PD IEC TR 61191-7:2020



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Printed board assemblies

Part 7: Technical cleanliness of components and printed board assemblies

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Part 7: Technical cleanliness of components and printed board assemblies

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PRINTED BOARD ASSEMBLIES –

Part 7: Technical cleanliness of components and printed board assemblies

FOREWORD

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IEC/TR 61191-7, which is a technical report, has been prepared by IEC technical committee 91: Electronics assembly technology.

The text of this Technical Report is based on the following documents –

Draft TR	Report on voting
91/1583/DTR	91/1595/RVDTR

Full information on the voting for the approval of this Technical Report can be found in the report on voting indicated in the above table.

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This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61191 series, published under the general title *Printed board assemblies*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http//www.webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,
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INTRODUCTION

The Technical Report applies to electric, electronic and electromechanical components, circuit boards and electronic assemblies and describes the resulting level of technical cleanliness that can be expected for products that are manufactured with state-of-the-art standard production methods and processes.

The Technical Report is an informative document which serves to illustrate the technically feasible options and provide a basis for customer and supplier agreements. It is not intended to be regarded as a specification or standard. It does not cover the production of electric motors, batteries, cable harnesses and relays.

Its primary focus is on loose or easily detachable particles (labile particles). Film residues, chemical and biological contamination are also briefly covered. It does not deal with the cleanliness of functional fluids and/or gases.

This Technical Report provides information, how the requirements put down in VDA 19.1 and VDA 19.2 could become reasonably applied in electronic industry It provides information about particle generation considering processes and materials, illustrates their impact on performance and reliability and describes suitable countermeasures as well as procedures for risk assessments.

Related standards issued by the automotive industry and the electronic industry are gathered in the bibliography.

The Technical Report has been prepared based on material provided by the working group on component cleanliness of the ZVEI (Zentralverband Elektrotechnik- und Elektronikindustrie e.V., Germany).

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PRINTED BOARD ASSEMBLIES –

Part 7: Technical cleanliness of components and printed board assemblies

1 Scope

This part of IEC 61191 serves as a Technical Report and provides information, how technical cleanliness can be assessed within the electronics assembly industry. Technical cleanliness concerns sources, analysis, reduction and control as well as associated risks of particulate matter, so-called foreign-object debris, on components and electronic assemblies in the electronics industry.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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 http://www.iso.org/obp

4 Technical cleanliness

4.1 What is technical cleanliness?

The term 'technical cleanliness' was coined by the automotive industry to address particle-related system interruptions in the automotive industry. In contrast to 'optical cleanliness', which relates to the cosmetic or visual appearance, e.g. vehicle coating, technical cleanliness always refers to the performance of components, assemblies and systems.

Particulate contamination in the automotive industry is often not limited to a certain area but may migrate from a previously non-critical to a sensitive location and hence impair performance. For instance, a particle on the lens of a traffic sign detection camera may cause it to malfunction. Similarly, a conductive particle from the aluminum cover of an electronic control unit may cause a short circuit on the circuit board and undermine its performance. This is why the cleanliness requirements of the automotive industry often apply to complete systems, whereby the most particle-sensitive component (weakest link in the chain) determines the cleanliness level and admissible limiting values for the entire system and all components within it. With regard to components, technical cleanliness refers to the specification, observance and verification of limiting values, e.g. according to weight of residual contamination, particle count, type and size. At the same time, the automotive industry tolerates failures only in the ppm range. New stipulations are continuously being added to the existing specifications. These are often tailored to suit the specific requirements of a company or component and its performance. Their scope of application is limited, i.e. they are valid in-house and/or for suppliers.

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Although the term 'technical cleanliness' was coined by the automotive industry, the procedures relating to cleanliness inspections in accordance with VDA 19 (liquid extraction, membrane filtration and subsequent analysis of the retained particles) have been increasingly adopted by other industries such as medical technology, the optical industry, hydraulic and mechanical engineering. Since there is no such thing as total cleanliness or purity, the focus should be on the most practically feasible and economically viable solution for the designated location and purpose.

4.2 History – standardisation of technical cleanliness

Contamination had been a growing problem for the automotive industry since the early 1990s as systems became increasingly complex and installation spaces ever smaller. The anti-lock braking systems in general or direct fuel injection systems for diesel engines were particularly prone.

In some cases, customers and suppliers concluded individual agreements about technical cleanliness to address the risk of potential damage.

As a result, the automotive industry called for the introduction of general standards regulating the technical cleanliness of components. In summer 2001, TecSa was founded, an industrial alliance for technical cleanliness. This panel published VDA 19 (*Inspection of Technical Cleanliness – Particulate Contamination of Functionally-Relevant Automotive Components*) in 2004, which was revised in 2015 and republished as VDA 19 Part 1. These guidelines make recommendations for inspecting the technical cleanliness of automotive products.

Its international counterpart is standard ISO 16232, which was published in 2007.

In 2010, VDA 19 Part 2 (*Technical Cleanliness in Assembly*) was published, detailing cleanliness-related design aspects for assembly areas.

4.3 Technical cleanliness in the electronics industry

The industry increasingly uses the generally valid VDA 19 guidelines in addition to company-specific standards.

This Technical Report outlines a system for designing and implementing component cleanliness analyses to enable quantifiable comparisons of component cleanliness levels. However, VDA 19 does not specify any limiting values for component cleanliness. These must be defined according to component function, producibility and verifiability.

This Technical Report supplements VDA 19 and ISO 16232 by addressing outstanding questions and providing practical solutions.

The producibility of a component as well as its performance must be considered in this context, as is the case when defining dimensional tolerances. Production processes, production environment and final packaging also influence component cleanliness. This often calls for agreements concerning compliance with limiting values between customer and supplier or product development and production. This is particularly relevant in instances where limiting values are exceeded without necessarily impairing performance. A careful review shall be carried out to ensure that efforts to comply with these values do not outweigh the potential risk, thereby avoiding excessive cleanliness requirements.

4.4 Potential particle-related malfunctions

Limiting values for component cleanliness ensure component performance and should be defined as early as possible during the component development stage. The following possible malfunctions should be considered:

- electrical short circuit;

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- shorter creepage and clearance distance;
- electrical insulation of contacts;
- impairment of optical systems such as cameras;
- reduced wettability/solderability;
- mechanical obstruction;
- increased or reduced friction;
- increased or reduced power;
- leaks.

If the remaining particulate contamination – also called residual contamination – is sufficiently low in a technical system to cause no short or long-term performance impairment or system damage, the system is considered adequately clean in the context of technical cleanliness.

5 Technical cleanliness as a challenge for the supply chain

5.1 General

In the past, drawings usually contained rather general information on component cleanliness, which was not systematically verified. Example:

Parts must be free from contamination e.g. swarf, release agents, grease, oil, dust, silicone...

With the publication of VDA 19 and ISO 16232, standardised cross-company procedures were defined to record, analyse and document component cleanliness information.

General attributive provisions that had previously been customary and checked via visual inspection were replaced, e.g. by specifying particle size classes with maximum particle count, which can be verified by means of laboratory analysis.

The procedures to determine component cleanliness according to VDA 19 are standardised, reproducible and also more objective than previously applied methods. However, the following points should be observed when applying these procedures:

- particle generation may vary significantly, even from the same production glass;
- particle detection depends on the method and quality of analysis;
- inspections are costly and require a laboratory;
- measurement system analyses (MSA) are not possible for the entire inspection process of technical cleanliness;
- in-process inspections with associated regulatory measures can be implemented only after lengthy delays.

In practice, cleanliness analyses according to VDA 19 are used for production releases or requalification, during production and when there are reasonable grounds for suspicion.

Limiting non-metallic particle contamination (e.g. dust, lint, abrasion) poses a further challenge to the supplier. If these particles are classified as functionally critical and hence limited, account shall also be taken of the manufacturing environment, suitability for subsequent cleaning, packaging (to maintain cleanliness) and logistical considerations when determining the limit. Detailed information is provided in VDA 19 Part 2. The controlled production conditions (clean zone grades) necessitated by this require more effort and expenditure. For this reason, it is advisable to determine limiting values only where functionally relevant.

