



BSI Standards Publication

Road vehicles — Cleanliness of components and systems

National foreword

This British Standard is the UK implementation of ISO 16232:2018. It supersedes BS ISO 16232-1:2007, BS ISO 16232-2:2007, BS ISO 16232-3:2007, BS ISO 16232-4:2007, BS ISO 16232-5:2007, BS ISO 16232-6:2007, BS ISO 16232-7:2007, BS ISO 16232-8:2007, BS ISO 16232-9:2007, BS ISO 16232-10:2007, which are withdrawn.

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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.

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.

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>

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

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

**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

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

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.

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

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.

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

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 $\geq 4\,000$.

3.100

ultrasonic bath

technical device used to clean components by means of ultrasonic vibration

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]

FT-IR	Fourier transformation infrared spectrometer
m_C	Mass of particle load related to number of components tested
m_A	Mass of particle load in relation to controlled surface
m_V	Mass of particle load in relation to controlled volume
h	Absolute particle count
H_A	Particle count in relation to controlled surface
H_C	Particle count in relation to test lot size
H_V	Particle count in relation to controlled volume
Hz	Frequency ($\triangleq$ movements per second) [1/s]
IR	Infrared
ISO-MTD	ISO medium test dust
λ	Wavelength
LIBS	Laser-induced breakdown spectroscopy
m_1	Tare mass of analysis filter
m_2	Total mass of occupied analysis filter
m	Residue mass of particle load
n	Number or test lot size
N	Unit of reference "per component" when specifying the CCC
nA	Numerical aperture
η	Dynamic viscosity [Ns/m ²]
ν	Kinematic viscosity [m ² /s]
PET	Polyethylene terephthalate
Re	Reynolds Number, $Re = w \cdot d/\nu$
SEM	Scanning electron microscope
SE detector	Secondary electron detector
U/S	Ultrasonic
V	Unit of reference "per 100 cm ³ " when specifying the CCC
V_C	Wetted volume of all test objects in a test lot
w	Velocity of the fluid [m/s]
x	Variable for the particle size, e.g. $150 \mu\text{m} \leq x < 200 \mu\text{m}$
z	Particle height [μm]

5 Cleanliness inspection principles

5.1 General

The purpose of a cleanliness inspection is to detect the particulate contamination which is present on the relevant surfaces of a test component.

In contrast with other inspections, which can generally be performed directly on a test component, e.g. optical or tactile (contact) tests, the inspection of technical cleanliness is an indirect test that requires an extraction step. The relevant surfaces of functionally-critical components utilized in the automotive industry are often located inside pipes, channels, casings, tanks, pumps, valves or similar components. Fluids often flow through such components and these are capable of transporting particles to sensitive areas of a system. The inner surfaces cannot generally be accessed to allow a direct e.g. visual inspection. Furthermore, due to their material composition, roughness or lack of contrast with the particulate contamination, many surfaces are not suitable for visual inspections.

Consequently, in order to analyse technical cleanliness, first of all an extraction (or sampling) step is necessary. Here, the particles present are first removed from the component by means of a laboratory cleaning process (see [Figure 1](#)). The complete test fluid is then filtered, the particles extracted from the component deposited on an analysis filter and then subjected to analysis.

This also means that **it is impossible to repeat the cleanliness inspection on the same test component** because its cleanliness state has been altered as a result of the inspection method (extraction).

As in some cases a single particle may be functionally critical, it is essential that the collective of particles present on the component is removed as entirely as possible by the extraction step. As reference test components with a defined level of contamination do not exist to assess the efficacy of extraction procedures, the effect of extraction conditions for cleanliness inspection needs to be investigated based on the following:

- **Qualification of the extraction procedure (qualification test):** the appropriate extraction procedure for a test component is determined by performing qualification tests. The qualification criteria are stated in this document. They serve to ensure that as many of contaminant particles are removed from the test component as possible. Finally the qualification results, requirements and parameters of the extraction procedure chosen are documented.
- **Blank level:** the cleaner a test component is (i.e. the lower the number of particles expected to be determined in a cleanliness inspection), the higher the risk that external contamination introduced into the test procedure will falsify results. The quantity of extrinsic particles permitted in a test is stated in this document. This permissible blank level is orientated towards the cleanliness requirements of the respective test component.

The cleanliness inspection (see [Figure 1](#)) is made up of the following steps:

- a) provision of the test component;
- b) removal of the particles from the test component (extraction);
- c) filtration of the particles (except with shortened analysis);
- d) analysis of the particles; and
- e) documentation of the inspection and results.

In order to perform cleanliness inspections, special equipment, suitable premises and skilled, experienced staff are required.

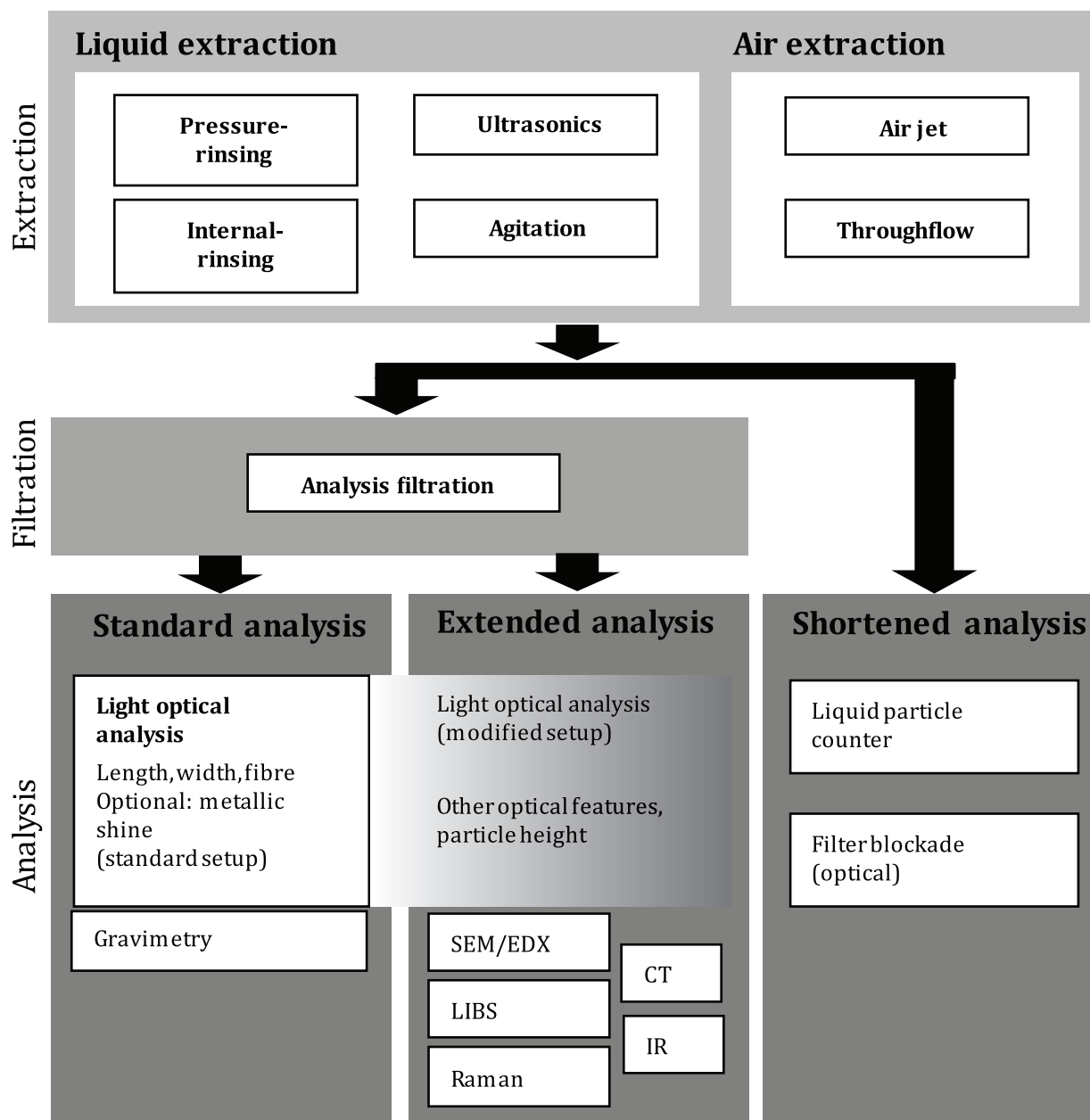


Figure 1 — Inspection methods

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

[Annex I](#) describes possible procedures to be taken when the result of a cleanliness inspection exceeds the permissible value stated in the cleanliness specification.

5.2 Selecting the inspection method

With respect to [Figure 1](#) the following shall be considered.

