preferred test is a dynamic test, where the fuel injectors operate close to as they would in service;

— if the dynamic test is not practical, a Syringe (solvent dispenser) or hand flushing test should be used.

5.6.2 Dynamic test

5.6.2.1 Equipment set up and verification of cleanliness

a) Set up the equipment for verifying the system as shown in Figure A.1.

b) Use a pressure source in accordance with 4.2.3, and the high-pressure pipe assembly specified in 4.3.

c) Fit an injector for verification purposes (see 4.5), to be replaced by the test injectors during testing.

d) Use a test fluid specified in 4.8.3.

e) Operate the system in the same condition as scheduled for the test.

f) Verify the system according to Annex C.

5.6.2.2 Test procedure

a) Remove the system verification injector and cap the nozzle end and inlet port with clean caps.

b) Carefully fit the first injector under test in place of the calibration injector while avoiding any possible source of contamination.

c) Operate hand-lever-operated apparatus (see 4.2.3) 50 times with a swift action ensuring injector operation on all strokes.

d) Collect the output in a suitably cleaned container (see 4.5 and ISO 3722).

e) Remove the injector; carefully strip and wash out high-pressure wetted areas only, and add to previously collected amount.

f) Measure the contaminant according to Clause 6.

g) Report the results according to Clause 7.

5.6.3 Syringe test (washing out injectors)

5.6.3.1 Equipment set up and verification of cleanliness

a) Set up the equipment as shown in Figure A.2.

b) Operate the system in the same condition as scheduled for the test.

c) Verify the system according to Annex C.

5.6.3.2 Test procedure

a) Thoroughly clean all external surfaces prior to dismantling an injector.

b) Dispense the filtered solvent as specified in 4.8.3 in accordance with 4.7.2.5 onto the required area in a jet form, so as to disturb any loose particles in a controlled manner.

NOTE 1 Take great care in dismantling in order to avoid introducing/producing contaminant not relevant to this procedure.

c) Remove and wash all surfaces wetted by the high-pressure fluid; if required, wash all surfaces wetted by the low-pressure fluid separately.

NOTE 2 Ensure all drillings and holes are thoroughly flushed to remove any particles.

d) Collect the contaminant in a suitably cleaned container (see 4.5 and ISO 3722).

e) Measure the contaminant according to Clause 6.

f) Report the results according to Clause 7.

5.7 High-pressure fuel injection pipes

5.7.1 General

This subclause describes three test procedures for checking the cleanliness of high-pressure fuel injection pipes:

— preferred test is a dynamic test, utilizing a high-pressure supply pump and is suitable for the removal of typical pipe contaminants;

— if the dynamic test is not practical, a high-pressure flushing test should be used;

— if neither the dynamic test nor the high-pressure flushing test are practical, a syringe (solvent dispenser) or hand-flush test should be used.

5.7.2 Dynamic test

5.7.2.1 Equipment set up and verification of cleanliness

a) Set up the equipment for verifying the system as shown in Figure A.1, using a pressure source in accordance with 4.2.4.

b) Use a verification injector in accordance with 4.4 and solvent in accordance with 4.8.2.

c) Use a verification high-pressure pipe assembly in accordance with 4.3.

d) Circulate the test fluid through a clean-up filter until the level given in Annex C is achieved.

e) Determine the flow rate required to ensure a turbulent flow in the high-pressure pipes (recommended flow rate 0f at least 2,5 l/min).

f) Operate the system for 10 min and collect all downstream fluid for cleanliness control.

g) Verify the system according to Annex C.

5.7.2.2 Test procedure

a) Remove the verification high-pressure pipe and carefully fit the first test pipe while avoiding any possible source of contamination.

b) Run the pump or pressure source to obtain the flow rate greater than minimum calculated in 5.7.2.1 e) and allow cyclic flow variation between zero and this value at a frequency of 0,2 Hz to 1 Hz for 30 s (see 4.2.4). Remove any end restriction and reduce pressure to a constant 1,4 MPa for a further 15 s.

c) Collect the contaminant output from the test pipe.

d) Measure the contaminant according to Clause 6.

e) Report the results according to Clause 7.

5.7.3 High-pressure flushing test

5.7.3.1 Equipment set up and verification of cleanliness

a) Set up the equipment for verifying the system, shown in Figure A.1, using a suitable pressure source such as that specified in 4.2.6. Use of a test injector is not required.

b) Use a verification high-pressure pipe assembly as specified in 4.3.

c) Use the solvent as specified in 4.8.3.

d) Operate the system in the same condition as scheduled for the test.

e) Measure the contaminant according to Clause 6.

f) Verify the system according to Annex C.

5.7.3.2 Test procedure

a) Remove the calibration high-pressure pipe and carefully fit the first test pipe while avoiding any possible sources of contamination.

b) Run the pump at a flow rate that guarantees a recommended flow rate of at least 2,5 l/min for a period of 30 s.

c) Collect the contaminant output from the pipe outlet.

d) Measure the contaminant according to Clause 6.

e) Report the results according to Clause 7.

5.7.4 Syringe (solvent dispenser) or hand flush test

5.7.4.1 Equipment set up and verification of cleanliness

a) Set up the equipment as shown in Figure A.2, and carefully clean it to the initial cleanliness level CL (see Annex C).

b) Operate the system in the same condition as scheduled for the test, but without using any tube. Use the same volume of fluid as would be used for the number of tubes to be tested, pouring it directly to the funnel of the collection vessel.

c) Verify the system according to Annex C.