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5.2 Contamination

5.2.1 Definition of particles

5.2.1.1 General

VDA 19 Part 1 defines a particle as a solid body composed of metal, plastic, minerals, rubber or a salt. Paste-like fractions are not considered to be particles.

The following terms and definitions for metallic and non-metallic particles apply to the terminology used in this document.

5.2.1.2 Metallic particles

Metallic particles are particles that are primarily characterised by a shiny metallic reflective surface. They can be detected through a combination of normal and polarised light imaging. An optical microscope with the relevant features normally suffices for identifying metallic particles.

However, using optical microscopy for metallic particle detection bears the following potential risks:

- extremely small metallic particles or sintered metals cannot be identified as metallic particles;
- strongly oxidised metallic particles cannot be identified as metallic particles;
- reflective non-metals, such as glass, may be wrongly classified as metallic particles owing to their reflective behaviour.

Since it would be too costly and time-consuming to differentiate between electrically conductive and non-conductive particles when assessing the technical cleanliness of the production process, or indeed impossible, the analysis concentrates on detecting metallic and shiny metallic particles.

Shiny metallic particles are generally assumed to be both metallic and conductive.

It must be stressed that differentiating between metallic and non-metallic particles by their metallic lustre does not permit a reliable distinction to be made regarding their electrical conductivity.

The following steps can be taken to avoid these pitfalls: manually re-examine the biggest metallic and biggest non-metallic particles detected using an optical microscope; subsequently reclassify these particles if necessary.

Other systems such as EDX, Raman or laser-induced breakdown spectroscopy provide more detailed and conclusive results. However, this entails greater expenditure.

5.2.1.3 Non-metallic particles

Non-metallic particles are particles that are not primarily characterised by a shiny metallic, reflective surface. They contain no fibres.

5.2.2 Definition of fibres

Component cleanliness analyses invariably detect textile fibres from clothing, which are ubiquitous in any production or laboratory environment where people are present. Fibres are non-metallic particles, which, although usually mentioned in the test reports, are not considered in the evaluation. To be classed as afibre, they must meet the following specific geometric boundary conditions in accordance with VDA 19 Part 1:

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- stretched length/maximum incircle > 20; and
- width measured across maximum incircle ≤ 50 µm.

In simple terms, this means that:

- the length-to-width ratio is between 1 and 20; and
- the width of a fibre is ≤ 50 µm.

Notes on the definition:

- implementing this theoretical approach with customary two-dimensional optical test systems often lacks a certain amount of precision;
- compared with previous definitions, a shift in the number of non-metallic particles and fibres must be envisaged with this approach;
- based on the current definition, a human hair with a thickness of approximately 60 µm to 80 µm would be classed as a non-metallic particle rather than a fibre;
- in contrast, a glass or carbon fibre with a thickness of 40 µm would be classed as a fibre rather than a particle, although it clearly has the potential to cause damage.

The following potential errors may occur when identifying fibres:

- fibres with a strong curl cannot be detected;
- particles may be wrongly identified as fibres if the width and height are very small in relation to the length (e.g. plastic burr);
- fibres positioned vertically to the membrane (in the z-axis) may be analysed incorrectly or not at all;
- fibres may be visually "chopped" and not detected as one fibre.

5.3 Test procedure to determine technical cleanliness

5.3.1 Fundamentals

The technical cleanliness of components refers to the level of particulate contamination on the relevant surfaces of test objects.

The aim of cleanliness inspections is to determine and measure the particle count as accurately as possible.

VDA 19 describes the application methods and conditions to determine and document particulate contamination. It also specifies the different extraction and analysis methods.

The following extraction methods are suggested for removing particles on electric, electronic and electromechanical components, circuit boards and electronic assemblies (hereafter referred to as 'components'):

- pressure rinsing,
- ultrasonic techniques,
- internal rinsing,
- agitation,
- air extraction.

According to the ZVEI working group on component cleanliness, 'pressure rinsing' as defined in VDA 19 has proved to be a reliable extraction method for a number of applications. Components are rinsed with liquid pressure jets during this process. The liquid is then filtered to separate the released particles for further analysis.

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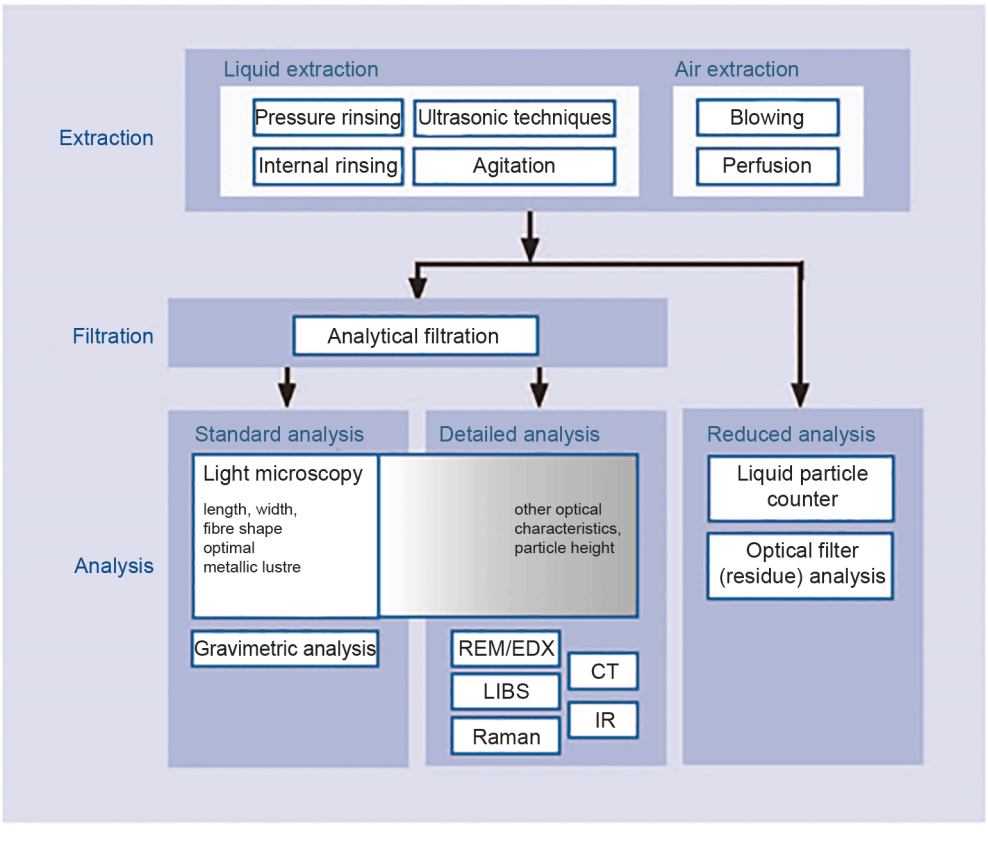


Figure 1 – Test method as per VDA 19 Part 1

To properly evaluate the cleanliness level of the component, the pressure rinsing extraction process shall be qualified. This is done by repeating the process several times and reevaluating the results each time. The count of extracted particles shall continuously decrease. By the sixth analysis at the latest, the particle count shall be ≤ 10 percent of the sum of all previous analyses (all relevant particles in total). This is referred to as an extraction curve. The extraction curve is a prerequisite for series analyses and shall be determined once for each component type.

The cleanliness of an extraction system and hence its suitability is determined without components. The same parameters are used for this component-free pressure rinsing process as for an analysis with components. The particle count obtained provides the basis for the release of the system for the next test and is referred to as the blank value.

The extraction method described in 5.3.4 is based on VDA 19 and details the use of pressure rinsing to separate particles from components and collect them on a filter membrane for subsequent measurement and analysis.

Particles that cannot be separated from the components by extraction are classified as "tightly adhering" and are not considered in the context of component cleanliness.

