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Diesel engines — Cleanliness assessment of fuel injection equipment

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

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Foreword

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

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

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

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.

This corrected version of ISO 12345:2013 incorporates the following corrections.

5.9.1: The second paragraph is replaced by the following:

Cleanliness of the clean side of fuel filters is already covered by ISO 4020 and is not detailed in this International Standard, although the procedures should be compatible. The extraction method from ISO 4020 may be used, however, the FIECC according to Clause 7 shall be used for reporting results.

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.