- Particle extraction: particles are detached from the component by means of a test fluid in a cleaning process. The extraction method is determined by the features of the test component(s), such as size, shape, accessibility to the surfaces requiring inspection, component material and type and adhesion of the contamination to be removed (see [Clause 7](#)).

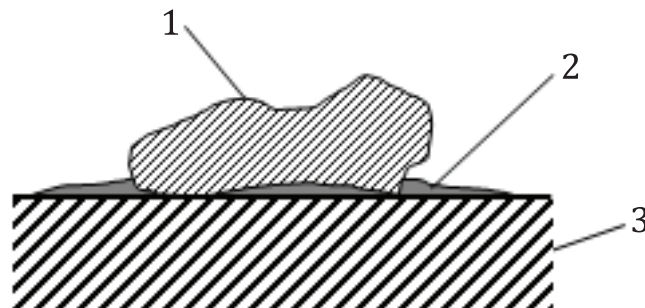
- Particle filtration: particles with a size relevant to the analysis are deposited on an analysis filter. The type of analysis filter is selected according to the size and quantity of the particles requiring analysis as stated, for example, in the cleanliness specification (see [Clause 8](#)).
- Particle analysis: relevant particle features are analysed in accordance with the information stated in the cleanliness specification, for example. Such features include aspects such as size, quantity, material composition and properties. Where no specific features are stated, the standard analysis procedure shall be applied (see [9.2](#)).

NOTE 1 In the shortened analysis (see [Figure 1](#)) there is no filtration step. Once detached by the test liquid, particles are advanced directly for analysis, e.g. with a liquid particle counter.

The purpose of selecting an extraction method, deriving parameters for it and subsequently validating the method is to adapt and optimize a cleaning task. According to Sinner's circle (see [Figure A.2](#)), the following parameters influence the extraction result:

- test fluid (chemical cleaning aspect);
- temperature;
- cleaning mechanism (extraction method with parameters);
- time (time the controlled surface is exposed to the extraction method).

A particle bonded to a component surface by forces of adhesion is used as a model for the cleaning purpose. The particle in [Figure 2](#) could adhere, for example, because of Van der Waals forces, or alternatively capillary forces subsequent to the presence of humidity in the air or process media (coolants, lubricants or anti-corrosives). The purpose of the extraction method is to overcome these forces and detach the particle.



Key

- 1 particle
- 2 layer enhancing adhesion (humidity in the air, process media)
- 3 component

Figure 2 — Particle bonded to the component surface by forces of adhesion

NOTE 2 Burrs can detach from the component during the extraction procedure, which are then also included in the cleanliness inspection.

5.3 Start parameters

After selecting the extraction method (cleaning mechanism), which is essentially determined by the size, shape, material and location of the component surfaces requiring inspection, there is considerable options for variations regarding the specific parameters that can be chosen, e.g. diameter of the spray nozzle, flow rate, ultrasonic frequency, etc. In order to obtain comparable extraction (and thus

also analysis) results, it is advisable to commence qualification tests using the start parameters recommended for the various methods (see [Clause 7](#)).

NOTE To optimize an extraction procedure for a specific component with regard to extraction time or particle detachment (without damaging the component surfaces concerned), the recommended start parameters can be modified provided they are documented appropriately.

5.4 Cleaning mechanism parameters

The extraction effect and even probability of damage to the component surface is primarily dependent on the parameters of the extraction method responsible for the mechanical action on the component (impulses, forces etc.). In order to select suitable parameters, sound knowledge of the test component, its manufacture and later usage may be necessary. However, if there are no requirements or experience known which justifies the implementation of specific extraction parameters, the start parameters recommended for the respective extraction method should be used.

For more details see [Annex A](#).

5.5 Staff skills

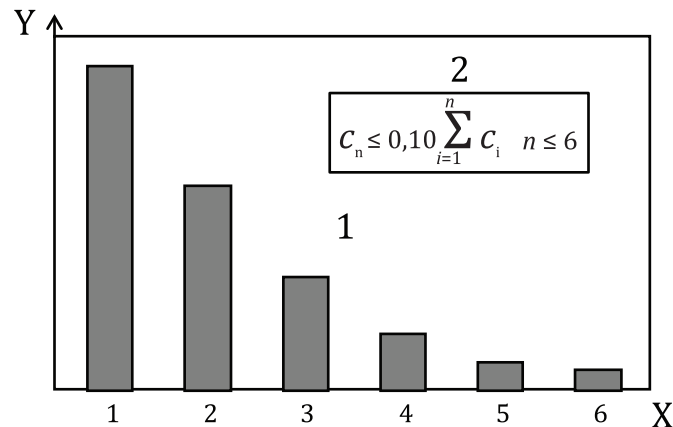
The cleanliness inspection is a very complex task including the understanding of cleanliness specifications, the selection and careful execution of extraction procedures, precise analysis and an accurate documentation. Therefore, well trained and highly motivated staff members are essential (see also [Annex J](#)).

6 Qualification tests and blank level

6.1 General

Qualification tests are carried out to define the appropriate extraction method for routine inspection. They represent the final step in the procedure that started in [Annex A](#). The qualification tests are therefore the fourth element (time) in Sinner's Circle shown in [Figure A.2](#). The qualification tests are carried out by means of a declining test, as illustrated in the extraction curve in [Figure 3](#). The qualification and blank level tests shall be conducted and evaluated as described in [6.2](#), [6.3](#) and [Annex B](#).

Qualification tests and cleanliness inspection are different tasks requiring separate test lots. For the purpose of an initial cleanliness inspection at least 2 test lots are needed, one for the qualification test and one for the subsequent routine inspection.



Key

- X consecutive extraction steps n
- Y cleanliness value C_i
- 1 extraction curve
- 2 declining criterion

Figure 3 — Cleanliness values determined by carrying out repeated extraction steps on a component (declining performance)

Determining blank levels and observing the corresponding permissible limits guarantees that the cleanliness inspection is performed under sufficiently-clean testing and environmental conditions. This ensures that any contaminants collected during the test procedure from sources other than the test component may not falsify the analysis result.

To verify that no particles are lost during the various steps of extraction, final rinsing of the extraction equipment, handling and drying of the analysis filter and analysis – with the consequence that they would be lacking in the analysis result - the recovery rate of test particles can be optionally determined.

When controlling cleanliness specifications in the customer-supplier relationship, extraction conditions shall be qualified according to this document.

Even in the case of an extended analysis, especially for microscopic analysis, qualification tests are mandatory, because any form of analysis demands an efficient and representative extraction procedure.

6.2 Qualification tests

6.2.1 Principle

In order to assess the cleanliness of a component correctly, an extraction method shall be effective. Therefore, it shall be proved that the maximum amount of detachable contaminant particles has been extracted from the test component in a cleanliness inspection. Unfortunately, there is no absolute method to determine the particle load actually present. Additionally, “norm-contaminated” products (i.e. in a defined and reproducible state of contamination), which cover the full spectrum of cleanliness-relevant automotive components as far as their geometry, material, particle content and adhesion of contaminants are concerned, simply do not exist. Consequently, to evaluate the efficacy of an extraction method, declining tests are performed.

The decline in cleanliness values is assessed in order to derive appropriate extraction conditions for a component or a group of similar components (component family) and to define an “inspection specification”.

By carrying out repeated extractions on a component, it can be determined whether the particulate load detached each time decreases and thus whether the extraction method applied is suitable (see

[Annex B](#)). The declining criterion (see [Figure 3](#)) determines whether the particulate contamination has been effectively detached. This identifies the point on the extraction curve where the current value of extracted contamination is less than 10 % of the total quantity of contamination extracted in all previous extraction steps including the current step. This point is used to develop the routine inspection procedure.

At the same time as performing the declining tests, it can also be determined whether the extraction method attacks the component, causing particles to be detached from the component surface that are not relevant contamination (see also [B.2](#)), e.g. burrs, coatings or component material.

The routine inspection procedure is qualified and specified at least once for each component or component family. Should any modifications be made to the component (constructional) or to the production process that could affect the removal of contamination from the component using the existing extraction procedure (different component geometry or different type, quantity or method of adhesion of contamination), the qualification tests shall be repeated.

Qualification tests shall never be repeated on a component which has already been analysed.

The qualification procedure comprises the following steps (see [Figure B.1](#)):

- a) declining test (see [6.2.3](#) and [Figure B.1](#));
- b) development of the routine inspection procedure ([6.2.3](#));
- c) optional: validation of the routine inspection procedure by carrying out a double inspection;
- d) determination of blank levels (see [6.3](#));
- e) optional: test particle recovery (see [6.2.3.2](#)).

If the blank level and declining performance meet the requirements described in [Clause 6](#), the procedure developed is documented as a qualified inspection specification for the routine inspection.