5.3.2 Clarification form

The clarification form defines all the specific test parameters required for an analysis. It is required not only for performing an analysis, e.g. in an analytical laboratory, but also for the internal review of different analyses and for submission to the customer for approval based on the test parameters from the requirements specification.

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How else can we ensure that comparable measurements have been analysed under the same conditions, e.g. with the same filter types and the same mesh width?

It is always advisable to design a clarification form that clearly defines those parameters which ensure comparability of analyses.

All options for performing an analysis shall be specified (see Figure 1 and Figure 2).

This Technical Report includes sample clarification form templates for 'environmental cleanliness' and 'component cleanliness' (see Annex B). Not everyone who requires an analysis has the specialist knowledge required to complete a clarification form in full.

For this reason, the clarification form is divided into two sections.

The first section covers the following points and must be completed by the requester:

- information about the test component,
- sampling conditions,
- cleanliness requirements,
- etc.

The second section should be completed by the specialist:

- details of particle count,
- type of filtration and filter,
- presentation of results,
- how packaging is dealt with,
- etc.

The use of a clarification form greatly simplifies the internal management of analyses which are intended to be compared with another. Furthermore, it also simplifies the commissioning process by reducing follow-up inquiries from the analytical laboratory regarding unclear or missing parameters.

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Figure 2 – Examples of extraction systems

5.3.3 System technology

The following criteria shall be considered when designing a pressure rinsing system:

Component holder

Containers or funnels that discharge directly to the filter membrane. If necessary, a suitable sieve can be placed in the container to hold the component. If particles are simultaneously extracted from several components, the components shall not be placed on top of each other but next to each other. It is important to avoid generating new particles during the extraction process.

Pressure rinsing equipment

An easily manoeuvrable pressure rinsing tool (lance) with a round nozzle of e.g. 4 mm in diameter is suitable for pressure rinsing components manually at stable flow rates.

Membrane holder

Membrane filters shall be easily removed from storage containers and loaded into the equipment, if necessary using tweezers. To ensure that no liquid remains between the container and the membrane filter, which would prevent the detection of particles, it is advisable to extract the test liquid from the container holding the components (if necessary by vacuum suction).

Number of components per test

The surface of the test components shall be sufficiently large to provide statistical data on component cleanliness. It is advisable to select the number of components per test that ensures the smallest possible extrapolation factor based on a 1 000 cm^2 reference surface area. However, no more than 50 components should be tested for practical reasons (see 5.5.2).

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5.3.4 Process parameters for pressure rinsing extraction

1) Extraction method: pressure rinsing in accordance with VDA 19
2) Test liquid [1] : solvent cleaners based on non-aromatic aliphatic of alicyclic hydrocarbons with a terpene content of < 30 percent, e.g. Haku 1025-921[2], DE-SOLV-IT 1000[3], Glogar G60 spezial[4]
3) Flow volume: 1 000 ml/min ± 200 ml/min
4) Nozzle: lance with 4 mm round nozzle
5) Filter type (membrane): 5 µm pore size, approx. 47 mm membrane diameter; material e.g. cellulose nitrate, PET mesh
6) Pressure rinse volume: result of extraction curve (approx. value of 2 l to 6 l)
7) Final rinse volume[5]: approx. value ≥ 2 000 ml
8) Number of components: 1 to 50 units or ideally ≥ 200 cm^2 surface area

5.3.5 Pressure rinsing process

Care shall be taken to ensure that the spray reaches the target surface of all components during the pressure rinsing process. To achieve this, the pressure rinsing device (lance) is directed along the entire surface of all components at a distance of approximately 1 cm to 10 cm until the rinse volume has been reached (see Figure 3). The test components shall be handled in a manner which ensures that no further particles are generated during the extraction process (e.g. owing to abrasion).

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1 The compatibility of solvent, components and assemblies should be verified at least once during testing.

2 Haku 1025-921 is the trade name of a product supplied by Chemische Werke Kluthe GmbH. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

3 DE-SOLV-IT 1000 is the trade name of a product supplied by Mykal Industries Ltd or A. + E. FISCHER-CHEMIE. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

4 Glogar G60 spezial is the trade name of a product supplied by Fa Glogar Umweltechnik GmbH. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

5 The final rinse volume is **not** determined by the decay test, but by the extraction chamber used.

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Figure 3 – Component holder during manual pressure rinsing

The components are then removed and the empty component holder with container is rinsed as part of the extraction process.

5.3.6 Preparing membrane filters for measurement analysis

On completion of the extraction process, the membrane filters shall be dried at room temperature or using a drying oven. To prevent additional contamination or loss of particles on membranes, the oven should be operated without air recirculation. A desiccator may also be used for drying the membrane filters at room temperature (approximately 12 h to 24 h) to protect them from contamination. Petri dishes can be used to facilitate the handling of moist membrane filters (see Figure 4).

This process shall take place in a clean environment which will not adversely affect the results.

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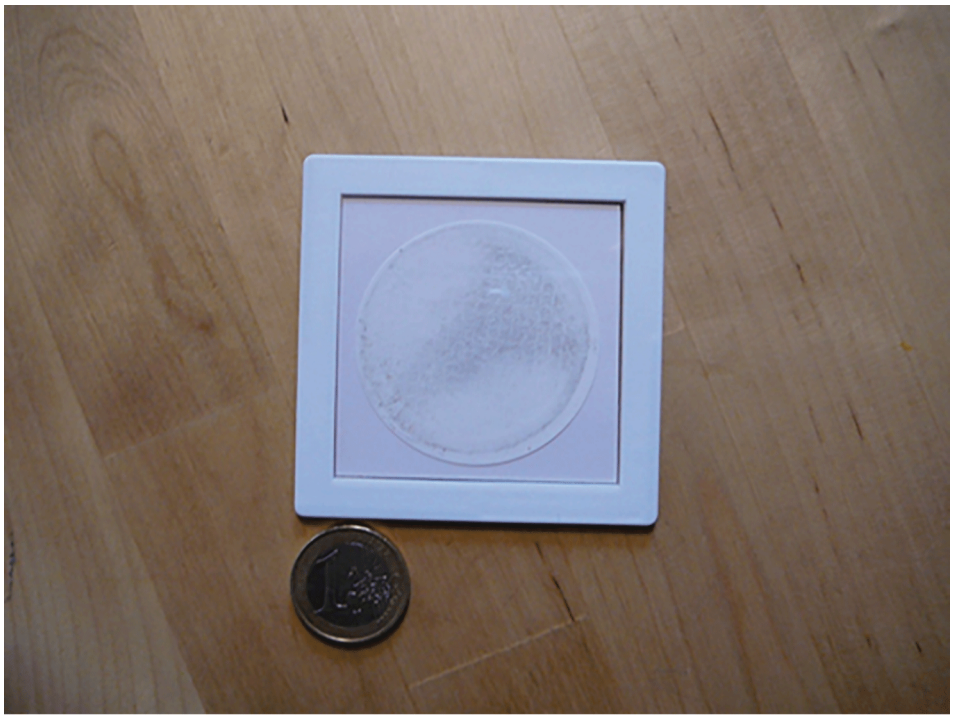
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Figure 4 – Examples of different options for drying membrane filters

The dried membranes can be mounted in standard slide frames (60 mm × 60 mm) for the measurement analysis (see Figure 5).



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Figure 5 – Slide frame with membrane filter

The qualification test (extraction curve) and blank value determination shall be performed in line with VDA 19 Part 1.

For the first decay test to determine the extraction curve, 1 litre of pressure rinsing liquid per extraction process may be used for reference.

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In the event that no decay takes place and the decay criterion is not reached, the process shall be repeated with a higher volume of liquid and new components.

Once dried, the components used for analysis purposes may be re-fed to the production process.

5.4 Measurement analysis

Light microscopy is normally used to evaluate the particles on the membrane filters. The microscope and camera automatically scan the membrane filters and determine the shape and dimensions of the individual particles. Software then classifies the particles according to the size classes defined in VDA 19, differentiating between metallic and non-metallic particles according to 5.2.1. Fibres (see 5.2.2) are not usually considered in the evaluation.

