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# Road vehicles — Cleanliness of components and systems

*Véhicules routiers — Propreté des composants et des systèmes*

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# Foreword

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

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

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

This edition of ISO 16232 cancels and replaces the entire ISO 16232:2007 series (all parts) which have been technically revised and consolidated into a single document.

The main changes are described in Annex L.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.


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# Introduction

In order to achieve reliable performance of components and systems, control over the amount of particles introduced during the build phase is necessary, and measurement of particulate contaminants is the basis of control.

Based on a world-wide broadening and ongoing development of technical cleanliness issues this document is intended to:

— further improve the comparability of cleanliness inspection results;

— include new (extraction and analysis) techniques; and

— provide information on how to define cleanliness specifications and explain how to react when cleanliness limit values are exceeded.

This document has been prepared to fulfil the requirements of the automotive industry, since the function and performance of modern automotive components and systems are sensitive to the presence of a single or a few critically sized particles. Consequently, this document deals with the analysis of the total volume of extraction liquid and of all contaminants collected using an approved extraction method.

To be able to compare inspection results the same extraction procedure, the same test fluid and also same parameter settings for the analysis instruments are intended to be used.

This document is based on existing International Standards such as those developed by ISO/TC 131/SC 6. They have been extended, modified and new ones have been developed to produce a comprehensive suite of International Standards to measure and report the cleanliness levels of components and systems fitted to road vehicles.

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# Road vehicles — Cleanliness of components and systems

## 1 Scope

**WARNING — The use of this document can involve hazardous materials, operations and equipment. This document does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this document to establish appropriate safety and health practices and to determine the applicability of any other restrictions prior to its use.**

This document specifies requirements for applying and documenting methods for determining particulate contamination on functionally-relevant components and systems (cleanliness inspection) of road vehicles.

A cleanliness inspection comprises the basis of an assessment of technical cleanliness, which is performed, for example, under the following circumstances:

— initial inspection and evaluation;

— inspection of incoming and outgoing components; and

— quality control or monitoring of manufacturing processes relevant to cleanliness (e.g. cleaning, surface treatment and assembly processes).

This document is intended to improve the informative quality and comparability of test results. It also defines the standardized expression of cleanliness specifications and cleanliness test results in the quality chain of the automotive industry.

This document does not apply to the following:

— detection of filmy contamination (grease, oils, etc.);

— application of non-quantifiable particulate detection methods on test components (e.g. visual assessment, wipe test with clean cloth, etc.); and

— characterization of operating fluids (fuel, oils, coolants, brake fluid, etc.).

This document does not define any cleanliness limit values for specific components or systems. The degree of cleanliness required for a specific component or system is dependent on a number of highly-individual factors. Cleanliness specifications are intended to be undertaken only by specialists who not only know the component concerned but also the system it is built into, the later conditions of use, technically-feasible practices and possible consequences for manufacturing processes and the supply chain. Guidance for deriving limit values can be found in Annex H.

## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

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**3.1**
**active component**
component which may set the fluid in motion or be activated by the fluid during operation

EXAMPLE Pump, cylinder, distributor, injector, valve regulator.

**3.2**
**aerosol formation**
atomization of a liquid to create small droplets, e.g. in pressure-rinsing due to the shape of nozzles or impaction of the pressure-rinsing jet on a surface

**3.3**
**agglomerate**
two or more particles which are in intimate contact and cannot be separated by gentle stirring and the small shear forces thus generated

**3.4**
**agitation**
extraction method implemented for internal surfaces

Note 1 to entry: Its cleaning effect is based on the turbulent change in direction of the test liquid inside the component.