NOTE Based on the inspection specification derived for a similar component (geometry, material, coating, etc.), in some cases the qualification test can be reduced to steps c) and d).

6.2.2 Materials and equipment

Cleaning mechanism, test fluid, and temperature of the extraction procedure, as well as filtration and analysis method are determined as described in [5.2](#).

Declining tests are evaluated using the analysis method that is also applied to validate the cleanliness specification (e.g. gravimetry and light optical analysis).

At the beginning of the declining tests, the start parameters recommended for the respective extraction method are set and implemented — or other parameters, if they are more suitable and strictly documented (see [Clause 7](#)).

An adequate supply of identical components (same model, same manufacturing lot) shall be available in the event that the declining test needs to be repeated.

Ensure that the test component is delivered to the test laboratory in accordance with [Clause 11](#).

6.2.3 Procedure

6.2.3.1 Declining test

[Figure 3](#) shows an example of an extraction curve obtained if a suitable extraction procedure is utilized.

- a) Determine a test lot size estimated to be suitable.

- b) Clean testing equipment as required and validate the cleanliness level by performing a blank level measurement.

Because the later routine procedure has not been determined at this stage at the start of the qualification, the blank level cannot yet be determined using the final extraction volume or extraction time. The parameters used to determine the “provisional” blank level are initially selected by the person carrying out the inspection. The respective start parameters may be useful guides to help choose these as well as the experience gained by the inspecting person with regard to the inspection equipment used. Additionally, an equipment blank level is often known, i.e. a blank level that can be attained with the extraction setup using a defined procedure and volume of liquid or period of time. If the equipment blank level is used as the “provisional” blank level for the qualification tests, it shall also fulfil the blank level criteria.

- c) Using the start parameters, carefully perform the extraction procedure on the same component or test lot six times in succession and determine the cleanliness value C_i for each of the six extraction steps. The extraction setup shall be subsequently rinsed using an effective final rinsing procedure after each extraction step.
- d) Then, for each cleanliness value C_i , calculate the ratio between the cleanliness value under consideration and the total of all cleanliness values including the current extraction step. The declining value for step n of declining test is calculated using [Formula \(1\)](#).

$$\frac{C_n}{\sum_{i=1}^n C_i} = D_n \quad (1)$$

- e) If the declining value D_n is $\leq 0,10$ (10 %), the declining criterion has been achieved.

$$C_n \leq 0,10 \sum_{i=1}^n C_i \quad n \leq 6$$

- f) Once the declining criterion has been attained, the details for the routine inspection procedure (i.e. inspection specification) are determined (see [6.2.3.2](#)).
- g) If the declining criterion is not achieved after six extraction steps, extraction parameters need to be modified, or a different extraction method chosen, and the declining test repeated with **a new component or test lot**. It may be necessary, for example, to reduce the strength of the extraction process if the component material is damaged by the extraction. If components have very low particle loads (i.e. are very clean to start with), it may be very difficult to identify a decline. In such cases, it may be wise to increase the number of components of the test lot (test lot size).
- h) If, despite optimizing the extraction parameters, the declining criterion still cannot be attained, the component is regarded as an exceptional inspection case (see [6.4](#)).

The six cleanliness values C_i obtained from each respective extraction step can be illustrated in a graph as an extraction curve, as shown in [Figure 3](#).

A range of curve shapes that may be obtained in the course of declining tests is shown in [B.2](#) which also describes methods for interpreting them.

To determine declining values and assess the declining performance (point d) and e)) the cleanliness values C_i stated in the cleanliness specification of the component are used. They are:

- in the case of gravimetric information, the residue mass;
- in the case of a light-optical or other method to determine particle size distribution, the particle counts in the respective particle size classes. To simplify the determination and representation of declining performance, all particle size classes included in the cleanliness specification can be added together. However, care shall be taken that there is a decreasing trend in each size class.

All particles with the exception of (textile) fibres are included in the declining test.

If fibres are part of the cleanliness specification they can be included in the declining test.

If no cleanliness specification has been defined, or if only a maximum permissible particle size is specified (e.g. no particles $> x \mu\text{m}$ permitted), all particle size channels are considered in the declining test that can be reliably measured with the magnification and pixel resolution selected in the light-optical analysis method (see [9.2.3](#)).

NOTE 1 Under certain circumstances, it can be necessary to consider particle size classes which are not included in the cleanliness specification by adding size classes with at least 20 counting events.

NOTE 2 To obtain further information, the declining performance of individual particle size classes can also be assessed without adding them together.

6.2.3.2 Developing the routine inspection

From the findings in [6.2.3.1](#), the appropriate routine inspection conditions are derived for the respective extraction method.

- Pressure-rinsing: the required total pressure-rinsing time, as well as the related total volume calculated on basis of the flow rate.
- Ultrasonic: the required total length of time in the ultrasonic bath.

- Internal rinsing: the required total rinsing time as well as the related total volume calculated on basis of the flow rate.
- Agitation: the required total agitation time as well as total number of shaking movements calculated on basis of the agitation frequency.
- Air jet extraction: the required total time the component is cleaned with the air jet.
- Air through-flow extraction: the required total time air flows through the component.

If n single extraction steps are required for the qualification (to achieve the 10 % criterion), the routine inspection procedure is carried out over the $(n - 1)$ -fold total extraction time minimum. The aim of a qualified routine inspection is to extract at least 90 % of detachable contamination from the component within the period of time it is subjected to the extraction process.

The final rinsing procedure to remove residual particles from the extraction devices remains unchanged. The volume of liquid or final rinsing time used in the procedure is independent of the extraction of particles from the component and therefore not multiplied by $(n - 1)$. In order to determine whether the selected final rinsing procedure is effective, the final rinsing procedure can be repeated or test particles utilized, for example (see [Annex C](#)).

Once qualified and determined, the routine inspection (see [Figure B.3](#)) is utilized to extract particles from components in order to validate the component cleanliness and thus also cleanliness specifications defined between the customer and the supplier.

6.2.3.3 Verification of the routine inspection/double inspection (informative)

To further verify a qualified routine inspection procedure, a double inspection can be performed.

- The routine inspection developed in the preceding section is carried out twice on another non-inspected test lot and the cleanliness values C_1 and C_2 determined.
- If the second cleanliness value is lower than/equal to 30 % of the sum of both cleanliness values, the applicability of the routine inspection conditions developed is verified and can be documented in the inspection specification.

$$C_2 \leq 0,30 (C_1 + C_2)$$

- If the criterion is not fulfilled, it should be investigated whether it is possible to implement more appropriate extraction parameters.

6.3 Blank level

6.3.1 Principle

The use of extraction methods to inspect the cleanliness of components involves the risk that not only particles from the test component are included in analysis results but also extrinsic particles are introduced into the test. If the proportion of extrinsic particles (blank level) is too high, this could lead to a faulty assessment of component cleanliness. The blank level represents the total value of contamination that does not originate from the component. Origins of such interfering particles include:

- test fluid,
- extraction equipment (baths, basins, tubing, valves, etc.),
- all objects coming into contact with the component and test liquid,
- handling processes during preparation, extraction and analysis,
- environment and staff.

The cleanliness grade of the test environment shall be appropriate for the required cleanliness state of a component.

If the required blank level is not achieved, the cause shall be investigated among the above-mentioned influencing factors.

NOTE Tips on optimizing cleanliness suitability, which can also be transferred to a cleanliness laboratory, are described in Reference [8].

To ensure that the blank level does not have an adverse influence on the test result,

- it shall be correctly determined, and
- it may not exceed a specific maximum ratio as far as the required/derived component cleanliness is concerned.

A blank level test is not mandatory before each routine inspection. However, a blank level test shall be performed, for example, if there is a risk that the cleanliness state of the extraction equipment is unsuitable or unknown, e.g.:

- if extraction equipment has not been used for a prolonged period of time, if stopped overnight, over the weekend or for longer periods;
- on changing from a component inspection with high particle content to a component with lower particle content, because there is a major risk of transferring an impermissible quantity of particles to the clean component.

6.3.2 Deriving blank levels

The permissible blank level is calculated on the basis of a component's cleanliness values.

The blank level may not exceed 10 % of the required/expected cleanliness values for the component. Further conditions apply for the blank level regarding the maximum permissible particle size (see [Table 1](#)).

If the cleanliness values of a component are not known — e.g. on inspection for the first time — the basis for calculating the blank levels can only be attained after performing the qualification tests.