Heavily contaminated membrane filters can result in analytical errors owing to overlapping particles. In this case, the number of test components per analysis should be reduced to minimise the risk. Alternatively, cascade filters can be used.

In addition to extremely contaminated membrane filters, other parameters such as:

- filters (pore size, material, mesh structure),
- filter handling (positioning in measurement system, transport),
- microscopes ,
- image processing (software),
- analysis methods (cross-polarisation, EDX, Raman spectroscopy),
- illumination systems (incidental light, light/dark field, transmission light),

can skew the results of the particle count.

5.5 Evaluating the results of cleanliness analyses

5.5.1 Overview

Particles on components are not generated deliberately using defined methods, but arise as incidental waste products. For this reason, the particle generation process is neither stable nor actionable, and therefore particles have a wider spread compared with characteristics that have been specifically produced. Although component cleaning effectively reduces the number of particles, it does not significantly alter their spread.

VDA 19 Part 1, Ch. 2.1, defines cleanliness limits as action control limits rather than tolerance limits. When a limit is exceeded, it does not necessarily mean that an error has occurred; it increases its likelihood of occurrence. An error occurs only when a critical particle is found at the right time in the right location on a sensitive position within the system.

The aim of the cleanliness analysis is not to find random errors arising from the large spread of cleanliness values, but to find systematic errors such as worn tools, errors in the cleaning process, incorrect storage conditions and incorrect process parameters.

Particle numbers and dimensions are difficult, if not impossible, to predict during the planning phase. They are influenced by numerous process and environmental parameters which are difficult to control. Measuring particles on existing components (samples if necessary) or using comparable components for reference (creating groups) is the most reliable method of obtaining information on particulate contamination for (future) series production.

Of the different procedures available to measure particles, the two variants below are the most common:

a) determining particle count per particle class; and

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b) determining maximum particle length.

The appropriate variant is selected on the basis of the parameters, specifications or requirements.

5.5.2 Particle count relative to component surface

The option mentioned in VDA 19 Part 1 is most widely chosen in practice, in which the number of particles detected is expressed relative to a 1 000 cm^2 component surface area. This is useful when comparing the contamination level of different sized components. If during the extraction process, fewer components are rinsed than would be necessary to achieve 1 000 cm^2, the number of particles detected per class shall be extrapolated to 1 000 cm^2.

Determining the component surface area is difficult and time-consuming owing to the complex surface structure of assembled circuit boards. The working committee has therefore specified a standard method to determine the surface area, which provides largely accurate and comparable results while minimizing time and effort (see Annex A).

When measuring technical cleanliness, it is important to aim for the largest possible component surface area (at least 200 cm^2, ideally 1 000 cm^2). However, a tiny chip component, e.g. EIA0603, would have to be extrapolated by a factor of 300 or more to avoid having to use several thousand parts for a cleanliness analysis. Clearly, it would not make economic sense to use such a large number of components.

This extrapolation process may result in a very high particle count for a specific particle class, when in reality only a single particle may have been found in this class on one occasion. In such cases, it is not normally possible to comply with the permitted blank value (10 % rule as per VDA 19 Part 1) because small components carry too few particles. The smaller the total surface area of the components being analysed, the greater the disproportionate rise in the ratio of particles originating from the analytical equipment with no products.

A method is proposed below to reduce the influence of the blank value on the measurement results during the extrapolation process. After the measurement, the (theoretical) blank value is initially deducted, the measurement result is extrapolated to 1 000 cm^2, and then the blank value is added to the extrapolated result. In this case, the blank value is estimated to be x percent of the total contamination (see also Table 1).

This procedure is expressed in the following extrapolation formula:

$$N = n \times (1\,000 + B) / (A + B)$$

where:

N = number of particles extrapolated to 1 000 cm^2 component surface;

n = number of particles on all components measured;

A = surface area of components, measured in cm^2;

B = blank value equivalent in cm^2, corresponds to x % of 1 000 cm^2).

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Table 1 – Influence of the blank value on the measurement results for different material surfaces (examples for a blank value fraction of 2,2 % and above)

Surface of components measured in cm²	1000	500	200	29	10	1
Blank value equivalent in cm² (corresponds to 2.2% of 1000 cm²)	22	22	22	22	22	22
Blank value fraction in %	2.2%	4.2%	10%	43.1%	68.8%	95.7%
Pie chart showing blank value fraction (light blue)						
Example (see blue column in the table): One Class H metallic particle (200–400 µm) was found during a cleanliness inspection of 50 components with a total surface area of 29 cm². A 'normal' extrapolation to 100 cm² (multiply 1000/29) gives a value of 35 Class I particles on 1000 cm². Extrapolation using the abovementioned formula gives a value of 20 metallic particles on 1000 cm².						

5.5.3 Procedure for violation of action control limits

Owing to the large spread of particle occurrence, a single analysis has only limited meaningful value. In order to distinguish between systematic and random discrepancies, several cleanliness analyses shall be performed.

The following course of action is recommended (see Figure 6).

If a particle count is exceeded in one class, a further analysis shall be performed.

If only one part of a component surface was analysed owing to its very large size, when the test is repeated, at least three parts per analysis shall be tested to increase the reliability of the information obtained from the new analyses.

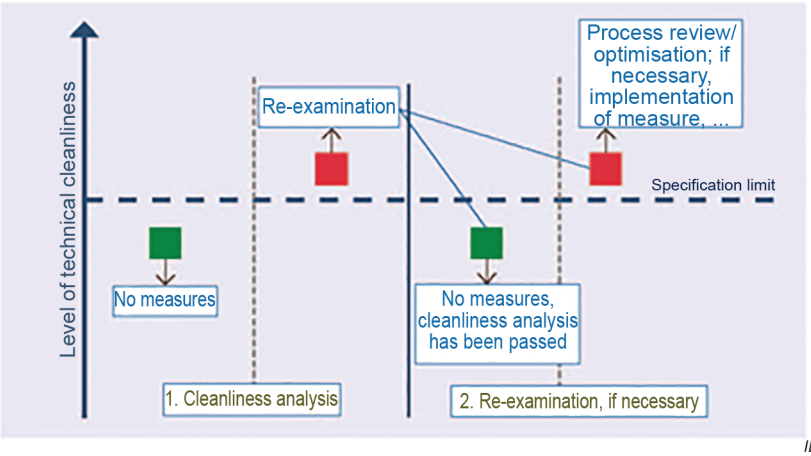


Figure 6 – Example procedure if specifications are exceeded

If the cleanliness values obtained from these additional analyses lie within the agreed limits, it is fair to assume that the discrepancy was a random event and the entire cleanliness test is deemed to have been passed successfully.

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However, if one value from these additional analyses again lies outside the agreed values, it can be a systematic discrepancy. Different follow-up measures can then be taken:

- review and optimise the manufacturing process and perform further follow-up tests; it is useful at this point to perform materials tests on the particles found to help pinpoint their source;
- re-clean;
- exceptional release in individual cases following an appropriate risk assessment;
- increase the confidence interval by testing further components from the same production batch.

5.6 Extended risk assessment

5.6.1 General

The cleanliness risk can be estimated more accurately by applying the following approaches; the likelihood of occurrence of particles above a certain size can be inferred from the data obtained from a single cleanliness analysis.

1) Use one or several analyses to determine raw data by particle measurements according to VDA 19 Part 1 or 5.3. The greater the number of analyses, the more accurate the estimation. The data should contain the true sizes of the relevant particles. The number of relevant particles should be sufficient to enable statistical evaluation.
2) Experience shows that particle size and count create a function similar to exponential distribution. The data shall be transformed into a natural distribution using a suitable program to allow statistical evaluation.
3) It is also possible to obtain information on the likelihood of occurrence of particles above a certain size even if these were not found in the analysis by taking into account the test samples used for the analysis.

