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ICS 49.140

**Raumfahrtproduktsicherung –
Ultra-Reinigung von Flug-Hardware;
Englische Fassung EN 16602-70-54:2019**

Space product assurance –
Ultracleaning of flight hardware;
English version EN 16602-70-54:2019

Assurance produit des projets spatiaux –
Ultranettoyage des matériels de vol;
Version anglaise EN 16602-70-54:2019

Gesamtumfang 75 Seiten

DIN-Normenausschuss Luft- und Raumfahrt (NL)

Nationales Vorwort

Dieses Dokument (EN 16602-70-54:2019) wurde im Technischen Komitee CEN/CLC/JTC 5 „Raumfahrt“, dessen Sekretariat von DIN (Deutschland) gehalten wird, erarbeitet.

Das zuständige deutsche Normungsgremium ist der Arbeitsausschuss NA 131-06-02 AA „Interoperabilität von Informations-, Kommunikations- und Navigationssystemen“ im DIN-Normenausschuss Luft- und Raumfahrt (NL).

Dieses Dokument (EN 16602-70-54:2019) basiert auf ECSS-Q-ST-70-54C.

Dieses Dokument enthält unter Berücksichtigung des DIN-Präsidialbeschlusses 1/2004 nur die Englische Fassung von EN 16602-70-54:2019.

Dieses Dokument wurde speziell zur Behandlung von Raumfahrtssystemen erarbeitet und hat daher Vorrang vor jeglicher Europäischen Norm, die denselben Anwendungsbereich hat, jedoch über einen größeren Geltungsbereich (z. B. Luft- und Raumfahrt) verfügt.

Für die in diesem Dokument zitierten internationalen Dokumente wird im Folgenden auf die entsprechenden deutschen Dokumente hingewiesen:

ISO 14644-1:2015	siehe	DIN EN ISO 14644-1:2016-06
ISO 14644-8:2013	siehe	DIN EN ISO 14644-8:2013-06
ISO 14644-9:2012	siehe	DIN EN ISO 14644-9:2012-12
ISO 14644-10:2013	siehe	DIN EN ISO 14644-10:2013-06
ISO 14698-1:2003	siehe	DIN EN ISO 14698-1:2004-04

Nationaler Anhang NA (informativ)

Begriffe und Abkürzungen

Die Benummerung der folgenden Begriffe und Abkürzungen ist identisch mit der Benummerung in der englischen Fassung.

3.1 Begriffe aus anderen Normen

- a) Für die Anwendung dieses Dokuments gelten die Begriffe nach ECSS-S-ST-00-01 und insbesondere die folgenden Begriffe:
 - 1) Reinheit;
 - 2) Qualifizierung;
 - 3) Prüfung;
 - 4) Validierung;
 - 5) Verifizierung.
- b) Für die Anwendung dieses Dokuments gelten die Begriffe nach ECSS-Q-ST-70-01 und insbesondere die folgenden Begriffe:
 - 1) Reinraum;
 - 2) Ausgasen.

3.2 Für diese Norm spezifische Begriffe

3.2.1

Bioaerosol

feinverteilte biologische Agenzien in einer gasförmigen Umgebung

[QUELLE: ISO 14698-1:2003]

3.2.2

biologische Verunreinigung

Verunreinigung von Werkstoffen, Einrichtungen, Personen, Oberflächen, Flüssigkeiten, Gasen oder Luft mit lebensfähigen Partikeln

Anmerkung 1 zum Begriff: In Abhängigkeit des Kontexts kann eine biologische Verunreinigung als organisch oder als Teilchenkontamination (Kontamination durch Partikel) betrachtet werden. Eine Bakterienzelle hat eine Masse von ungefähr $1\text{E-}13\text{ g}$ (der organische Anteil einer Zelle liegt unter der Nachweisgrenze der meisten chemischen Verfahren).

Anmerkung 2 zum Begriff: Abgesehen vom Wachstum der Zellen ist das Problem, dass Zellen und Sporen oftmals über extrazelluläres Material verfügen, welches mehr Masse ausmachen kann als die Zelle selbst.

3.2.3

Reinheit (einer Feststoffoberfläche)

Zustand einer Feststoffoberfläche, bei der die Menge an Verunreinigungen auf ein bestimmtes Niveau reguliert wird

Anmerkung 1 zum Begriff: Beispiele für die Menge an Verunreinigungen umfassen chemisch molekulare oder lebensfähige Partikel.