Table 1 — Blank level criterion and examples

Cleanliness specification	Blank level criterion	Example			
		Cleanliness specification		Blank level derived	
Residue mass	10 % of permissible or measured residue mass ^a	7 mg		0,7 mg	
Particle size distribution (also CCC)	10 % of the quantity of permissible or measured particles in each size class (without exception, digits after the decimal point shall be rounded off)	Size channel [µm]	Permissible quantity	Size channel [µm]	Quantity permitted in blank level
		100 ≤ x < 150	90	100 ≤ x < 150	9
		150 ≤ x < 200	28	150 ≤ x < 200	2
		200 ≤ x < 400	12	200 ≤ x < 400	1
		400 ≤ x < 600	0	400 ≤ x < 600	0
Largest permissible particle	Maximum permissible particle size is halved; no particles permitted in this size class or larger	No particles >500 µm permitted		500 µm/2 = 250 µm, lies in the size class H 200 µm ≤ x < 400 µm Therefore: no particles ≥ 200 µm permitted in the blank level	
None	No particles >50 µm permitted ^b	—		No particles >50 µm permitted	

^a Take resolution of balance into account, see 9.2.2 for more details.

^b Only applies if no information is available in terms of a cleanliness specification, analysis results from the component, experience with similar components.

The blank level always refers to the specific component inspection. In order to be able to calculate permissible blank levels where cleanliness specifications are stated per controlled surface or wetted volume, or in the case of coded cleanliness specifications, the permissible quantity of contamination for the test lot analysed (one or more components) shall always be calculated first.

If different cleanliness features are combined in one cleanliness specification, e.g. residue mass and particle size distribution, the blank level shall be calculated and attained for all features specified.

If two possible blank levels are determined, e.g. with a specified particle size distribution and a maximum permissible particle size, both blank levels shall be fulfilled.

When validating cleanliness specifications, it is not permitted to subtract the calculated blank level from the analysis result of a component cleanliness inspection.

6.3.3 Materials and equipment

To determine blank levels, exactly the same equipment, materials, settings and parameters for extraction, filtration and analysis shall be used as defined in the inspection specification for the component under test.

6.3.4 Procedure

- Calculate the permissible blank level either on the basis of the cleanliness specification or on the basis of the cleanliness values determined in 6.2.3.
- Perform exactly the routine inspection developed in 6.2.3 without a component and determine the cleanliness value (= blank level).
- Check that the attained blank level is within the permitted limit.

If blank level criteria are not fulfilled, elements of the testing equipment or environment are unsuitable and require optimization.

Another reason why blank levels cannot be attained may be due to an inadequate final rinsing step; as a result, particles remain in the testing apparatus and are only detected in the course of the blank level test.

6.4 Exceptional cases

If it is proven that the qualification criteria for the declining and/or blank level cannot be fulfilled after the repeated optimization of extraction conditions, the inspection procedure best-suited for the task can be specified for the routine inspection in the customer-supplier relationship.

Before a cleanliness inspection procedure (failing the qualification criteria) is declared to be an exceptional case, firstly all possible causes of error shall be investigated and remedied, e.g. incorrect handling, particles transmitted from non-relevant component areas, etc.

The following may prove to be exceptional cases.

- Active components and assemblies which need to be operated during extraction (e.g. valves, pumps, injectors, etc.). In such cases, detached contaminant particles and particles generated during break-in may overlie one another with the consequence that the decline in particulate contamination cannot be observed separately.
- Components that release particles, e.g. from the component material or from sacrificial coatings.
- Extremely clean components, with which an assessment of the declining performance cannot be achieved despite increasing the test lot size and optimizing blank levels.

For further details see [Annex B](#).

7 Extraction methods

7.1 Principles

Because of their geometry and surface characteristics, functionally-relevant components in automotive systems cannot usually be fully inspected directly for the presence of particles (e.g. using a direct visual or microscopic technique). In such case, particles are removed from components by extraction or sampling.

The aim is not just to detect a representative quantity of particles but to ensure that the maximum number of detachable particles is detected, including the reliable detachment of single critical particles. Procedures for qualifying and validating this requirement are the same as those described in [Clause 6](#).

Depending on the test component, several different extraction methods may need to be implemented. It may also be necessary to activate parts of a component mechanically in order to inspect the controlled surfaces concerned.

In some cases, the packaging coming directly into contact with the component may also need to be included in the cleanliness inspection.

A component may possess controlled surfaces that have different cleanliness specifications and which therefore shall be inspected separately.

After detaching the particles from controlled surfaces using a liquid or possibly air (see also [5.2](#)), the contamination is deposited on an analysis filter membrane, which is then investigated using a standard and/or extended analysis method. In the case of shortened analysis, no filtration step is required and particles are analysed directly in the fluid (usually liquid).

Because the result of a cleanliness inspection is highly dependent on the care with which the always manual extraction procedure is performed, it is essential that inspection staff are well-trained. The inspection specification shall contain a detailed description of the extraction procedure. To design and develop applicable extraction procedures, the principal settings and configurations described in [Annex D](#) shall be considered.

7.2 General requirements of extraction equipment

All items of the extraction setup coming into contact with the test fluid, and all surfaces thereof whose cleanliness could affect the result of the component cleanliness inspection, shall be constructed and kept clean in such a way to ensure that the permissible blank level is not exceeded. The following points shall be taken into account in their design and operation:

- low degree of surface roughness;
- high chemical and mechanical resistance;
- no particle traps, such as dead zones or undercuts;
- easy to clean;
- non-magnetic;
- not electrostatically chargeable;
- tilted surface and angled piping (as short as possible) from extraction cabinet or collection funnel to analysis filtration;
- no particles emitted from the apparatus (or only particles which are not relevant to the component inspection), including when components are activated, moved or driven.

To facilitate achievement of and compliance with blank levels, the surfaces of extraction setup in contact with fluid that are located between the purification filter of the test fluid and the analysis filtration unit should be kept as small and as geometrically simple as possible.

7.3 Preparatory steps and post-treatment of test components

7.3.1 General

Although the preparation step should be performed near the test environment, if there is a risk of particles being generated or released when preparing components for a cleanliness inspection, it should be carried out at a different suitable workplace.

7.3.2 Unpacking

Test components shall be supplied for inspection in an appropriately clean manner. In many cases, suitable packaging is required. From the moment it is removed from the respective manufacturing step and arrives at the cleanliness inspection laboratory, the packaging protects the test component against re-contamination during storage or transportation.

When opening packaging and removing test components, care shall be taken to avoid contaminants adhering to the outside of the packaging from being released and reaching the controlled surfaces of components. Appropriate action includes miscellaneous options such as:

- cleaning external packaging surfaces before opening;
- changing gloves between opening the packaging and removing the test components;
- ensuring that packaging is opened by one person and test components removed by another;
- onion skin principle (two layers of packaging and lock concept).

7.3.3 Clarifying which surfaces require inspection

In many cases, only part of the surface area of a component is relevant to cleanliness or has been designated a cleanliness specification (e.g. only the interior of the casing for an electronic device).

Alternatively, more than one area of a component is relevant and these have different cleanliness requirements (e.g. refined oil inlet and outlet). The following needs to be specified.

- The exact location of the controlled surface(s) to derive further steps, e.g. possible disassembly or other preparation processes, and plan the extraction strategy (e.g. sequence of the various extraction steps, pressure-rinsing procedure, etc.).
- The exact size of the controlled surface(s). This is especially important if the cleanliness specification is normed or coded, e.g. per 1 000 cm² or 100 cm³. In such cases, the permissible quantity of contamination for the test component is calculated using the actual size of the controlled surface, and subsequently used to derive the permissible blank level for the test. Additionally, when developing a declining test, the required quantity of test liquid can be determined on the basis of the start parameters.

7.3.4 Preparatory steps

Where controlled surfaces are not the full size of the component, or where a component possesses several relevant controlled surfaces with different cleanliness specifications (see also [7.3.3](#)), it may be necessary to isolate the various component areas from one another. In this way, test liquid cannot inadvertently come into contact with another controlled surface during the procedure and transfer particles to it that are not relevant.

Areas not requiring inspection shall be isolated, for example by plugging openings, coating, masking, sealing or marking them. Isolation measures shall be carried out in an appropriately clean manner and used materials should not affect the cleanliness inspection results.

Design and material of isolation items shall be cleanliness suitable.

If non-relevant areas of a test component do not require pre-cleaning, care shall be taken to ensure that no particles or other substances are transferred to the relevant controlled surfaces or removed from them.

For the extraction, it may still be necessary to fix the test component in mounting, lifting or sampling devices, or to use adapters for items such as rinsing lines, drives or electrical connections. This may also cause particles to be generated or released. Consequently, the same recommendations apply as those mentioned in [7.3.5](#).

In some cases, it can be useful to design adapters for components in bright colours. If coloured particles then appear in the analysis, the particles originate from the adapter and are not due to an inadequate cleanliness level of the test component.