**3.5**
**air cleanliness class**
specification of air quality based on the concentration of particles in a defined volume of air

**3.6**
**analysis balance**
balance with a high ($10^{-4}$ g) to very high ($10^{-6}$ g) resolution capable of weighing minute quantities of particulate residue

**3.7**
**analysis filter**
**filter membrane**
thin membrane, either meshed or foamed, possessing defined deposition properties that cause particles of a specific size to be retained during filtration

**3.8**
**analysis parameters**
settings on an *analysis system* (3.9) that are used in the analysis step

**3.9**
**analysis system**
device to measure and/or characterize particles

**3.10**
**automatic particle counter**
**APC**
counting system that works on the light extinction principle

**3.11**
**back-scattered electron detector**
**BSE detector**
device that supplies scanning electron microscope (SEM) images with a high material contrast, used for the detection of particles on a membrane filter


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**3.12**
**blank level**
**blank value**
amount of contaminant introduced from sources other than the test component, such as reagents, glassware, preparation of test units, and the environment

**3.13**
**blank level criterion**
maximum value that may not be exceeded when determining the blank level, i.e. max. 10 % of the required or expected cleanliness value

**3.14**
**blank level test**
analysis carried out in the same operating conditions as on the test component but without the test component

Note 1 to entry: The blank test enables quantification of the contamination introduced from sources other than the test component, such as reagents, glassware, preparation of test units, and the environment.

**3.15**
**cavity**
cavity in the test component, which cannot be wetted by the test liquid due to the presence of gas

**3.16**
**clean**
state of *cleanliness* (3.18) of a component or fluid that meets the specified cleanliness level

**3.17**
**cleaning**
process to make a liquid, object or extraction setup as clean as required

**3.18**
**cleanliness**
condition of a product, surface, device, liquid, etc., characterized by the absence of particulate contamination

**3.19**
**cleanliness inspection**
extraction and analysis of component contamination including documentation

**3.20**
**cleanliness level**
$C_L$
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 may apply to the presumed, specified or measured extent of contamination.

**3.21**
**cleanliness specification**
documentation of permissible particle features and quantities for a component

**3.22**
**cleanliness state**
**component cleanliness**
*cleanliness value* (3.23) or values of a component that may change over time due to external influences

**3.23**
**cleanliness value**
single value specifying the cleanliness of a component, e.g. residue mass, longest particle or particle count

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**3.24**
**cleanroom**
room within which the number concentration of airborne particles is controlled and classified, and which is designed, constructed and operated in a manner to control the introduction, generation and retention of particles inside the room

Note 1 to entry: The class of airborne particle concentration is specified.

Note 2 to entry: Levels of other cleanliness attributes such as chemical, viable or nanoscale concentrations in the air, and also surface cleanliness in terms of particle, nanoscale, chemical and viable concentrations might also be specified and controlled.

Note 3 to entry: Other relevant physical parameters might also be controlled as required, e.g. temperature, humidity, pressure, vibration and electrostatic.

[SOURCE: ISO 14644-1:2015, 3.1.1]

**3.25**
**coincidence**
particles grouped together, which can therefore not be analysed as single particles, e.g. by an optical particle counter or microscope

**3.26**
**collection equipment**
any device (e.g. conical flask, beaker, tray, funnel, collection surface of the extraction cabinet) with a size and a shape suited to the collection of all the extraction liquid draining from the test component

**3.27**
**component**
part, sub-assembly, or part assembly used in a road vehicle

Note 1 to entry: This definition differs from that given for the same term in ISO 5598.

**3.28**
**component cleanliness code**
**CCC**
alpha-numeric expression of the *cleanliness level* (3.20) of a *component* (3.27) measured or specified by the particle size distribution of the contaminants

**3.29**
**component contamination**
amount or nature of contaminants extracted from the wetted or controlled surfaces of a *component* (3.27), as measured by an applicable analysis method

**3.30**
**conditioning**
preparation step in which the *analysis filter* (3.7) is pressure-rinsed, dried and dehumidified before its tare mass is weighed

**3.31**
**contaminant**
undesirable solid substance that is in suspension in a fluid or in a component or on a *controlled surface* (3.33) of a component

Note 1 to entry: For the purposes of this document, contaminants are particles as defined in 3.77**.** This definition differs from ISO 5598 in its exclusion of liquids and gases.