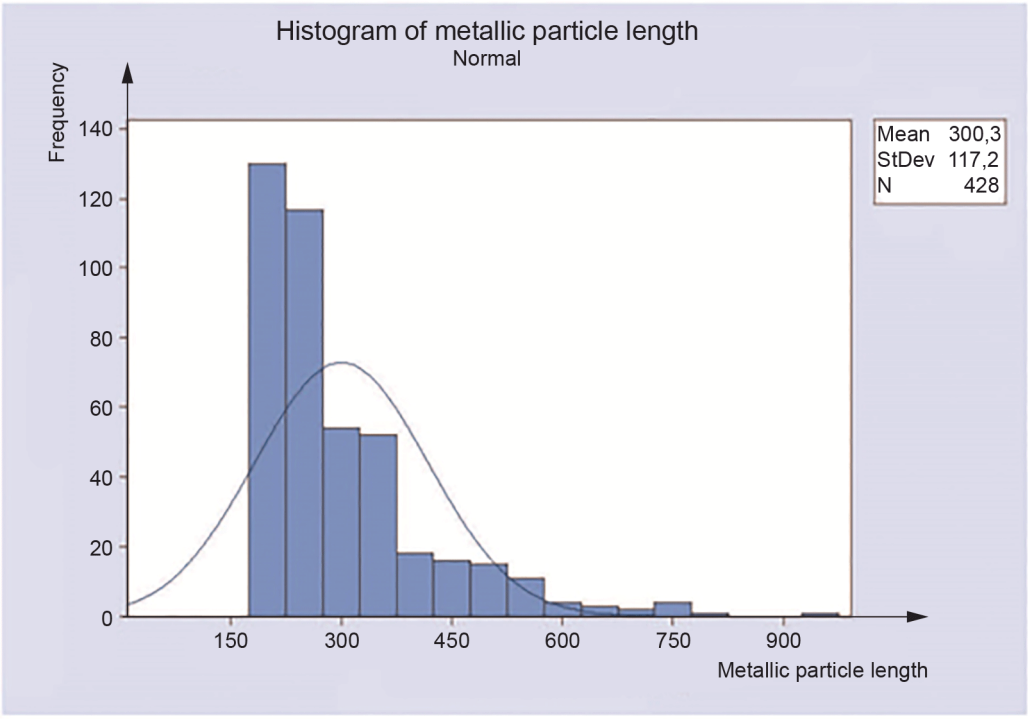
5.6.2 Example

A total of 428 particles (≥ 200 µm) has been extracted from 1 510 contacts and analysed in terms of size in this example (see Figure 7).

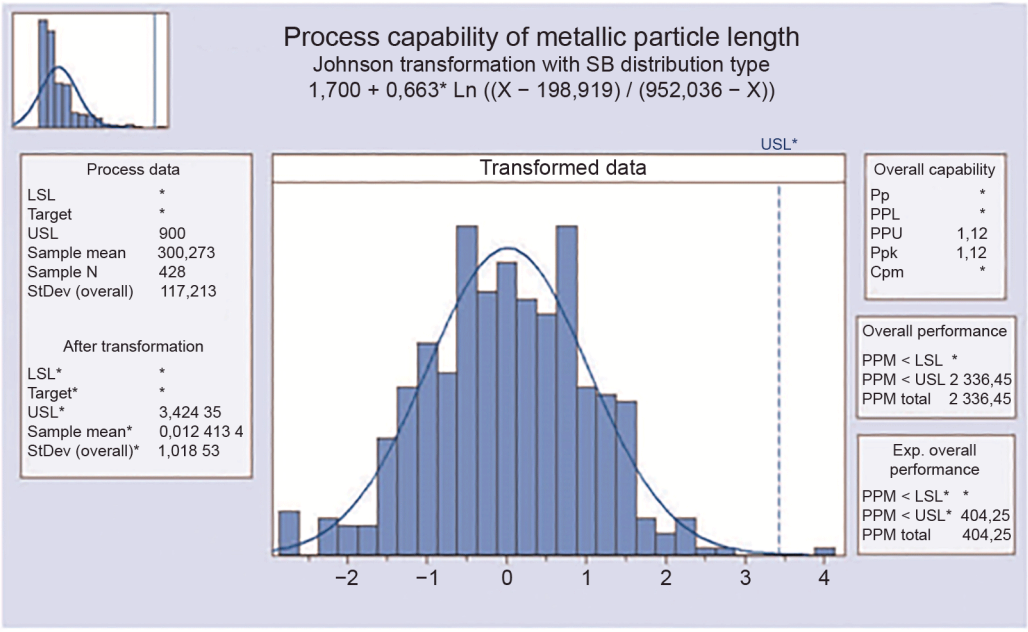
- When extrapolated, this corresponds to 283 443 particles (≥ 200 µm) out of one million contacts.
- Statistically, 404,25 ppm or 114 particles of these are ≥ 900 µm.

Assuming an even particle distribution, i.e. a maximum of 1 particle per contact, one metallic particle ≥ 900 µm can be found on 114 out of 1 million contacts, which corresponds to a failure rate of 114 ppm.

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Figure 7 – Particle size distribution and corresponding process capability

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5.7 Component cleanliness – Data management and visualization

5.7.1 Component cleanliness analysis – flow diagram

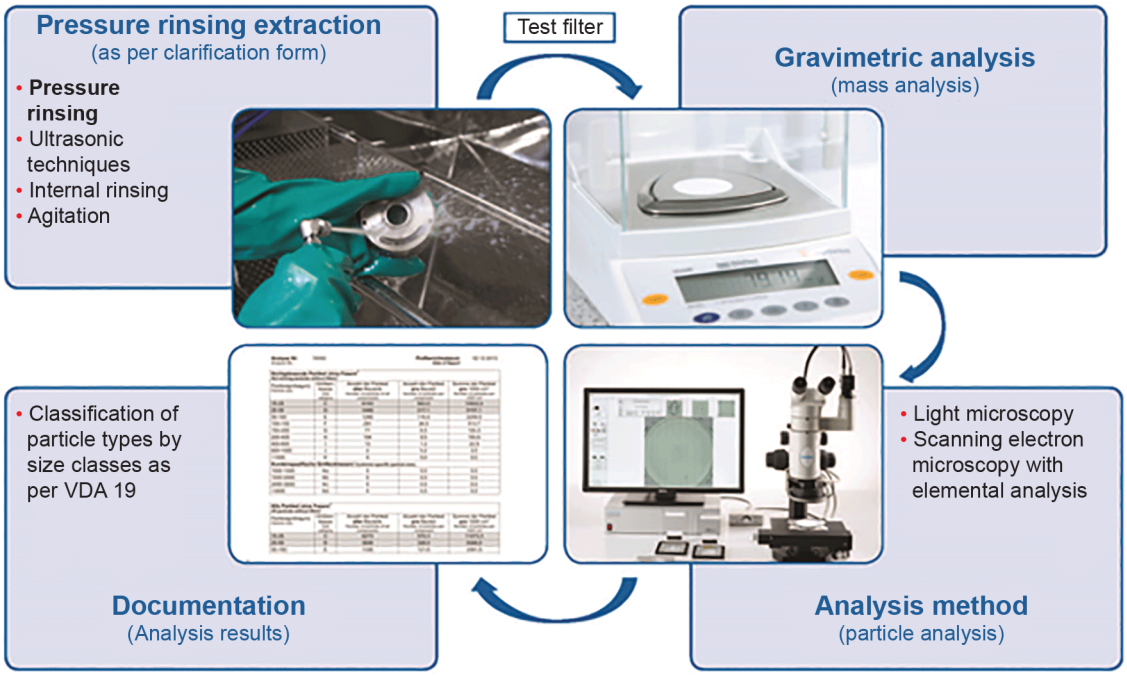


Figure 8 – Flow diagram for component cleanliness analysis

Figure 8 shows the flow diagram for component cleanliness analysis. All test and analysis parameters shall be defined before conducting component cleanliness analyses. The clarification form or a company specification sets out the conditions under which the laboratory is to perform the analysis in question (regulation of analytical values/parameters), see Annex B.