7.3.5 Disassembly

In some cases, it may be necessary to partially or fully dismantle the test component before the cleanliness inspection in order to gain access to the functional surfaces relevant to the extraction.

During disassembly, there is a high risk that particles be generated and released, e.g. from joints. To prevent particles generated during disassembly from reaching component controlled surfaces, disassembly tasks shall be carefully planned and performed in an appropriately clean manner. Particles originating from disassembly steps shall be removed (e.g. by suction cleaning or wiping) the moment they are generated/released or immediately afterwards. All tools and auxiliary equipment shall be kept clean and designed with low abrasion levels.

There is also a risk during disassembly that particles from external surfaces that are not relevant to the inspection are transferred to internal surfaces that are relevant to component cleanliness. This can essentially be avoided by cleaning external surfaces before carrying out the disassembly process.

Due to the risk of the cleanliness state of controlled surfaces being altered by disassembly processes, disassembly steps shall be carefully documented; alternatively, precise instructions for disassembly shall be given.

7.3.6 Demagnetization

Magnetism causes magnetizable particles to adhere more strongly to the test component. Therefore, ferromagnetic test components should be assessed for residual magnetism and, where necessary, demagnetized before commencing tests.

EXAMPLE The non-critical residual magnetism value of components of diesel injection systems in contact with fluid is 2,5 Gauss or 200 A/m.

Machining steps during a component's manufacture may cause it to become magnetized. If a product requires demagnetization, it shall be documented. Features relevant to the function of a component may be destroyed by demagnetization processes.

Components which cannot be demagnetized for technical reasons are usually exceptional cases; these shall be specified in the customer-supplier relationship. In such cases, extraction with liquid or air is generally only suitable to a very limited extent and methods highly-specific to the component concerned need to be applied in order to detach particles; such methods are not addressed in this document.

7.3.7 Post-treatment

It shall be documented whether a tested component shall be scrapped or returned to the production line after inspection. Any post-treatment steps, such as removing residual test liquid, drying the component or applying a preservative shall be specified.

7.4 Liquid extraction

7.4.1 General

As described in [Annex A](#), liquid extraction is suitable for the majority of functionally-relevant components encountered in the automotive industry.

7.4.2 Test liquid

The test liquid (and final rinsing liquid) shall be compatible with the component as well as with the extraction and filtration equipment, including all seals and filters used.

As far as the cleaning effect is concerned, the test liquid is mainly selected in dependence on the component material and the characteristics of the contaminants expected and with a suitable kinematic viscosity e.g. $\nu \leq 5 \text{ mm}^2/\text{s}$. Among others, these are dependent on the history of the component and its manufacturing process (see also [D.1](#)). Particles relevant to the inspection may, for example, be bound in assembly greases or preservatives.

If the test liquid and final rinsing liquid are not adequately clean, purification filters shall be used.

WARNING — With aqueous test liquid, for example, active cleansing substances present in the test liquid could be removed by the filter.

All volumes of liquid used in the extraction and final rinsing steps shall be included in the analysis.

In order to re-use a test liquid (e.g. in circulatory systems), it shall be treated so that it does not impair the quality of inspection results. The following points should be taken into account.

- The physical/chemical cleaning effect of the liquid may not be affected, e.g. by the depletion of detergents or the consumption of active chemical ingredients.
- No substances may be added which could impair the inspection results; e.g. greases or preservatives.
- No substances may be added which could damage the inspection equipment or component; e.g. water, acids, alkalis.
- Viscosity of blended liquid might change during usage.

[Annex K](#) considers risk assessments for tasks carried out in the laboratory, in particular with the use of cold cleaners for the extraction process.

7.4.3 Pressure-rinsing

7.4.3.1 Principle

Pressure-rinsing describes the localized application of a suitable test liquid to a component via an open jet. The cleaning effect is mainly due to the momentum transferred by the jet on impacting on the test component. As a rule, a rinsing effect also takes place as the test liquid runs off the component.

The method is suitable for cleaning external geometries and easily-accessible inner geometries. If coarse-meshed baskets or filters are used, small components with simple geometries can also be extracted one at a time or in bulk (see also [Figure D.2](#)).

With most applications, a full-jet nozzle with a round cross-section is utilized. However, depending on the geometry of the test component, it may be more practical to use different-shaped nozzles (see [Figure D.1](#)).

Pressure-rinsing tools (nozzles) can also be implemented to clean the inner surfaces of components if they are applied to the aperture of a boring or tubing. Care shall be taken to ensure that the complete internal area is filled and wetted with test liquid. The extraction effect in this case is no longer that of pressure-rinsing but rather of internal rinsing because the surface is not impacted by an open jet (see [7.4.5](#)).

The most important parameters influencing the efficacy of the pressure-rinsing method are the:

- characteristics of the test liquid,
- flow rate combined with the cross-sectional area of the nozzle,
- geometry of nozzles and lances,
- distance away from the object and the angle of the jet,
- sequence implemented when extracting the object surfaces,
- time per surface or forward feed, and
- repetition rate of extractions per controlled surface.

NOTE The pressure of the jet can only be used to characterize its cleaning effect to a limited extent. Although the flow rate of a nozzle with a given nozzle diameter is proportional to the pressure at the nozzle, it is often difficult to measure the pressure directly at nozzle level. Liquid feed pressures measured in other areas of the system (e.g. in a pressure tank or behind a pump), can vary significantly from the actual pressure at nozzle level and are therefore unsuitable as parameters. On the other hand, the flow rate remains constant regardless of where it is measured. Even if the flow rate is not measured via a sensor in the liquid feeding system, it can be simply calculated by means of volumetric measurement (e.g. filling rate of a beaker into which the pressure-rinsing jet is directed) and is thus suitable as a parameter.

In the cases of nozzles with round outlet cross-sections and a non-widened cylindrical jet (or several such nozzles in a pressure-rinsing tool), the efficacy of the pressure-rinsing jet is much less dependent on its distance away from the component as would be the case with a widening flat-jet nozzle (fan nozzle). This makes it easier to perform a defined extraction on the test component (see also [D.2](#), [Figure D.1](#) a), d) and e)).

The efficiency of the pressure-rinsing method is very dependent on the extraction steps that are generally carried out manually. The pressure-rinsing procedure suitable for the respective test shall be documented in the inspection specification.

If the pressure-rinsing method is implemented using a solvent as a test liquid, aerosols could be generated. These aerosols may form a combustible mixture even in cases where the flashpoint of the test liquid is much higher than the testing temperature/room temperature. If there is a risk of aerosol

formation, the extraction should be performed in a suitable extraction cabinet which does not contain any potential ignition sources.

To find out when aerosols may occur, refer to [Figure D.4](#).

[Figure D.4](#) can be used as a guide to determine the combinations of nozzle diameter and flow rate which may lead to aerosol formation. The graph was developed for round full-jet nozzles. Due to the fact that aerosol formation is generally to be expected if flat-jet nozzles (fan nozzles) or other nozzles that widen and mist the pressure-rinsing jet are used, it is essential that all relevant work safety directives are followed.

7.4.3.2 Start parameters

In order for extraction equipment to be used for as many components as possible, pressure-rinsing start parameters shall be selected (see [5.3](#)) so as to generate a jet with a maximum cleaning efficacy without the risk of aerosol formation (see [Table 2](#)).

Table 2 — Start parameters for pressure-rinsing

Parameter	Start value/Condition
Nozzle shape	Round full-jet nozzle
Nozzle diameter	2,5 mm
Flow rate	1,5 l/min
Distance from component	Max. 15 cm
Pressure-rinsing volume/controlled surface	5 ml/cm ²
When inspecting larger surfaces, several nozzles (e.g. combined in a pressure-rinsing tool) can be used together to reduce the extraction time. However, care shall be taken to ensure that the above-mentioned parameters apply for each nozzle aperture.	
Due to the way existing extraction equipment is constructed, it may not be possible to avoid the risk of the operator being sprayed with liquid reflected back from the component or of detached particles from being lost if the recommended parameters are used. In these justified cases, which shall be documented, the initial flow rate of the pressure-rinsing liquid can be decreased to 1,0 l/min.	

When using pressure-rinsing for small components that shall be inspected in bulk it is recommended that the test lot contains a minimum controlled surface of 200 cm² (see [Figure D.2 c](#))).

As part of the qualification tests/declining tests (see [Clause 6](#)), the final pressure-rinsing volume per controlled surface is determined for the routine inspection in dependence on after which extraction step the declining criterion is attained. If the declining criterion is not achieved using these start parameters or if other parameters are more suitable and strictly documented, start parameters may be modified.

7.4.3.3 Materials and equipment

The materials and equipment used in the extraction step shall comply with the general requirements of extraction equipment described in [7.2](#).