**3.32**
**contamination**
all contaminants in a fluid, system or on a component


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**3.33**
**controlled surface**
surface of a component that is subject to a cleanliness requirement

**3.34**
**controlled volume**
volume of a component that is subject to a cleanliness requirement

Note 1 to entry: The controlled volume may differ from the wetted volume.

**3.35**
**critical particle**
particle which geometric dimensions or chemical-physical nature could cause *component* (3.27) damage

Note 1 to entry: A sub-category of critical particles is formed by so-called "killer" particles, which cause an immediate component failure.

**3.36**
**decline**
decrease observed in the contamination level of a component, on repeated extraction

**3.37**
**declining criterion**
threshold for assessing the suitability of extraction conditions

**3.38**
**declining test**
procedure used to verify the efficacy and suitability of extraction parameters in which the extraction step is repeated six times on the same test component in an identical manner

**3.39**
**declining value**
$D_n$
quotient of the cleanliness value under consideration and the sum of all preceding cleanliness values (including that under consideration)

Note 1 to entry: It is expressed in percent.

**3.40**
**dissolving liquid**
test liquid used for extraction or another liquid with stronger solvent action to speed up dissolving step during the extraction process, compatible with the test component and inspection equipment

**3.41**
**double inspection**
procedure in which two identical extraction steps are performed in order to confirm the efficacy and suitability of qualified extraction parameters

Note 1 to entry: In this case, the declining criterion is set at 30 % instead of the 10 % that applies for declining tests.

**3.42**
**effective filter surface area**
area of the analysis filter membrane through which extraction liquid flows during the filtration step

**3.43**
**element analysis**
**EDX analyses**
energy dispersive X-ray spectroscopy capable of analysing elements based on their characteristic X-ray spectra

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**3.44**
**extraction**
**sampling**
operation required to transfer as much contaminant as possible that is present within a controlled volume or on a controlled surface into a test fluid and its collection for subsequent analysis

**3.45**
**extraction curve**
**declining curve**
progress curve of the cleanliness level of an extraction fluid applied to the test component as a function of the number of extractions

Note 1 to entry: This is related to the extraction time or to the volume of test fluid passed through or over the test component.

**3.46**
**extraction liquid**
**analysis liquid**
**extraction fluid**
**extraction air**
test medium loaded with contaminants extracted from the test component

**3.47**
**extraction method**
technique to detach the particle load from the test component

**3.48**
**extraction parameters**
totality of all physical parameters influencing the extraction which can be set on or calculated from the extraction setup

**3.49**
**extraction procedure**
complete sequence of all extraction steps performed

**3.50**
**extraction setup**
**extraction device**
equipment used to perform the extraction

**3.51**
**extraction step**
**sampling step**
single work step forming part of the *extraction procedure* (3.49) that is performed either in a *declining test* (3.38) or when extracting several controlled surfaces

**3.52**
**extraction volume**
total volume of test fluid used to extract the contaminants from a component

**3.53**
**fibre**
long, thin structure which is defined by a ratio between stretched length and maximum inner circle diameter greater than 20, the width measured via maximum inner circle diameter being lower than or equal to 50 µm

Note 1 to entry: It is generally used to characterize a textile fibre (flexible, pliable, and made from organic materials) and differentiate it from compact particles.