Figure 9 – Scope of analytical report

Clearly defined performance standards, i.e. the same framework conditions, are the only way to ensure comparability with other analyses (see 5.3.2).

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The analytical laboratory shall provide the following information (see Figure 9):

- analysis report in compliance with e.g. VDA 19 Part 1, including indication of blank value;
- test specification including decay test.

Optional:

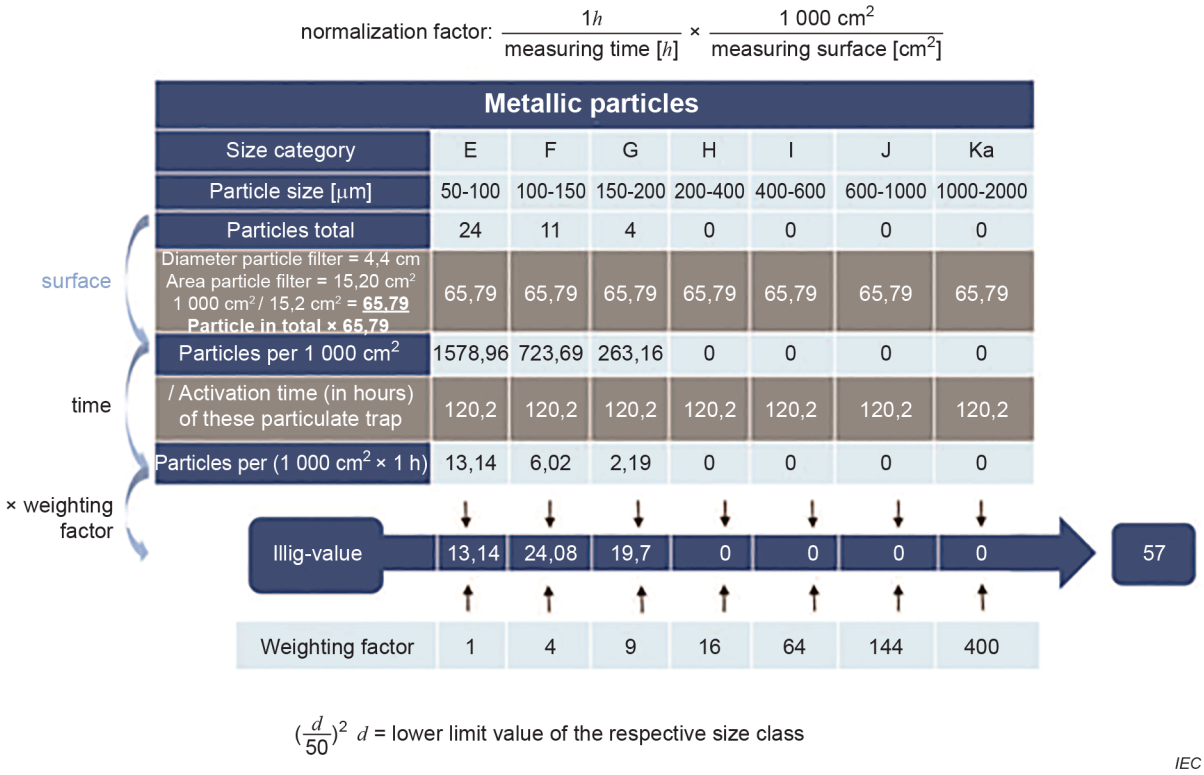
- video showing the performance of the decay measurement filter.

5.7.2 Explanation of SCI (Surface Cleanliness Index)

The derivation of the Illig value is shown in Figure 10. The Illig value can be used to compare the environmental cleanliness of production areas and assess measures that have been introduced. For example, does a new ventilation system achieve the desired effect?

This need to provide evidence applies not only to environmental cleanliness, but also in particular to the products. For example, does an additional cleaning process achieve the desired effect?

This can be verified using the SCI (surface cleanliness index), which is a variation of the Illig value. The derivation of the SCI is shown in Figure 11. It indicates the significant sum of particles. Like the Illig value, the SCI is a single numerical value which reflects the results of analysis for the relevant particle type.



Scaling factor: see VDA 19 Part 2.

Figure 10 – Derivation of Illig value

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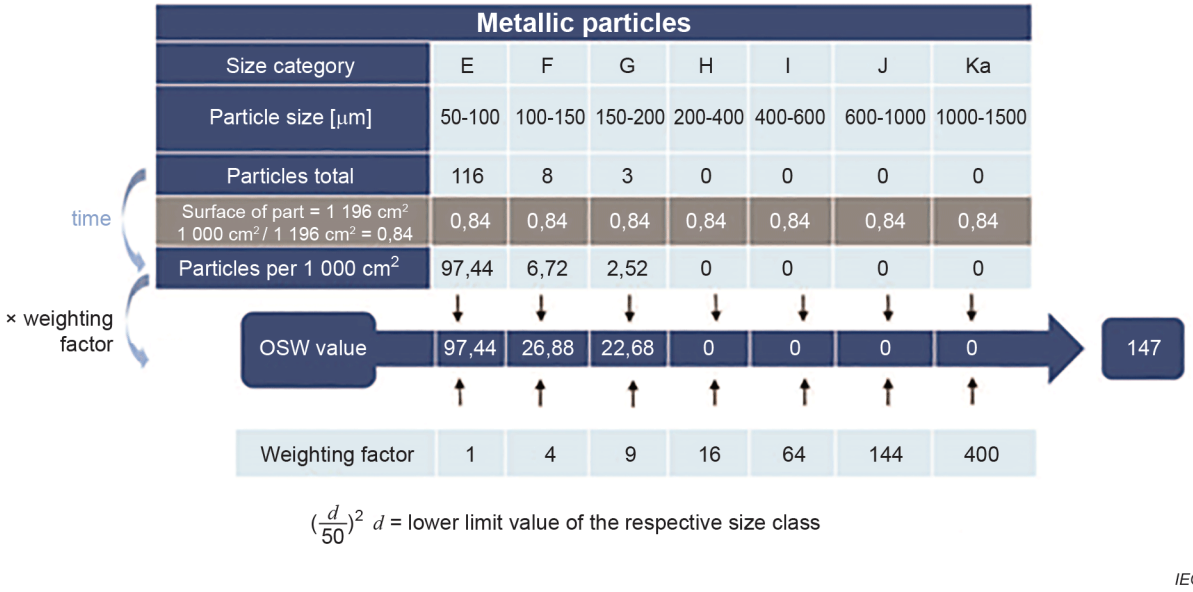


Figure 11 – Derivation of SCI

The SCI differs from the Illig value only in the absence of scaling over time.

It is obtained by calculating the combined surface area of all test components in an analysis and then scaling up the number of particles per size class and type to 1 000 cm^2. Like the Illig value, the SCI uses the same weighting factors for each size class. These are derived from the lower limit d of the size class divided by 50 and squared. The number of particles in each size class per 1 000 cm^2 is multiplied by this weighting factor to obtain the SCI per size class. The SCIs for each class are then added up to give the SCI for the complete analysis.