- Test liquid, kinematic viscosity $\nu \leq 5 \text{ mm}^2/\text{s}$.
- Pick-up for component: e.g. rest, tweezers or mount for single objects; coarse-meshed basket for small components; manipulators for large components.
- Extraction setup consisting of:
 - pressure-rinsing tool(s): e.g. nozzle pen, which can be controlled manually during the component extraction process and final rinsing of the extraction setup, lances for component inner surfaces, or similar;
 - media supply with container for test liquid, purification filter, pump or pressure supply.

- d) Collection equipment: e.g. pressure-rinsing cabinet, funnel or container to collect extraction liquid.
- e) Suction unit (optional): to remove residual liquid from component cavities.
- f) Where required, graduated vessel to measure volumes: e.g. beaker or measuring cylinder and stopwatch to control extraction times or calculate the flow rate if volumetric measurement is used for the pressure-rinsing step.

Laboratory wash bottles shall not be used for component extraction by pressure-rinsing, because it is not possible to attain a defined and stable pressure-rinsing parameter and is thus not a reproducible extraction step. However, in many cases, laboratory wash bottles are suitable for the final rinsing of extraction or filtration equipment.

7.4.3.4 Procedure

The following procedure shall be adapted to the features of the test component.

- a) Procure all resources required for the test.
- b) Pre-clean all surfaces of the extraction setup in contact with fluid; where appropriate, determine blank levels.
- c) Prepare the test component as described in [7.3](#).
- d) Place the test component in the extraction apparatus; if necessary, position the test component in such a way so as to enable the liquid to flow easily into the collection container or collection funnel.
- e) Perform the pressure-rinsing procedure and adhere to all parameters, times and exact pressure-rinsing sequence. The careful execution of the procedure is crucial to the result of the inspection. Avoid loss of liquid or wetting component areas that are not relevant to the test.
- f) Remove residual liquid (if required, repeatedly) from all areas of the component where liquid and particles can accumulate. Use suction apparatus to remove liquid from objects with cavities that are difficult to access (this liquid shall be included in the analysis).
- g) Where applicable (if specified): sample the inner surfaces of packaging (this liquid is also included in the analysis).
- h) Carry out a final rinse on all areas of the extraction equipment (chambers, mounting devices, etc.) that were in contact with the test liquid (this liquid is also included in the analysis). A suitable procedure should be elaborated, tested and defined for this final rinsing step.
- i) Transfer all the liquid for filtration and analysis.
- j) Fill out the inspection report.

7.4.3.5 Documentation

See [Clause 10](#).

7.4.4 Ultrasonic vibration

7.4.4.1 Principle

Extraction by ultrasonic vibration describes the action of mechanical oscillations ranging between 20 kHz and 400 kHz exerted on the surface of a test component via a liquid. The cleaning procedure is performed in immersion baths fitted with ultrasonic oscillating elements.

The particle-detaching effect of extraction by ultrasonic vibration is caused by high pressure peaks that form when cavitation bubbles implode.

The ability of ultrasonic vibration to detach contaminants is due mainly to the ultrasonic frequency and changes in ultrasonic pressure, which are influenced by the ultrasonic output and geometric features. As a rule, the higher the ultrasonic output and the lower the ultrasonic frequency, the stronger the physical cleaning forces become.

In the event that too-high quantities of particles are detached from the component surface as a result of unsuitable ultrasonic parameters, this can be corrected by setting a higher frequency or lower output. Special care shall be taken with cast iron because graphite may be released. Care is also required with cast aluminium surfaces, painted or coated surfaces and sintered materials, as the selection of unsuitable ultrasonic parameters can cause material damage with the result that non-relevant particles are released from the component surface.

Ultrasonic baths are suitable for inspecting external geometries as well as internal surfaces, provided the sound waves can penetrate component apertures with sufficient intensity. The smaller the openings for the sound waves and the larger the inner cavities become in proportion, the poorer the cleaning effect inside a component. Therefore, when extracting contaminants from the interior and exterior of a component at the same time, the cavitation threshold inside the component shall be exceeded without the component material on the outside being attacked.

Ultrasonic baths are especially suitable for extracting contamination from small components that are difficult to handle individually because they can be inspected in bulk. The use of small ultrasonic extraction baths or beakers reduces the total surface area wetted during the extraction step, which has a positive impact on achievable blank levels.

Ultrasonic vibration can also be used to enhance internal rinsing procedures. Here, the interior of the test component, which is generally pipe-shaped (no sound-absorbing materials), is subjected to a through-flow of test liquid and additionally immersed in an ultrasonic bath and treated externally with oscillations.

The main parameters influencing extraction by ultrasonic vibration are:

- characteristics and temperature of the test liquid,
- ultrasonic frequency,
- ultrasonic density,
- arrangement of ultrasonic oscillators in the bath,
- orientation of the component in relation to the ultrasonic source,
- extraction time, and
- movement of the component.

7.4.4.2 Verifying performance features of ultrasonic baths

To assess relative stability over time (aging) or to compare different ultrasonic baths, the efficacy of the ultrasonic system can be verified.

This is achieved for example by quantitatively determining the perforation of a sheet of aluminium foil by cavitation. The procedure shall be carried out under defined conditions (foil thickness, location and orientation of the foil in the bath).

WARNING — Erosion of aluminium foil may contaminate the ultrasonic bath.

NOTE A simple method to check the ultrasonic energy is the use of a commercially available indicator liquid in vials which is applied e.g. in pharmaceutical industry. After adding the vial to the ultrasonic bath a colour change shows if the ultrasonic bath is working.

7.4.4.3 Start parameters

The start parameters for extraction by ultrasonic vibration shall be carefully selected (see [Table 3](#)) in order to avoid highly-aggressive low ultrasonic frequencies, achieve a good cleaning effect with the power density set without subjecting the component to excessive stress and also to attain short start times for the declining tests (see [5.3](#).)

Table 3 — Start parameters for ultrasonic vibration

Parameter	Start value/Condition
Ultrasonic frequency	35 kHz to 40 kHz
Power density	10 W/l
Time	30 s to 60 s

The power density is set via an output regulator on the ultrasonic bath (if available) or via the filling quantity of the bath (without the component). In general, double half-wave devices are used. The power density documented shall correspond with the effective power density and not the peak power density.

When using ultrasonic vibration on small components that are inspected in bulk, the test lot shall contain sufficient components so as to achieve a minimum controlled surface of 200 cm² (see [Figure D.5](#) a) and b)).

During the qualification tests/declining tests (see [Clause 6](#)), the required duration in the ultrasonic bath is determined for the routine inspection depending on after which extraction step the declining criterion is attained. If the declining criterion cannot be achieved with these start parameters or if other parameters are more suitable and strictly documented, the recommended start parameters may be modified.

7.4.4.4 Materials and equipment

The materials and equipment used in the extraction step shall comply with the general requirements of extraction equipment described in [7.2](#).

- a) Test liquid, kinematic viscosity $\nu \leq 5 \text{ mm}^2/\text{s}$.
- b) Ultrasonic bath: the bath shall be made from stainless steel or other suitable material. Data and performance features shall be documented, especially the output, frequency and bath volumes or filling level. As a rule, the bases and/or walls of ultrasonic baths are fitted with transducers to optimize the homogeneity of ultrasonic distribution and cleaning effect.
 - Mounting device to secure the test component in the bath (no contact with the base or walls); materials shall be permeable to ultrasonic waves (e.g. baskets with very coarse mesh, no mounting devices made from compact absorbent plastics).
 - Where appropriate: beaker for holding small components and corresponding mounting device for beaker.
 - Device (manual/automated) to oscillate the components by half the wavelength vertically in relation to the surface emitting the ultrasonic waves. This compensates for inhomogeneities in the ultrasonic effect due to the formation of stationary waves (oscillation velocity $\leq 1 \text{ cm/s}$).
- c) Where appropriate: additional containers (funnels, beakers) to collect the extraction liquid.
- d) Pressure-rinsing test set-up for the final rinsing of components and equipment and/or for dispensing test liquid (see [7.4.3](#)).
- e) Graduated vessel to measure volumes; e.g. beaker or measuring cylinder.
- f) Suction unit (optional): for removing residual liquid from component cavities.

WARNING — In addition to general safety requirements applicable to all extraction methods the following points shall be considered when using ultrasonic baths:

- Due to the coupling of ultrasonic vibration in the test liquid and the resulting energy input, liquids may become hot if subjected to ultrasonic waves for an extended period of time. This shall be given special consideration and validated accordingly in cases where combustible liquids are used (temperature shall be kept 20 °C below respective flashpoint).
- During the application of ultrasonic vibration, do not place hands or any other part of the body in the test liquid (risk of embolus or destruction of skin cells!).

7.4.4.5 Procedure

The following procedure shall be adapted to the features of the respective test component.