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**3.54**
**filter background**
colour of the analysis filter

**3.55**
**filter housing**
casing consisting of an upper and lower section with an inlet and outlet as well as a supporting grid; used to clamp and tension the *analysis filter* (3.7)

**3.56**
**filter occupancy**
ratio between surface area of the *analysis filter* (3.7) covered with particles to entire analysed filter area

**3.57**
**filter pore size**
<mesh filter> nominal mesh width

**3.58**
**filter pore size**
<foamed analysis filter> equivalent mesh width measured by means of the bubble point test

**3.59**
**filtration**
process in which particles are deposited on the analysis filter

**3.60**
**final rinsing**
application of fluid to remove any particulate residues from the surfaces of the extraction setup and deposit them on the analysis filter

Note 1 to entry: With "final rinsing", liquid flows over a component without any pressure being used. The step is implemented after extraction to remove any particles that may be adhering slightly to the component or surfaces of the extraction equipment due to re-sedimentation and to forward them to the analysis step. The liquid is applied to the surface using a spray.

**3.61**
**final rinsing liquid**
(test-) liquid used after the extraction step to remove any particulate residues from the surfaces of the extraction setup and deposit them on the analysis filter

**3.62**
**fixative**
liquid used to fix particles on the *analysis filter* (3.7) to prevent their loss though electrostatic charging

**3.63**
**fan nozzle**
**flat jet nozzle**
nozzle that generates a linear jet on impaction on a smooth surface

Note 1 to entry: Parameters include jet width and equivalent bore diameter.

**3.64**
**functional test bench**
closed circuit of test liquid onto which the test component is installed in order to be subjected to stresses or to provide similar functions to those to which it will be subjected to under final use operating conditions

**3.65**
**gravimetry**
analysis method used to determine the mass of all residues present on the analysis filter by measuring differences in mass

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**3.66**
**inspection procedure**
**inspection method**
full sequence of all work steps including preparatory steps, extraction, filtration, analysis, carried out in the course of a *cleanliness inspection* (3.19)

**3.67**
**inspection report**
document that contains clear, summarized, general information together with details of the test component, information about the extraction, filtration and analysis steps as well as a representation of the inspection results

**3.68**
**inspection specification**
**inspection document**
detailed description of the *inspection procedure* (3.66)

Note 1 to entry: Where appropriate, it can also include illustrations to provide assistance.

**3.69**
**internal rinsing**
extraction method with a cleaning effect that is based on a turbulent flow of liquid inside the component

**3.70**
**internal rinsing apparatus**
technical construction consisting of a media supply and set-up to integrate the test component

Note 1 to entry: It is used exclusively to perform an internal rinsing extraction step, e.g. an adapted test bench for a hydraulic component.

**3.71**
**isolation**
screening of areas of the test component that do not form part of the controlled surface and which should not come into contact with the test fluid

Note 1 to entry: Sealing or masking are examples of isolation methods.

**3.72**
**limit value**
maximum permissible value for the residue mass, particle dimension (length, width, height) or particle quantity, which cannot be exceeded

**3.73**
**material analysis**
accurate characterization of a material by means of chemical, spectroscopic, mechanical or metallographic methods

**3.74**
**material classification**
assignment of elemental composition to a material class based on the percentages of individual elements identified

**3.75**
**microscope**
device used to magnify and visualize small objects, often containing an integrated camera system with image-processing

Note 1 to entry: A differentiation is made between material, stereo and zoom microscopes.


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**3.76**
**monitoring**
inspection of cleanliness at regular intervals with the purpose of evaluating processes relevant to cleanliness

**3.77**
**particle**
tiny structure made from solid organic or inorganic matter

**3.78**
**particle count**
number of particles counted by their size or other characteristics

**3.79**
**particle load**
totality of all particles present on a surface or in a liquid

**3.80**
**particle overlap**
particles overlaying one another, which prevents them from being optically recorded as single particles

**3.81**
**particle size**
geometric feature of a particle that is stated in the cleanliness specification

Note 1 to entry: If this is not stated, the particle size corresponds with the longest dimension $Feret_{max}$.