5.7.4.2 Test procedure

a) Thoroughly cleanse the outer surface and unions of each tube using solvent (see 4.8.3).

b) Flush the inside of the tube using solvent dispensed by syringe (see 4.7.2.5) and collect into either the funnel of the vacuum flask (see 4.7.2.3) or a separate collection vessel for subsequent analysis (see Clause 6). Use a volume of at least 10 times the volume of the tube.

c) On completion of the flushing of all tubes, ensure that any contamination remaining on the filtration funnel (see 4.7.2.2) is removed to the filter membrane by washing down with the syringe/solvent dispenser.

d) Measure the contaminant according to Clause 6.

e) Report the results according to Clause 7.

5.8 Rails

5.8.1 General

This subclause describes three procedures for analysing the cleanliness of rails:

— The preferred test is a pressure vessel flushing test.

— If the pressure vessel flushing test is not practical, a low pressure flushing test should be used.

— If neither the pressure vessel flushing test nor the low pressure flushing test are practical, a syringe (solvent dispenser) or hand flush test should be used.

The aim of these procedures is to analyse the particle contamination on the inner surfaces of the rail including the nipple inside area (i. e., the contamination on those surfaces, which are hydraulically wetted by the fuel during the operation).

Before commencing the test procedure, the outer surface of the complete rail shall be in an appropriately clean condition, so that there is no risk of particle carry.

Care should be taken when connecting the rail to the test system to avoid cross contamination.

5.8.2 Pressure vessel flushing test

5.8.2.1 Equipment set up and verification of cleanliness

a) Set up the equipment according to Figure A.4.1.

The flushing parameters (volumetric flow and flushing volume) shall be determined according to D.2 by agreement between rail manufacturer and customer.

b) Install a verification rail for test bench blank value determination.

c) Place the analysis membrane into the vacuum filtration unit.

d) Set both distributor valves V1 and V2 in the position 1 as shown in Figure A.4.1.

e) Operate and flush the rail with the determined parameters according to 5.8.2.1 a).

f) Collect the contaminant output.

g) Analyse the filter membrane with an automated filter analysis microscope.

h) Measure the contaminant according to Clause 6.

i) Repeat steps a) to h) until the cleanliness result of the blank value measurement is acceptable.

j) Report the result according to Clause 7.

5.8.2.2 Test procedure

5.8.2.2.1 Preparation of the complete rail

a) Remove the rail to be tested from its packaging (immediately before testing).

b) Before commencing the test procedure the outer surface of the complete rail is thoroughly cleansed by using a solvent (see 4.8.3).

c) Place an analysis membrane into the vacuum filtration unit.

d) Remove the protection caps of the high pressure connections.

5.8.2.2.2 Inflow process (step 1)

a) Carefully fit the rail to be tested into the cleanliness test bench.

b) Operate the system and flush the rail (inner surface) according to Figure A.4.1 (both valves V1 and V2 in position 1) with the determined volumetric flow and flushing volume (see 5.8.2.1a)).

5.8.2.2.3 Draining process (step 1)

Switch both distributor valves V1 and V2 in position 2, so that the fluid inside the rail can escape (see Figure A.4.2).

5.8.2.2.4 Inflow and draining processes (step 2)

Repeat 5.8.2.2.2 and 5.8.2.2.3 as determined according to the evaluation process described in Annex D.

5.8.2.3 Analysis of contaminated filter membrane

a) Prepare analysis filter membrane for automatic analyses by microscope:

   1) dry analysis membrane inside an oven,

   2) fix analysis membrane inside a slide frame;

b) Measure the contaminant according to Clause 6;

c) Report the results according to Clause 7.

5.8.3 Low pressure flushing test

5.8.3.1 Equipment set up and verification of cleanliness

a) Set up the equipment as shown in Figure A.1 (see A.2.2, NOTE 4), for verifying the system, using the low pressure flushing pump as described in 4.2.8.

b) Fit a clean rail for verification purposes, to be replaced by the test rail during test.

c) Use as test fluids either

   1) calibration fluid as specified in 4.8.2, or

   2) demineralised, pre-filtered water as specified in 4.8.4.

   NOTE The reason for the use of water is the easier handling compared with the handling of the calibration fluid.

d) Operate the system under the conditions as described in 4.2.8 and follow the three steps – one after the other – according to 5.8.3.2.

e) Verify the system according to Annex C. by collecting an appropriate amount (see C.3, NOTE).

5.8.3.2 Test procedure

5.8.3.2.1 Preparation of the complete rail

All components, necessary for the function of the rail, are mounted (e.g.: as listed in the parts list). Figure B.1 shows the rail to be tested.

During the test no component of the rail shall be disassembled.

5.8.3.2.2 Flushing of the inner surface of the complete rail (step 1)

a) Connect the pump to the inlet port (pump connection) according to Figure B.2.

— Only the "last" outlet port (injector connection) is opened, while the remaining outlet ports (injector connections) are closed by screw-on plastic covers.

b) Operate the system for 20 min: flush the rail (inner surface) according to Figure B.2.

c) Collect the test fluid.

5.8.3.2.3 Flushing of the ports (pump and injector connections) (step 2 and 3)

5.8.3.2.3.1 Flushing of outlet ports (injector connections) (step 2)

a) Connect the pump to the "first" nearby outlet port (injector connection) according to Figure B.3.

— The "last" outlet port is still opened, while the rest of the ports is closed by screw-on plastic covers.

b) Operate the system for 45 s, flushing via the two ports as shown in Figure B.3.

c) Collect the test fluid.

d) Repeat this procedure for all of the remaining outlet ports (injector connections) according to Figure B.3.