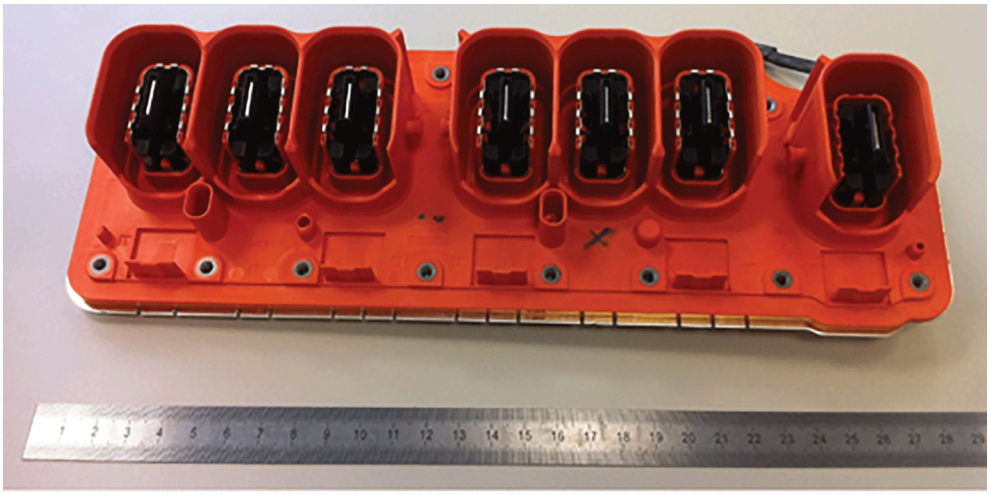
Note that in graphic representations, the SCI, like the Illig value, should always be shown in relation to the largest particles so that a comprehensive statement can be made about the effect of the measure (see Figure 12, Figure 13 and Figure 14 for an example). Individual "outliers" in particular tend to get lost with a high SCI.

The SCI is suitable for comparing measures such as cleaned/not cleaned. The maximum particle lengths, which are normally defined in the specifications, give an indication of the extent to which the outlier rules and escalation strategy should be characterised.

It is advisable to use diagrams or a database as a visualisation tool to provide a quick overview of the results of a measure.

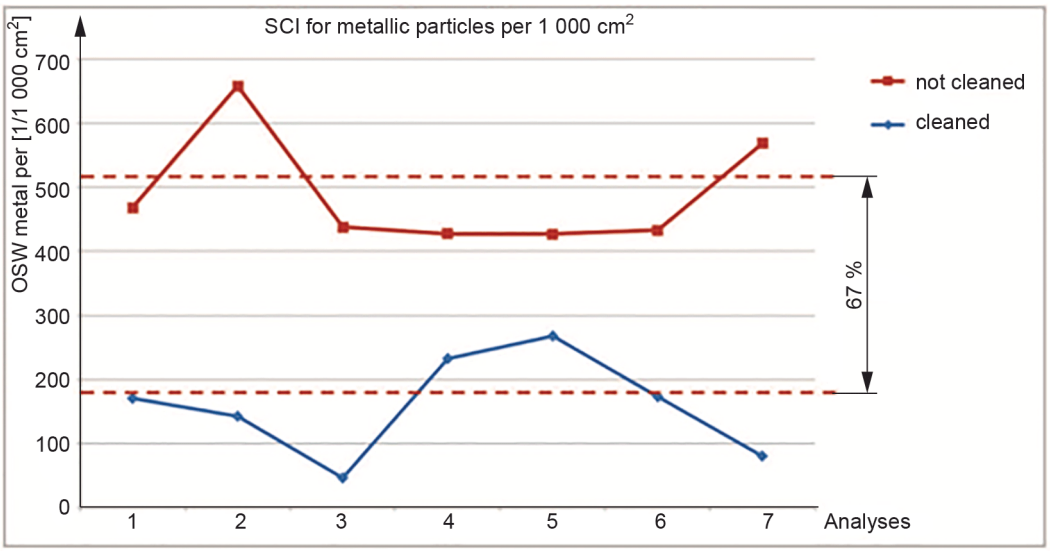
The informative value of a review of measures is directly related to the number of representative analyses. If one analytical value is worse after a measure (e.g. cleaning) than before, this is most likely due to the large standard deviation (see VDA 19 Part 1 Ch. 10.1).

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Figure 12 – Evaluation of 7-pin HV strip connector



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Figure 13 – Graph showing cleaning effect based on SCIs

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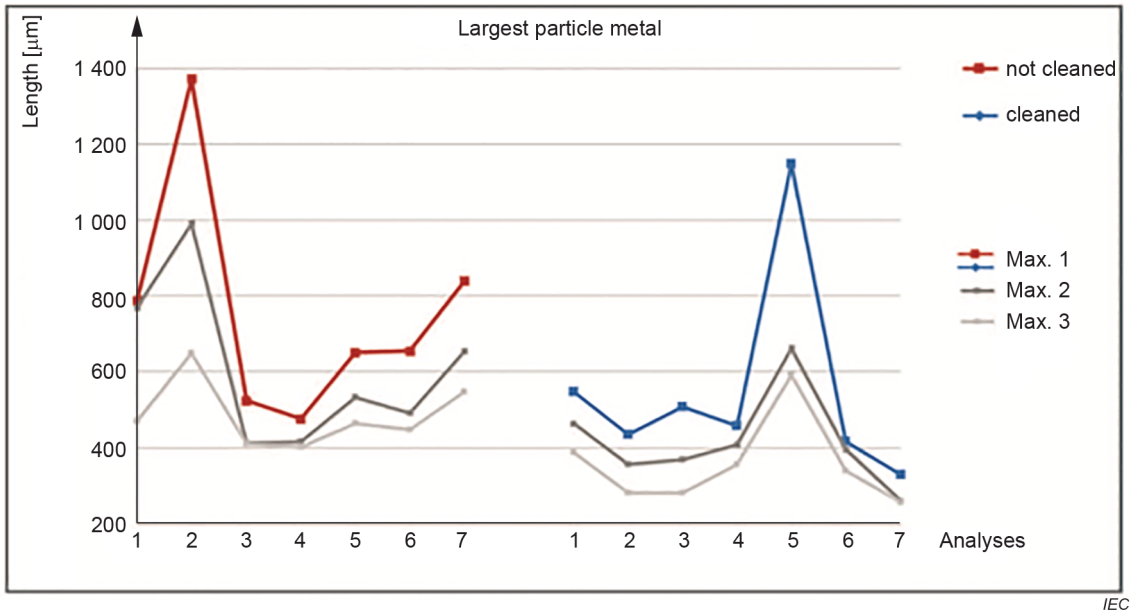


Figure 14 – Comparison of the three largest particles

5.7.3 Creating a database

Analytical reports can be transferred to a database manually or automatically.

Before a database can be set up, its scope must be defined. Experience shows that the spectrum of information increases over time; however, if every value from an analysis were to be transferred, the size of the database would increase very substantially.

Analyses are performed on the basis of individual cleanliness specifications. In most cases, analyses provide information specific to the given application only. For this reason, it is advisable to clarify (e.g. clarification form) which parameters should generally be stored.

If these parameters from the analyses are stored digitally in a database, they can be used for other purposes in the future.

Certain parameters from the analyses must be present in the database, depending on the requirements for the database. Ideally, a software program capable of performing evaluations of technical cleanliness is required.

Alternatively, an Excel[6] database can be used. This can be compiled at low cost and with little programming expertise.

Different options for structural levels of a database are illustrated in Figure 15 to Figure 19.

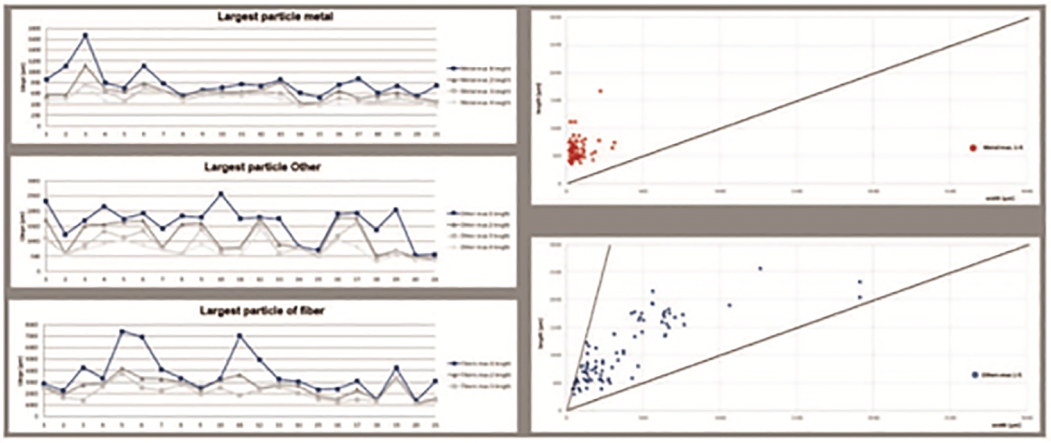
6 Excel is the trade name of a product supplied by Microsoft®. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