**3.82**
**particle size class**
**size class**
particle size range with an upper and lower class limit

**3.83**
**particle size distribution**
particle count grouped into *particle size classes* (3.82)

**3.84**
**particle standard**
substrate marked with objects of a known shape and size used to verify that optical analysis systems are correctly calibrated

**3.85**
**passive component**
component which does not set the fluid in motion and is not actuated by the fluid

EXAMPLE Connector, tube, tank, etc.

**3.86**
**preparatory steps**
totality of all measures carried out after delivery of the component and before execution of the extraction procedure in order to enable all particles present solely on the controlled surface to be detached during the extraction step, e.g. disassembly, demagnetization, isolation, pre-cleaning

**3.87**
**pressure-rinsing**
extraction method with a cleaning effect that is generated by the kinetic energy of an open jet (impulse)

**3.88**
**qualification report**
documentation of the qualification test, including declining test and derivation of the routine inspection procedure

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**3.89**
**qualification test**
performance of declining tests to work out a routine inspection

**3.90**
**residue mass**
mass of the particle load determined as the mass difference using the method of gravimetric analysis

**3.91**
**routine inspection**
cleanliness inspection performed with qualified extraction parameters (recurrent)

**3.92**
**scanning electron microscope**
**SEM**
high resolution microscope which images a sample by scanning it with a focused electron beam

**3.93**
**start parameters**
recommended parameters of a considered extraction method (e.g. pressure-rinsing) to commence qualification tests in order to achieve better comparability of extraction procedures and at last better comparability of cleanliness inspection results

**3.94**
**test component**
**test object**
**test piece**
single component, aggregate or system inspected for cleanliness

**3.95**
**test conditions**
circumstances under which the cleanliness inspection is performed

**3.96**
**test liquid**
**test fluid**
**test air**
medium of specified characteristics (e.g. viscosity, boiling point, cleanliness level, and solvency) used to extract contaminants from a component

**3.97**
**test lot**
all test components from which the combined particle load is measured in a cleanliness inspection

**3.98**
**test lot size**
number of test components comprising the *test lot* (3.97)

**3.99**
**turbulent flow**
flow of fluid with a cleaning effect generated by turbulences that is used to extract contaminants from internal component geometries

Note 1 to entry: An effective turbulent flow prevails in a liquid if the following applies: Reynolds number ≥4 000.

**3.100**
**ultrasonic bath**
technical device used to clean components by means of ultrasonic vibration


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**3.101**
**ultrasonic vibration**
extraction method with a cleaning effect based on the formation and subsequent collapse of vapour bubbles (cavitation) that is induced by high sound pressures

Note 1 to entry: Frequencies ranging between 20 kHz and 400 kHz are used (in some cases up to 1 GHz).

**3.102**
**vacuum rinsing**
**vacuum flushing**
method of contaminant extraction using vacuum to flow the test fluid through the test component

**3.103**
**validation**
process by which a test method evaluates the capability of the contaminant removal process

**3.104**
**volumetric measurement**
flow rate determined by the measurement of a volume of liquid and the time required to fill a vessel to a specific level

**3.105**
**wetted surface**
$A_C$
surface area of the component that is exposed to a system fluid

**3.106**
**wetted volume**
$V_C$
volume of the component that is exposed to a system fluid

## 4 Symbols and abbreviated terms

| | |
|---|---|
| $A$ | Unit of reference "per 1 000 $cm^2$" when specifying the CCC |
| $A_C$ | Controlled surface of all test objects in a test lot |
| ATR | Attenuated total reflection |
| APC | Automatic particle counter |
| BSE detector | Back-scattered electron detector |
| $C_i$ | Cleanliness value |
| CCC | Component cleanliness code |
| CCD | Charge coupled device |
| CT | Computer tomography |
| $d$ | Internal diameter (e.g. of piping) |
| $D_n$ | Declining value at repeated extraction step n |
| EDX | Energy dispersive X-ray spectroscopy |
| $Feret_{max}$ | the greatest possible perpendicular distance measured between two parallel lines touching the particle [µm] |

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