5.8.3.2.3.2 Flushing of the "last" outlet port (injector connection) and the inlet port (pump connection) (step 3)

NOTE i.e. flushing in the reverse direction.

a) Connect the pump to the furthest outlet port (injector connection) according to Figure B.4.

— Only the inlet port (pump connection) is opened, while the remaining outlet ports (injector connections) are closed by screw-on plastic covers.

b) Operate the system for 45 s, flushing via the two ports according to Figure B.4.

c) Collect the test fluid.

5.8.3.2.4 Collection of contaminants (step 4)

a) The total collected test fluid of the steps 1 to 3 shall be filtered.

b) Measure the contaminant according to Clause 6.

c) Report the results according to Clause 7.

5.8.4 Syringe or hand flush test

5.8.4.1 Equipment set up and verification of cleanliness

a) Set up equipment according to Figure A.2.

b) Operate the system in the same condition as scheduled for the test, but without using any rail. Use the same volume of fluid as to be used for the number of rails to be tested and pour the fluid directly to the funnel of the collection vessel.

c) Measure the contaminant according to Clause 6.

d) Verify the system according to Annex C.

5.8.4.2 Test procedure

Measure the cleanliness of the inner surface as follows:

a) Cleanse the outer surface of each rail thoroughly using solvent (see 4.8.3); do not collect the fluid for measurement.

b) Pour solvent (see 4.8.3) into the rail and close all open connections.

c) Shake the rail several times vertically and horizontally with the rail axis horizontal.

d) Collect the solvent into either a separate collection vessel for subsequent analysis.

e) On completion of the flushing of the rail, ensure that any contamination remaining on the filtration funnel (4.7.2.2) is removed to the filter membrane by washing down with the syringe or solvent dispenser (4.7.2.5).

f) Measure the contaminant according to Clause 6.

g) Report the results according to Clause 7.

5.9 Low-pressure systems

5.9.1 General

Traditional low-pressure systems contain elements as e. g. fuel tank, pipe-work, filter housings, lift pump, etc., as for the intended installation.

Cleanliness of the clean side of fuel filters is already covered by ISO 4020 and so will not be dealt with in detail in this International Standard, although the procedures should be compatible.

5.9.2 Equipment set up and verification of cleanliness

a) Maintaining a verification set-up similar to the system under test, set up the low-pressure system as for the intended installation. Use a pressure source as specified in 4.2.5.

b) Use a test fluid as specified in 4.8.3.

c) Maintain the fluid temperature at 23 °C ± 10 °C.

d) Set up the remainder of the system according to the actual application.

e) Establish the rated flow of system under test. Set the pressure source to achieve at least twice this flow or to ensure a maximum pressure differential of 0,02 MPa across the system. Circulate for 10 min and collect downstream fluid.

f) Measure the contaminant according to Clause 6.

g) Verify the system according to Annex C.

5.9.3 Test procedure

a) Carefully remove the verification low-pressure system components while avoiding any possible source of contamination. Fit the first system under test.

b) Allow the test fluid to flow through the system for 10 min, and collect/measure the debris produced.

c) Where components are operated in actual use (e.g. bulbous or plunger-type lift pumps), these should be operated similarly during this test at least 50 times.

d) The total collected test fluid shall be filtered and the contaminant output collected.

e) Measure the contaminant according to Clause 6.

f) Report the results according to Clause 7.

6 Sample analysis

6.1 General

Samples collected downstream of the fuel injection equipment for measuring its cleanliness may be analysed using different methods depending on the type of information required. In all cases, the analysis method shall be agreed between parties concerned and shall be validated.

6.2 Gravimetric analysis

See ISO 16232-6.

6.3 Particle size distribution

See ISO 16232-7 and ISO 16232-9 for the appropriate procedures to count the particles and to determine their size.

It is essential when using particle measurement devices and counting systems that the device be used and calibrated in a consistent manner. Particle measurement systems vary in the way they measure particles and hence in the end result given for the same input of particles.

6.4 Largest particle size

6.4.1 General

See ISO 16232-7 for determining by microscopy the dimension of the largest particles collected from the fuel injection equipment under test. Particle size analysis can be either manual, using an optical microscope, or automated, using an image analyser.

NOTE The largest particle is defined as the particle with the largest maximum dimension across the particle from one side to another, independent of its orientation to the measurement device.

The pore size of the selected membrane should be commensurate with the size of the particle being monitored, to ensure the membrane is not plugged prematurely by particle sizes much smaller than the size of interest. It has been found convenient to prefilter the contaminated test liquid through a coarse sieve and then flush the larger dirt off onto the analysis membrane.

6.4.2 Expression of results

For describing the largest particle, use the method given in ISO 16232-10:2007, Clause 8.

7 Reporting results

7.1 Principle of fuel injection equipment cleanliness code

The fuel injection equipment cleanliness code (FIECC) relates to the amount of debris measured per component, in order that sufficient quantity is collected to guarantee measurement accuracy, several components may be measured and the mean result used for the code.

The code can contain the following data:

— particle size class (see Table 1);

— maximum number of particles allowable within the size class;

— weight either per component or per wetted area in the form of $G_N n$ or $G_A n$,

where

G is the gravimetric measurement,

N refers to the measurement being by component,

A refers to the measurement being by wetted area per 1000mm^2,

n is the actual measurement in mg.

NOTE 1 Several size classes can be referred to within the code.

NOTE 2 Size classes are referred to in ascending order of size.

NOTE 3 The allowable number of particles within the size class immediately follows the size class letter, e.g. H20.

NOTE 4 The code can contain only particle size classes and maximum number of particles or weight only or a combination of the two measures.