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	Option A	Option B	Option C	Option D
	In order to perform simple evaluations of the largest particles in length and width, the following data from the analyses are required:	In order to compare the degree of contamination of different analyses using OSW (MCV, TCV and FCV) and, if necessary, to specify the residual dirt mass, the following data must also be integrated into the database:	Extension by a separate data sheet "direct comparison of test series":	Extension of the database by "comparison to customer standards":
Product-No.	X			
Designation	X			
Remark	X			
Reference for carrying out the analyses	X			
At least the three largest particles (per particle type) in length and width	X			
Number of particles in the respective size class and particle type of the inspection lot		X		
Residual dirt mass of the inspection lot		X		
Number of parts required per analyses		X		
Component surface per part		X		
Calculation operation that calculates an OSW value from the number of particles per class and, if applicable, the residual dirt mass (per analysis, per 1 000 cm^2 or per component)		X		
Description of measures, e.g. type of cleaning, as well as process and material assignements			X	
Selection fields for selecting analyses for comparisons			X	
Additional data sheet to compare the selection			X	
Establishment of TecSA customer/supplier standards in the database				X

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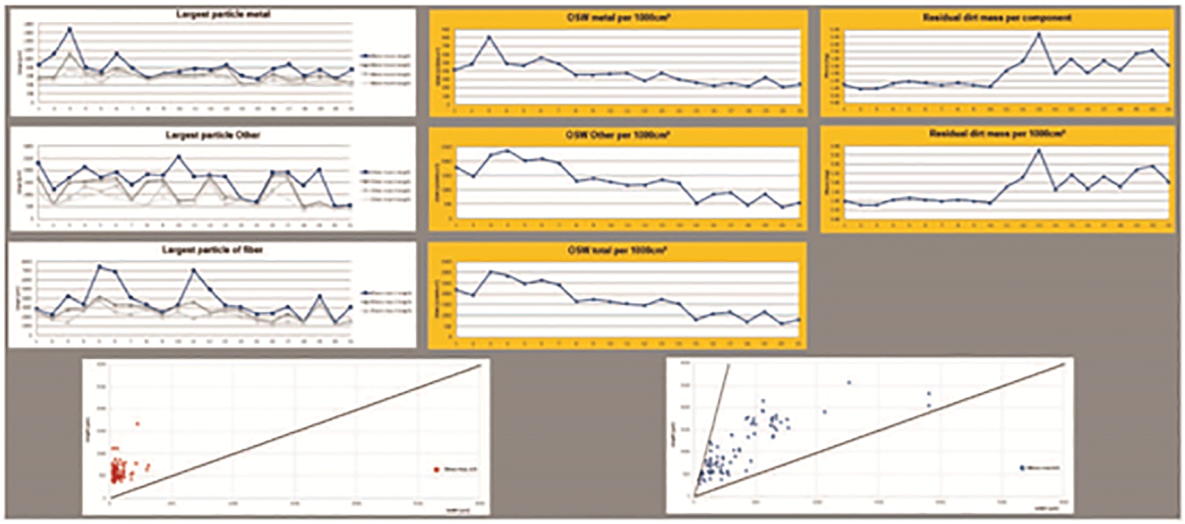
Figure 15 – Structural levels of a database



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Figure 16 – Option A – Evaluation of the largest particles by length and width

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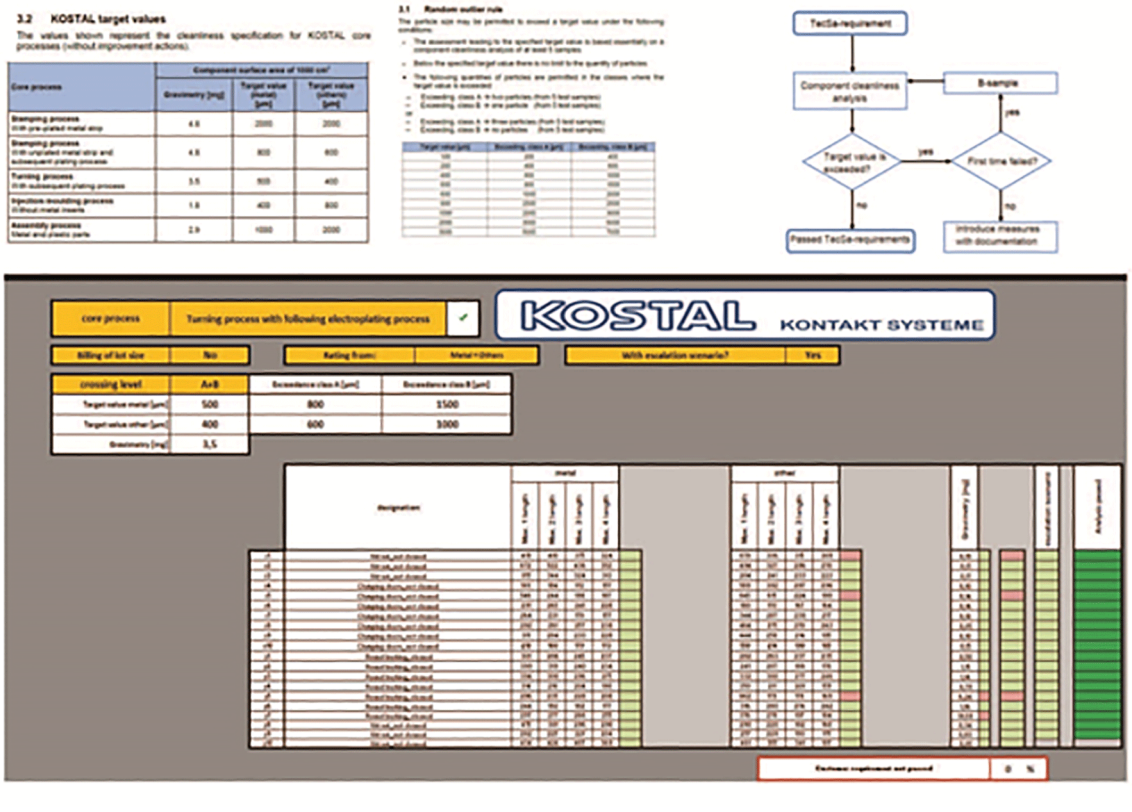
Figure 17 – Option B – Extension to include the degree of contamination – SCI



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Figure 18 – Option C – Extension to include a separate data sheet "direct comparison of test series"

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Example – LK3223 (Kostal Kontakt Systeme GmbH; Kostal Kontakt Systeme is a supplier of contact systems. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the supplier named).

Figure 19 – Option D – Extension of the database "to include 'comparison with customer standards'"

Factory standards on technical cleanliness are based on mathematical operations, so it is possible to integrate these into the database. Analyses can be automatically compared with standard specifications – e.g. particle type/s that is/are part of the specification, number of, the number of particles per size class, outlier rule, escalation strategy, etc.

5.7.4 Summary

The integration of an SCI enables statements to be made about the degree of contamination on the products themselves and comparisons with other test series if necessary. It is advisable to view this in the context of the "largest particles".

When the particle type/s of interest has/have been defined, a database is indispensable for providing retrospective/prospective statements. The greater the number of representative analyses available, the more accurate and informative the statements. Each analysis yields a substantial volume of data, but with the aid of a database, an overview can easily be obtained by selecting the three "largest particles"/analysing them (per particle type) and calculating the corresponding SCI. This is all the more important when comparing the status quo with two different cleaning methods, for example. In this case, it is advisable to use at least five analyses per test series.

Then at the "press of a button" measures or cleanliness levels can be evaluated and compared with customer standards as required.

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