- a) Procure all resources required for the test.
- b) Pre-clean all surfaces of the extraction setup in contact with fluid; where required, determine blank levels.
- c) Prepare the test component as described in [7.3](#).
- d) Fill the extraction device with clean test liquid.
 - 1) For tests carried out directly in the ultrasonic bath: fill the bath and set the output to achieve the required power density in the bath (10 W/l with start parameters). If the output cannot be adjusted, fill to the level which corresponds with the desired power density.
 - 2) In a beaker: fill the bath with water and a small amount of cleaning agent/detergent (to improve the wetting capacity). The water only serves to transmit the ultrasonic waves to the beaker and is not later analysed. The power density can be adjusted using an output regulator or, if not available, by altering the filling level of the bath. The volume subjected to ultrasonic vibration, which shall be known in order to calculate the power density, is the volume of water plus the contents of the beaker. Fill the beaker with clean test liquid.
- e) Place the test component(s) directly in the ultrasonic bath, or in recipients such as baskets, or in the filled beaker, which is also secured in the ultrasonic bath by a mounting device.
- f) Commence the ultrasonic extraction step using the power density, frequency and time stated in the inspection specification. Move the component or beaker while the ultrasonic step is in progress.

If the component shall be subjected to ultrasonic vibration from several sides or several positions, care shall be taken when changing its position (turning over, rotating, etc.) to avoid additional particles from being generated by this handling step.

If the component or beaker is not moved slowly through the sound field of the ultrasonic bath (min ½ wavelengths of the sound waves in the bath), the cleaning effect may not be homogeneous.

- g) Remove the test component(s), hold over the ultrasonic bath or beaker and carry out a final rinsing step with clean test liquid.
- h) Where applicable, empty objects to remove any residual liquid and particles contained inside.
- i) If required, extract particles from the inner surfaces of packaging (pressure-rinsing). The resulting liquid forms part of the extraction liquid.
- j) Empty the beaker; alternatively, where technically possible, drain the extraction liquid out of the bath.

When using laboratory ultrasonic baths, care shall be taken to ensure that no particles detached from the component remain in the baths. There is often a risk of particles sedimenting at the outlet of a bath where, for manufacturing reasons, there is often a gap or step hindering drainage. If taps

or similar drainage elements are fitted to the ultrasonic bath, it shall be checked that these fixtures do not generate particles when used as this could falsify analysis results (blank level).

- k) Then perform a final rinsing step on all surfaces wetted by the test liquid (e.g. beaker and/or baths) using a sufficient volume of test liquid. The resulting liquid is included in the analysis.
- l) Transfer the total volume of liquid for filtration and analysis.
- m) Fill out the inspection report.

7.4.4.6 Documentation

See [Clause 10](#).

7.4.5 Internal rinsing

7.4.5.1 Principle

Internal rinsing describes the extraction of contamination by means of a flow of liquid passed through the inner surfaces of a component. In the process, the entire (or almost entire) test component is completely filled with test liquid. In order to ensure that particles are detached effectively from the walls of the component, the flow through the interior should be turbulent and not laminar. A pulsed through-flow further enhances the efficacy of this extraction technique.

Consequently, internal rinsing is a suitable extraction method for automotive components that will conduct fluids in later use. Examples include:

- passive components such as tubing, lines, channels, filters and heat exchangers, and
- active components needing to be actuated for the through-flow process, such as valves and injectors, or even driven, such as pumps.

With internal rinsing, at least one point of the test component is connected hermetically to a line holding test liquid. Once the fluid has flowed through the test component, the liquid can be removed from the component via one or more lines connected to it. The liquid can flow into a closed rinsing system or be allowed to drain off into an extraction basin without the influence of pressure.

Depending on the test component concerned, the set-up for extraction by internal rinsing can be very simple. For example, a pressure-rinsing set-up such as that illustrated in [Figure D.3](#) can also be used to rinse fairly short sections of piping provided pressure-rinsing tools are replaced by rinsing devices. In the case of active components, internal rinsing test benches may be highly complex if components need to be powered, driven or subjected to high pressure.

Where components have wide cross-sections for connections, e.g. cooling systems of commercial vehicles, extraction by internal rinsing often reaches its limits because a major effort is required to construct the rinsing setup with the necessary volumes and flow rates of liquid. It may make sense in such cases to revert to extraction by agitation or pressure-rinsing.

The advantage of internal rinsing is that only inner areas are wetted, thus there is no risk of the test fluid flowing over external surfaces of the component that are not relevant to the extraction procedure. However, adapters for connections/rinsing tubing may generate and release particles due to friction. In the case of active components, there is a risk of excessive contamination being generated from running-in processes and frictional wear when the components are re-activated, which would falsify results.

The main parameters influencing the extraction method of internal rinsing are:

- characteristics of the test liquid,
- flow rate and rinsing time,
- geometry and model of the test component,

- pulsation and pulsation frequency, and
- type and frequency of movement (for active components).

7.4.5.2 Start parameters

As opposed to other liquid extraction methods, there are no meaningful start parameters for internal rinsing. This is because the flow rate required for a turbulent flow (calculable via the Reynolds number $>4\,000$) is dependent upon the geometry of the test component and upon the test fluid used.

However, the minimum throughput volume shall be several times the inner volume of the component.

[Table D.4](#) lists examples of flow velocities for two different test liquids (cold cleaners) with different viscosities. These rates are required for through-flows through tubes or lines of varying diameters in order to achieve a fully-turbulent flow and thus maximize the efficacy of the extraction.

7.4.5.3 Materials and equipment

The materials and equipment used in the extraction step shall comply with the general requirements of extraction equipment described in [7.2](#).

- a) Test liquid, kinematic viscosity $\nu \leq 5 \text{ mm}^2/\text{s}$.
- b) Where appropriate, use a component mount: e.g. fixing device or clamp. For active components, use switching, actuating or drive devices, etc.
- c) Internal rinsing apparatus consisting of:
 - adapters for filling the component, for the through-flow and for draining the liquid from component, and
 - media supply with container for test liquid, purification filter, pump or pressure supply; where appropriate, with pulsation mechanism.

NOTE Internal rinsing systems can also be designed as vacuum rinsing systems, i.e. the liquid is not advanced through the component under positive pressure but rather sucked through using a vacuum device.

- d) If required, use additional containers (funnels, beakers) to collect the extraction liquid.
- e) Pressure-rinsing apparatus for final rinse of equipment with test liquid using g).
- f) Graduated vessel to measure volumes; e.g. beaker or measuring cylinder.
- g) Suction device (optional): to remove residual liquid from component cavities.

With a closed internal rinsing circuit, it makes sense to place the analysis filter directly behind the test component. However, this is not usually possible because the analysis filter has a high flow resistance which would prevent the flow velocities required inside the test component from being achieved. These flow velocities are necessary in order for the extraction step to be efficient.

[Figure D.10](#) illustrates an example of an internal rinsing system.

7.4.5.4 Procedure

The following procedure shall be adapted to the features of the respective test component.

- a) Procure all resources required for the test.
- b) Pre-clean all surfaces of the extraction setup in contact with fluid; where required, determine blank levels.
- c) Prepare the test component as described in [7.3](#).

- d) Fit adapters to the test component for rinsing tubes; if required, position the test component in such a way so as to enable the liquid to flow easily into the extraction cabinet or collection container.
- e) Where appropriate: with active components, connect power, switching or drive device to the test component.
- f) Perform the extraction procedure on observing all internal rinsing parameters, times and, in the case of active components, operating parameters.
- g) Empty residual liquid from component areas in which liquid and particles could collect (if required, repeatedly). For objects with cavities that are difficult to access, use suction equipment (the resulting liquid is included in the analysis).
- h) Carry out a final rinsing step on all surfaces of rinsing setup, collection basins, etc., in contact with the liquid. A suitable procedure shall be elaborated, tested and defined for this final rinsing step (the resulting liquid forms part of the extraction liquid).
- i) Transfer all the liquid for filtration and analysis.
- j) Fill out the inspection report.

7.4.5.5 Documentation

See [Clause 10](#).

7.4.6 Agitation

7.4.6.1 Principle

The test component is partially filled with test liquid and all openings sealed. By agitating this liquid, particles adhering to the inner controlled surfaces are detached and transferred to the liquid. The agitation process enables the liquid to exert a force on the particles in different directions and also enables dead zones and undercuts to be reached effectively by the liquid. Detached particles are then held in suspension.

The method is suitable for objects with cavities that can be accessed at least via one opening and whose size and mass allow the test areas to be adequately agitated. The method is not suitable for inspecting narrow inner geometries, such as tubes or capillaries, because the impulse created by agitation is too low to be effective.