NOTE 5 The last (largest) size class stated denotes the max allowed particle size by default.

NOTE 6 Particle size classes can be bridged by referring to a range, e.g. C-F.

NOTE 7 Where particle size/ number and weight are required, the weight requirement always follows the size/ number classification.

NOTE 8 The largest particle allowable in the FIECC is 1000 µm.

Table 1 — Size classes for particle counting

Size Class	Size x (µ)m
A	2 ≤ x < 5
B	5 ≤ x < 15
C	15 ≤ x < 25
D	25 ≤ x < 50
E	50 ≤ x < 100
F	100 ≤ x < 150
G	150 ≤ x < 200
H	200 ≤ x < 400
J	400 ≤ x < 600
K	600 ≤ x < 1000

7.2 Examples of fuel injection equipment cleanliness code usage

7.2.1 Example 1

A maximum of 1000 particles in range 5 µm to < 15 µm, 500 in the range 15 µm to < 25 µm, 250 in the range 25 µm to < 50 µm, and 50 in the range 50 µm to < 1000 µm for each component. It also means the maximum allowable particle size is 1000 µm; no weight requirement.

FIECC = B1000/C500/D250/E-K50

7.2.2 Example 2

The allowable debris level is 3 mg per component; no particle size requirement.

FIECC = G_N3

7.2.3 Example 3

The allowable debris level is 5 mg per 1000 mm^2 of component wetted surface area; no particle size requirement.

FIECC = G_A5

7.2.4 Example 4

There is both a particle size requirement and a gravimetric requirement for the component; details as shown above on Examples 1 and 2.

FIECC = B1000/C500/D250/E-K50, G_N3

7.2.5 Example 5

The requirement is for no particles above 200 µm and there is no requirement for further particle size classes or gravimetric measurement.

FIECC = H0

8 Designation

The cleanliness requirement for fuel injection components shall be designated as follows:

a) the word “Cleanliness”;

b) reference to this International Standard: ISO 12345;

c) the FIECC in brackets [...] according to Clause 7.

Example:

Cleanliness: ISO 12345- [B1000/C500/D250/E-K50, GN3]

Annex A
(informative)

Typical test equipment for measuring fuel injection equipment cleanliness

A.1 General

Typical test equipment is shown in A.2 to A.5.

The basic principle of a test equipment (circuit) is shown in Figure A.1; this principle can be based on all component test procedures specified in Clause 5, except for one high-pressure supply pump (see 5.2.3 and A.3), for one rail test procedure (see 5.8.2 and A.4) and the syringe or hand flushing tests (see A.3).

For low-pressure systems: see 5.9.2.

A.2 Basic principle of test equipment

NOTE All numbers given in [...] refer to Figure A.1.

A.2.1 Components of basic test equipment:

a) The pressure source,[8] the pipe,[11] the injector,[12] and the clean-up filter[5] are variable components of the fuel injection equipment cleanliness test rig.

b) The remaining components are common.

c) The collecting vessel [13] is needed in order to

1) protect the filter assembly (if used online) from damage,

2) contain the total test volume in case of high test flow rate, and

3) store before transporting test fluid to laboratory for particle counting using a microscope or for gravimetric analysis.

NOTE For collecting vessel see also 4.5.

d) The test membrane filter [16] is optional in the flow system.

e) Facilities should be provided for the measurement of fluid temperature[9], line pressure[10] for pump tests, and flow rate[7] for high-pressure pipe tests.

A.2.2 Deviations from the basic principle of a test equipment

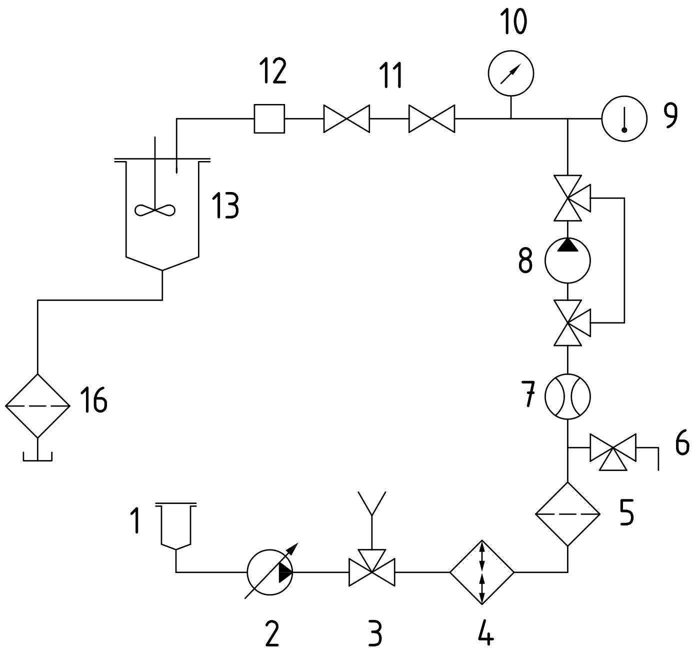
For some CR components the basic principle of the test equipment (circuit) as shown in Figure A.1 shall be modified. Details are given in the following NOTES.

NOTE 1 CR fuel injectors (with addition of an electronic control unit) whereby[11] is replaced with a pressure control, a valve, a rail and supply pipes.

NOTE 2 Unit injectors whereby items[8],[11] and[12] are replaced by the unit injector and an electronic control unit is added.

NOTE 3 High-pressure supply pumps according to 5.2.2 whereby[11] is replaced with rail and pipe (for 5.2.3; see A.4).

NOTE 4 Rails (for the low-pressure flushing test only; see 5.8.3) whereby the flushing pump as in 4.2.8 replaces[8] and[11] is replaced by rail and pipes[12] is not required.



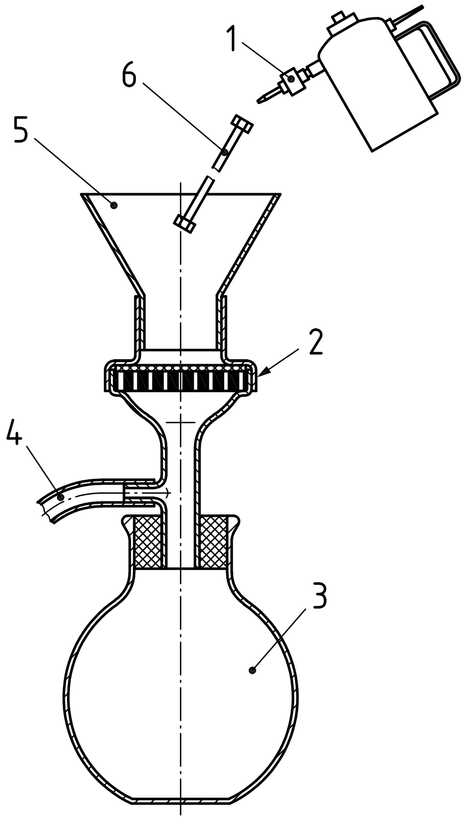
Key

1 Test reservoir
2 Feed pump (see 4.2.5)
3 Other pressure source (see 4.2.2, 4.2.3, 4.2.4)
4 Heat exchanger
5 Clean-up filter (see 4.9)
6 Sampling line or tap
7 Test flowmeter
8 Verification and test pressure source according to the used test procedure:
testing of high-pressure supply pumps: pump to be tested (see A.2.2, NOTE 3)
testing of unit injectors: together with (11) and (12) unit injector to be tested (see a.2.2, NOTE 2)
testing of fuel injection pumps: pump to be tested
testing of CR injectors: high-pressure supply pump (see A.2.2, NOTE 1)
testing of fuel injectors: no component; by-passed
testing of high-pressure pipes: verification high-pressure delivery pump (see 4.2.6)
testing of rails (low-pressure flushing test): flushing pump (see A.2.2, NOTE 4)
9 Temperature gauge
10 Pressure gauge (see 4.10)
11 Verification and test component according to the used test procedure:
testing of high-pressure supply pumps: rail and pipe (see A.2.2, NOTE 3)
testing of unit injectors: together with (8) and (12) unit injector to be tested (see A.2.2, NOTE 2)
testing of fuel injection pumps: verification high-pressure pipe assembly (see 4.3)
testing of CR injectors: pressure control, valve, rail and supply pipes (see A.2.2, NOTE 1)
testing of fuel injectors: verification high-pressure pipe assembly (see 4.3)
testing of high-pressure pipes: pipe to be tested
testing of rails (low-pressure flushing test): rail and pipes (see A.2.2, NOTE 4)
12 Calibration or test injector (see 4.4)
13 Collecting vessel (see 4.5)
16 Test membrane filter

Figure A.1 — Test equipment (schematic layout)

A.3 Test equipment for syringe or hand flushing test

See Figure A.2.



Key

1 Syringe/solvent dispenser (4.7.2.5) with solvent (4.8.3)

2 Filter assembly

3 Collecting vessel/vacuum flask (4.7.2.3)

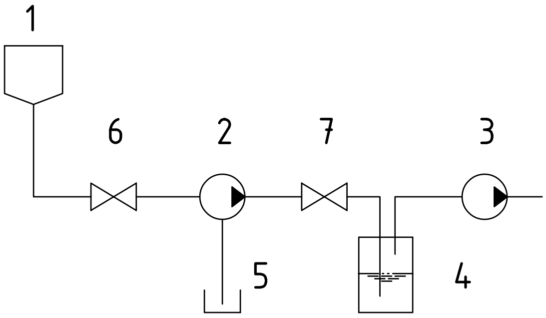
4 Vacuum device connection(4.7.2.4)

5 Filter funnel (4.7.2.2)

6 Sample to be tested (e.g. high pressure fuel injection pipe, rail, injector, individual components, etc.)

Figure A.2 — Test equipment for syringe test (schematic layout)

A.4 Test rig components for high-pressure supply pumps (test pump running by hand)



Key

1 test fluid tank (solvent reservoir)

2 high-pressure supply pump under test

3 vacuum pump, see 4.7.2.4

4 collecting vessel, see 4.5

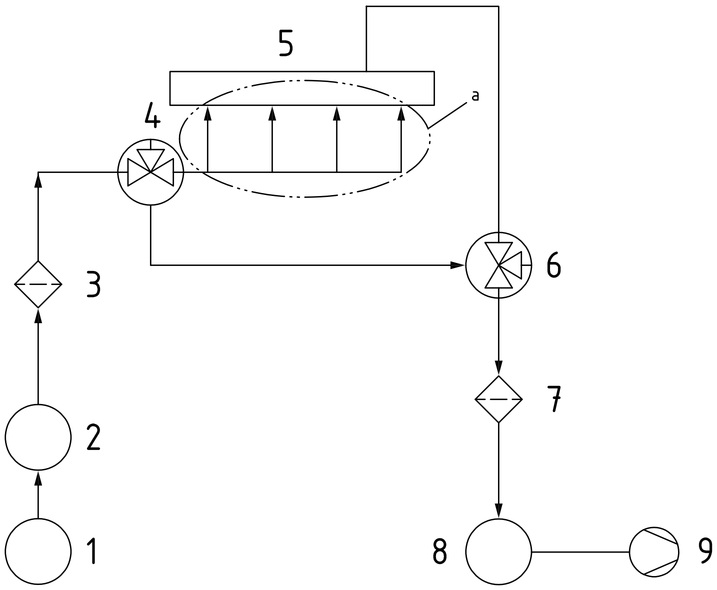
5 stainless steel collecting vessel, see 4.5