The set-up chosen for the agitation procedure depends on the shape, size and mass of the component concerned.

The method is not suitable for foaming liquids.

Agitation can be carried out manually or with the aid of an automated device.

It is not useful to place components in a sealed vessel in order to agitate the vessel manually or by means of a vibrating table. This is because particles can be generated if the components strike against one another. Ultrasonic vibration or pressure-rinsing are preferred methods in such cases.

The main parameters influencing extraction by agitation are:

- characteristics of the test liquid,
- volume of test liquid used,
- duration, amplitude and frequency of the agitation step,
- number of fillings, and
- final rinsing of the test component.

7.4.6.2 Start parameters

The start parameters for extraction by agitation shall be selected (see [Table 4](#)) to maximize the extraction effect (see [5.3](#)) whilst still allowing the process to be performed manually if desired.

Table 4 — Start parameters for agitation

Parameter	Start value/Condition
Filling volumes	30 % to 40%
Amplitude	approx. 30 cm
Frequency	1 Hz ^a
Time	15 s
^a 1 Hz is one movement per second.	

During the qualification tests/declining tests (see [Clause 6](#)), the agitation procedure or number of agitation movements is determined for the routine inspection depending on after which extraction step the declining criterion is attained. If the declining criterion is not achieved with these start parameters or if other parameters are more suitable and strictly documented, these start parameters may be modified.

However, a filling volume of 30 % to 40 % for components shall not be altered because a too-low or too-high filling quantity does not create the necessary mechanical action to generate an efficient cleaning effect.

7.4.6.3 Materials and equipment

- Test liquid, kinematic viscosity $\nu \leq 5 \text{ mm}^2/\text{s}$.
- Pressure-rinsing apparatus for final rinsing of components and equipment and/or dispensing the test liquid (see [7.4.3](#)).
- Graduated vessel to measure volumes, e.g. beaker or measuring cylinder.
- Funnel: for filling and/or emptying test liquid.
- Appropriately sized abrasion-resistant seals/stoppers for the test component.
- (Optional) Automated agitation device, e.g. vibrating table fitted with mounting device for the test component.
- Clock to control the duration of the agitation step.
- Sampling container, sampling vessel or analysis filter unit (dependent on application) to hold the extraction liquid.
- Suction equipment (optional): to remove residual liquid from component cavities.

7.4.6.4 Procedure

The following procedure shall be adapted to the features of the respective test component.

- Procure all resources required for the test.
- Pre-clean all surfaces of the extraction devices in contact with fluid; where appropriate, determine blank levels.
- Determine the internal volumes of the test component.

- d) Prepare the test component in accordance with [7.3](#); special care shall be taken to clean the exterior of the component well and to seal all component openings with suitable clean, abrasion-resistant closing devices.
- e) Remove the closing device from one opening that can be used to fully empty the test component.
- f) Determine the volume of test liquid required, i.e. 30 % to 40 % of the volume of the interior of the test component.
- g) Pour the test liquid into the object and seal the opening.
- h) Perform the agitation step on observing all the specified conditions (frequency, amplitude, duration).
- i) Remove one closing device and pour the liquid contained in the test component into a sampling vessel or filtration unit with the aid of a funnel. Avoid any loss of liquid or wetting of external component surfaces.
- j) Carefully perform a final rinsing step on the interior of the test component. This final rinsing procedure may take the form of a further agitation step using test liquid or a pressure-rinsing step. The resulting volume of liquid forms part of the extraction liquid.
- k) Ensure that the test component is fully emptied.
- l) Then, using a sufficient volume of test liquid, carry out a final rinsing step on all surfaces wetted by the test liquid (sampling vessel, filtration equipment, etc.). The resulting liquid is included in the analysis.
- m) Transfer all the liquid for filtration and analysis.
- n) Fill out the inspection report.

7.4.6.5 Documentation

See [Clause 10](#).

7.4.7 Dissolving

7.4.7.1 Principle

In cases where components have been treated with preservatives or grease, for example, effective particle extraction can only be achieved after first dissolving the layer of preservative or grease present. In consequence, a delayed decline may take place in the course of the qualification tests.

In such cases, **dissolving** can be carried out as a preparatory step before performing the actual extraction procedure. Here, the test component is first immersed in a suitable solvent (e.g. the test liquid used for the inspection) for an appropriate length of time without the aid of further physical cleaning effects, such as pressure-rinsing or ultrasonic vibration. Alternatively, components can also be completely filled and sealed if inner surfaces shall be inspected.

The volume of liquid used in the dissolving step as well as the final rinsing liquid for the vessel in which the dissolving step is carried out forms part of the extraction liquid and shall be included in the subsequent analysis.

The dissolving step can be speeded up during the extraction process by using a test liquid with a stronger chemical solvent action (verify compatibility with component).

The main parameters influencing the dissolving step are:

- characteristics of the dissolving liquid, and

— duration of the dissolving procedure.

7.4.7.2 Materials and equipment

- a) Dissolving liquid (e.g. test liquid, or solvent with stronger dissolving properties).
- b) Pressure-rinsing equipment to perform final rinsing step on the apparatus and/or to dispense the test liquid (see [7.4.3](#)).
- c) Where appropriate: funnel for filling or removing dissolving liquid.
- d) If required: suitable abrasion-resistant seals/stoppers for the test component.
- e) Clock to control the duration of the dissolving step.
- f) Dissolving container, beaker or bath from pressure-rinsing or ultrasonic device.

7.4.7.3 Procedure

The following procedure shall be adapted to the features of the respective test component.

- a) Procure all resources required for the test.
- b) Pre-clean all surfaces of the dissolving container in contact with fluid, where required, determine blank levels.
- c) Place the component in the dissolving container.
- d) Fill the dissolving container with dissolving liquid until the component is fully immersed. Ensure that all surfaces are completely wetted, e.g. components with cavities.
- e) Leave the component in the dissolving liquid during the dissolving period without the use of any further physical forces.
- f) Remove the component and transfer to the next step of the extraction procedure.
- g) Transfer the dissolving liquid to the filtration process.
- h) Then, using a sufficient volume of test liquid, perform a final rinsing step on all surfaces wetted by the dissolving liquid (sampling vessel, filtration equipment, etc.). The resulting liquid forms part of the extraction liquid.
- i) Transfer all the liquid for filtration and analysis.
- j) Fill out the inspection report.

If the dissolving procedure is only carried out on the inner surfaces of a component, the described procedure shall be modified accordingly. The component shall be completely filled with dissolving liquid (ensure that all surfaces are fully wetted and that no air bubbles are present) and sealed during the dissolving step (e.g. with stoppers). The component is then emptied and the dissolving liquid transferred to the filtration process.

7.4.7.4 Documentation

See [Clause 10](#).

7.5 Air extraction

7.5.1 General

Some components built into vehicles do not come into contact with liquids during their operation (and also some during their manufacture). Such components may even be damaged if they come into contact with a liquid, e.g. air filters, with the consequence that liquid cannot be used for the extraction process. Extraction using air is an alternative method for such components.

7.5.2 Air jet extraction

7.5.2.1 Principle

With this extraction method, particles are detached from the test component by means of a jet of clean, oil-free compressed air (see ISO 8573-1). The tools and procedure are similar to those required for liquid extraction by pressure-rinsing.

The method is suitable for external surfaces, or for the inner surfaces of components accessible with a jet of compressed air. It can be utilized, for example, to extract contaminants from electronic components, single components of engine air intake tracts that cannot be cleaned using the liquid through-flow method, or also to remove contamination from logistics packaging, such as blister packs, small load carriers or cardboard.

For this form of extraction, a completely-sealed cabinet with the possibility to intervene manually is required (e.g. glove box) as well as connections for compressed air. It shall be possible to vent the cabinet to prevent a positive pressure from being created inside it.

Air jet extraction is performed in two steps:

- a) Particles are detached from the test component with a jet of compressed air and subsequently adhere to the walls of a cabinet wetted with liquid. The test component is then removed from the cabinet.
- b) The particles adhering to the cabinet walls are rinsed off and transferred for analysis using a process similar to the final rinsing step performed after extraction by pressure-rinsing.

The main parameters influencing air jet extraction are (see also [Table 5](#)):

- pressure of the jet of compressed air,
- geometry of the jet nozzle,
- distance away from the object and the angle of the jet,
- sequence used when extracting the controlled surfaces,
- duration of jet per surface or feed rate,
- repeats per surface.

NOTE As opposed to extraction by pressure-rinsing, in which the pressure measured and information obtained are highly dependent on the place of measurement (at the nozzle, behind the pump, etc.), the pressure in air jet extraction fluctuates less at the various sites and can thus be considered as a suitable extraction parameter. However, the flow rate of the air cannot be measured by means of simple volumetric measurement.