6 suction side valve

7 drain side valve

Figure A.3 — Test circuit for flushing test at low speed with the test pump running by hand (schematic layout)

A.5 Rail pressure vessel flushing test (dynamic procedure)



Key

1 air pressure vessel

2 pressure vessel filled with cold cleaner solvent

3 fluid prefilter 2 µm mesh size

4 3-way-valve (in position 1 for the inflow process)

5 rail

6 3-way-valve (in position 1 for the inflow process)

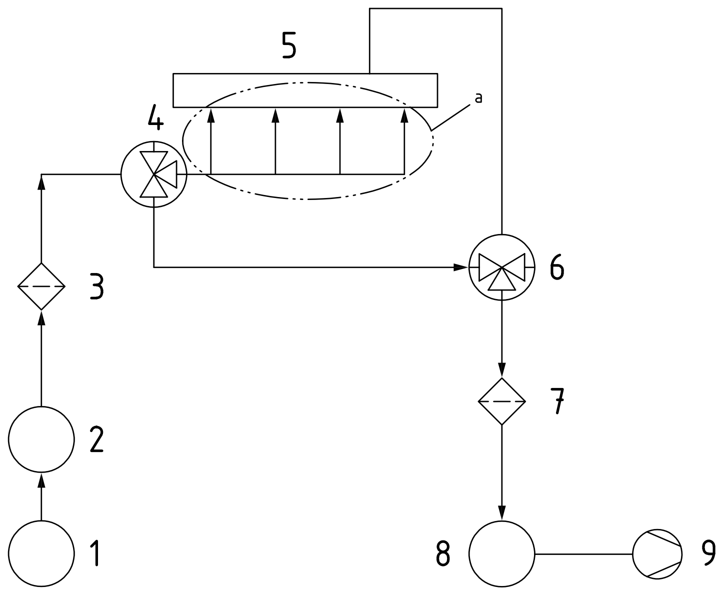
7 analyse membrane

8 collecting vessel, see 4.5

9 vacuum pump, see 4.7.2.4

a As shown in Figure D.2, different flushing configurations are possible.

Figure A.4.1 — Pressure vessel flushing test — Valves 4 and 5 positions during inflow process



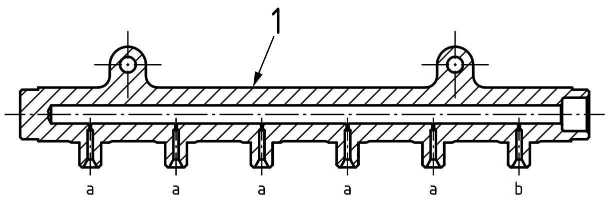
Key

1 air pressure vessel
2 pressure vessel filled with cold cleaner solvent
3 fluid prefilter 2 µm mesh size
4 3-way-valve (in position 2 for the draining process)
5 rail
6 3-way-valve (in position 2 for the draining process)
7 analyse membrane
8 collecting vessel, see 4.5
9 vacuum pump, see 4.7.2.4
a As shown in Figure D.2, different flushing configurations are possible.

Figure A.4.2 — Pressure vessel flushing test — Valves 4 and 5 positions during draining process

Annex B
(informative)

Rail low pressure flushing test



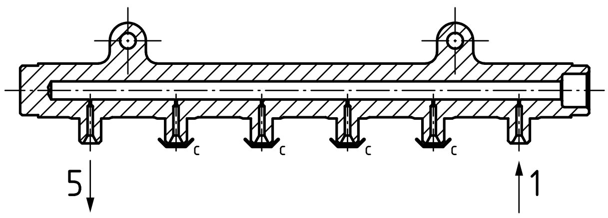
Key

1 Rail to be tested

a outlet fittings to the injectors

b inlet fitting from the high pressure pump

Figure B.1 — Rail to be tested



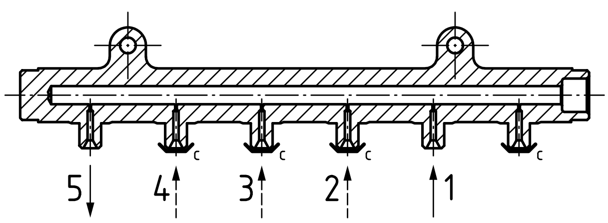
Key

1 flushing input

5 flushing output

c Screw-on plastic cover to close a fitting.

Figure B.2 — Step 1 of the test procedure



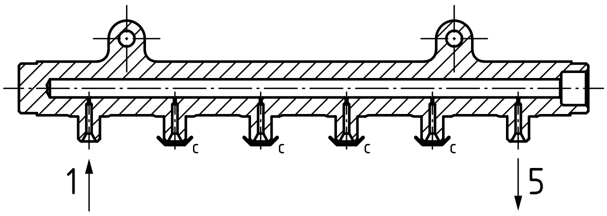
Key

1,2,3,4 flushing inputs in succession by changing the plastic covers (c) accordingly

5 flushing output

c Screw-on plastic cover to close a fitting.

Figure B.3 — Step 2 of the test procedure



Key

1 flushing input

5 flushing output

c Screw-on plastic cover to close a fitting.

Figure B.4 — Step 3 of the test procedure

Annex C
(informative)

Procedure for verifying test equipment initial cleanliness

C.1 Initial cleanliness verification procedures

Whatever the system being used or the components being tested, it is essential that the test equipment operates at a level of cleanliness superior to that of the components under test.

Dedicated test equipment should be used capable of providing a continuously clean level of output that will not influence the cleanliness inspection level of the components.

The performance of the system should be verified before testing begins by operating under the same conditions and over the same cycle.

C.2 Blank test

C.2.1 Sources of blank contamination

The overall blank value derives from contamination that results from handling and testing the component, beginning when it is unpacked and ending after of the particles have been analysed. Main sources of blank contamination are

— ambient air environment (air, operator, working area, etc.),

— extraction fluid,

— all non-component surfaces that come into contact with the extraction liquid such as containers and equipment for collecting and sampling the extraction fluid,

— analysis of the extraction fluid,

— analysis filter or optical particle counter and associated equipment, and

— handling during preparation and analysis of extraction liquid samples.

The overall blank value results from the combination and interaction of the above factors being applied for a specific test task.

The cleanliness of the environment where the cleanliness inspection is performed should be known and its effect on the presumed cleanliness of the component to be tested should be negligible. This is validated when performing the blank test.

If the stable blank value level shifts towards higher values, the sources of blank contamination shall be investigated in order to minimize unacceptable cross contamination.

C.2.2 System blank test

To verify that the operating conditions, equipment and products used contribute no more than negligible contamination to the examination of the component analysed, a dummy run should be performed at regular intervals.

For the determination of system blank values, identical conditions (same equipment, same total volume of extraction fluid) as the one applied during testing of the component shall be applied, but with the test components replaced with the known "clean" parts for system verification.

The blank value shall be determined for each analysis method specified in the inspection document.

Analyse the extraction fluid as specified in 6.

C.2.3 Cleanliness level CL

The acceptable cleanliness level CL depends on the component presumed or allowed contamination level and depending on the analysis methods, is as specifed in C.2.3.1 and C.2.3.2.

C.2.3.1 Gravimetric analysis

The gravimetric analysis should be performed according to ISO 16232-6.

Less than 10 % of this presumed gravimetric contamination level and greater than or equal to 0,3 mg.

Using a 4-digit balance under non controlled environmental conditions (non controlled humidity and temperature) the minimum measurable blank value is 0,3 mg. Thus at least 3 mg should be collected during the component test in order to meet the 10 % criterion.

C.2.3.2 Particle counting and sizing

a) Particle counts: less than 10 % of the differential counts at the relevant sizes specified in the inspection document, each calculated value being rounded down.

The relevant sizes should be as close as possible to the maximum particle size acceptable for the component and chosen to allow to count significant numbers of particles.

b) Maximum particle size: no particle at the ISO 16232 size range next lower to the half of the maximum particle size acceptable for the component specified in the inspection document.

c) If the component presumed contamination level is not known or if the inspection document states no requirement, the blank shall exhibit:

   1) less than 4000 particles longer than 5μm and less than 500 particles larger than 15 micron per 100ml of extraction fluid,

   2) no particle greater than 50 μm (maximum particle size).

If item c) is fulfilled but the blank value is more than 10 %, it is necessary to analyse additional components in order to collect a greater number of particles.

C.3 Criteria for acceptance

The acceptance criteria shall be the following, measured over the same cycle as the actual test:

— CL < 0,10 × CS (of the equipment alone);

— CS > 5 × x (of the equipment alone);

where x is any individual cleanliness reading in the last five readings (gravimetric or number of particles).

A reference set of verification equipment should be created and retained in a clean condition. When verifying new components, it could be necessary to run the equipment for an extended period in order to achieve stable CL (for the verification equipment only).

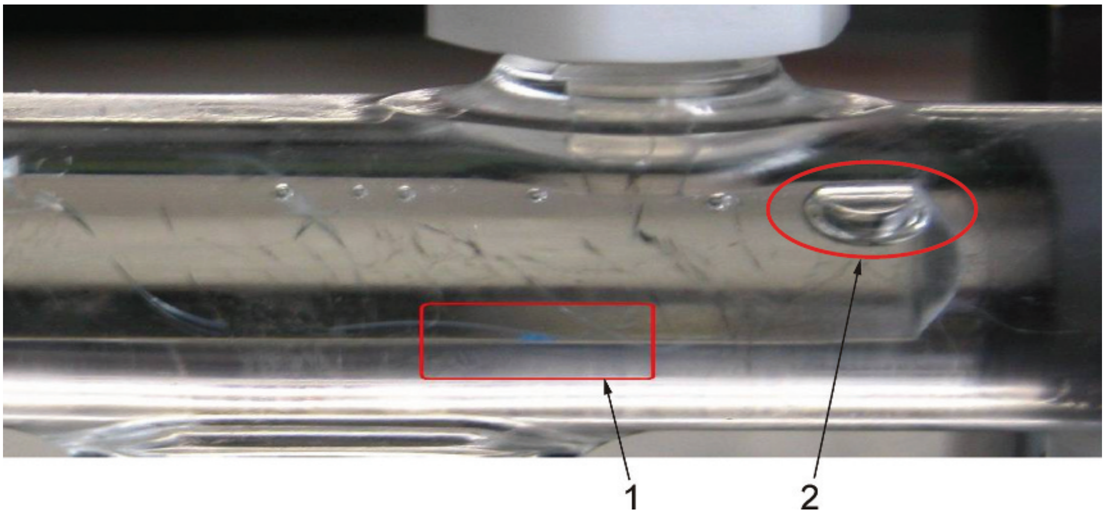
The appropriate amount shall be determined with the help of the extraction curve (see ISO 16232-5:2007, Figure 1).

Annex D
(informative)

Determination of flushing parameters for rail pressure vessel flushing test

D.1 Blowhole and particle collection point

Precondition for the optimal perfusion is the configuration of the inlet and outlet ports (fittings). There may be no blowholes and particle collection points inside the rail during perfusion; see Figure D.1.



Key

1 particle collection point

2 blowhole

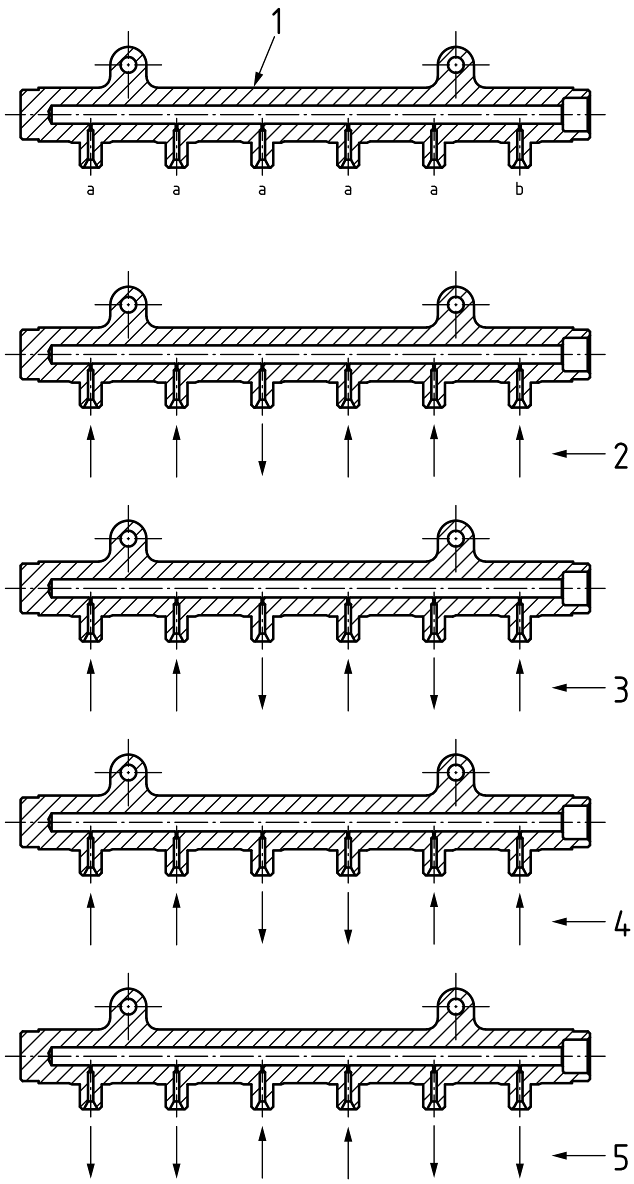
Figure D.1 — Example of a particle collection point and a blowhole inside a rail

D.2 Different flushing configurations to avoid blowholes and particle collection points

According to Figure D.2 different flushing configurations are possible. The most appropriate configuration includes no blowholes and no particle collection points.

Depending on rail geometry (hole diameters of fittings, through boring or blind hole) the appropriate volumetric flow will be between 2 and 6 l/min. The Reynolds number shall be ≥ 3000. The adequate flushing volume shall also be validated according to ISO 16232-5. An additional rail contamination with test particles (100-200 µm) is very helpful for the extraction curve evaluation.

NOTE As the inflow process has the biggest influence concerning particle emission, high amounts of flushing volumes (>400ml) are not useful. More appropriate is to repeat the flushing process with an interim draining process (see 5.8.2.2.4).



Key

1 rail to be tested

2, 3, 4, 5 different flushing directions given by the arrows

a outlet fittings to the injectors

b inlet fitting from the high pressure pump

Figure D.2 — Different flushing configurations of a rail

Bibliography

[1] ISO 3722, *Hydraulic fluid power — Fluid sample containers — Qualifying and controlling cleaning methods*

[2] ISO 4006, *Measurement of fluid flow in closed conduits — Vocabulary and symbols*

[3] ISO 7876-1, *Fuel injection equipment — Vocabulary — Part 1: Fuel injection pumps*

[4] ISO 7876-2, *Fuel injection equipment — Vocabulary — Part 2: Fuel injectors*

[5] ISO 7876-3, *Fuel injection equipment — Vocabulary — Part 3: Unit injectors*

[6] ISO 7876-4, *Fuel injection equipment — Vocabulary — Part 4: High-pressure pipes and end-connections*

[7] ISO 7876-5, *Fuel injection equipment — Vocabulary — Part 5: Common rail fuel injection system*

[8] ISO 7967-7, *Reciprocating internal combustion engines — Vocabulary of components and systems — Part 7: Governing systems*

[9] ISO 16232-1, *Road vehicles — Cleanliness of components of fluid circuits — Part 1: Vocabulary*

[10] ISO 16232-3, *Road vehicles — Cleanliness of components of fluid circuits — Part 3: Method of extraction of contaminants by pressure rinsing*

[11] ISO 16232-10:2007, *Road vehicles — Cleanliness of components of fluid circuits — Part 10: Expression of results*

[12] ISO 18413, *Hydraulic fluid power — Cleanliness of parts and components — Inspection document and principles related to contaminant collection, analysis and data reporting*

ICS 43.060.40

Price based on 36 pages

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.

...making excellence a habit.™