3.2.4

Verunreinigung

jede partikelbezogene, chemisch molekulare, nicht partikelbezogene und biologische Einheit, die das Produkt oder den Prozess negativ beeinflussen kann

3.2.5

Dekontamination

Reduzierung der unerwünschten Materie auf ein festgelegtes Niveau

3.2.6

direktes Messverfahren

DMM

(en: direct measurement method)

Messverfahren, bei welchem die zu bestimmende Verunreinigung ohne Zwischenschritte bewertet wird

[QUELLE: ISO 14644-9:2012, modifiziert]

3.2.7

indirektes Messverfahren

IMM

(en: indirect measurement method)

Messverfahren, bei welchem die zu bestimmende Verunreinigung mit Zwischenschritten bewertet wird

[QUELLE: ISO 14644-9:2012, modifiziert]

3.2.8

Oberflächenreinheit von Chemikalien

SCC

(en: surface cleanliness of chemicals)

Vorhandensein einer molekularen, chemischen, nicht partikelbezogenen Spezies im adsorbierten oder abgelagerten Zustand auf der Oberfläche eines Produkts, was schädliche Auswirkungen auf das Produkt, den Prozess oder die Einrichtung im Reinraum oder innerhalb der kontrollierten Umgebung haben kann

[QUELLE: ISO 14644-10:2013, modifiziert]

3.2.9

Oberflächenreinheit von Partikeln

SCP

(en: surface cleanliness of chemicals)

Die Klasse der Oberflächenreinheit von Partikeln ist eine Einstufungszahl, welche die maximal erlaubte Oberflächenkonzentration in Partikeln je m² für eine betrachtete Partikelgröße bestimmt, SCP-Klassen von 1 bis 8

[QUELLE: ISO 14644-9:2012, modifiziert]

3.2.10**Klassifizierung der Oberflächenreinheit von Partikeln**

SCP

(en: surface cleanliness of particles)

Stufe (oder Prozess der Bestimmung oder Spezifizierung der Stufe), welche die maximal erlaubte Oberflächenkonzentration in Partikeln je Quadratmeter für betrachtete Partikelgrößen bestimmt, ausgedrückt als ISO SPC Klasse N

[QUELLE: ISO 14644-9:2012]

3.2.11**Oberflächenpartikelkonzentration**

Anzahl der einzelnen Partikel je betrachteter Flächeneinheit

[QUELLE: ISO 14644-9:2012]

3.2.12**Verunreinigung in dünnen Schichten**

Schichten kritischer Verunreinigungen, die vom Nanometerbereich bis zum Mikrometerbereich reichen

3.2.13**lebensfähige Partikel**

Partikel, das aus einem oder mehreren, lebenden Mikroorganismen besteht oder diese unterstützt

3.2.14**Wirksamkeit der Reinigung**

Entfernung bestimmter Verunreinigungen von einer Oberfläche durch einen Reinigungsprozess, bestimmt durch die endgültig erreichte Oberflächenreinheit in Bezug auf die ursprüngliche Oberflächenreinheit

Anmerkung 1 zum Begriff: Die Wirksamkeit der Reinigung kann absolut (Oberflächenkonzentration) oder relativ (Prozentsatz) ausgedrückt werden.

Anmerkung 2 zum Begriff: Im Allgemeinen führt die wiederholte Anwendung des gleichen Reinigungsprozesses zu einer sukzessiven Verringerung der Wirksamkeit.

3.3 Abkürzungen

Für die Anwendung dieses Dokuments gelten die Abkürzungen nach ECSS-S-ST-00-01 und die folgenden Abkürzungen:

Abkürzung	Bedeutung	
DRD	Definition der Dokumentanforderungen	(en: document requirements definition)
ppm	Teile je Million (10^{-6})	(en: parts per million)

Nationaler Anhang NB (informativ)

Literaturhinweise

DIN EN ISO 14644-1:2016-06, *Reinräume und zugehörige Reinraumbereiche — Teil 1: Klassifizierung der Luftreinheit anhand der Partikelkonzentration (ISO 14644-1:2015); Deutsche Fassung EN ISO 14644-1:2015*

DIN EN ISO 14644-8:2013-06, *Reinräume und zugehörige Reinraumbereiche — Teil 8: Klassifizierung der Luftreinheit anhand der Chemikalienkonzentration (ACC) (ISO 14644-8:2013); Deutsche Fassung EN ISO 14644-8:2013*

DIN EN ISO 14644-9:2012-12, *Reinräume und zugehörige Reinraumbereiche — Teil 9: Klassifizierung der partikulären Oberflächenreinheit (ISO 14644-9:2012); Deutsche Fassung EN ISO 14644-9:2012*

DIN EN ISO 14644-10:2013-06, *Reinräume und zugehörige Reinraumbereiche — Teil 10: Klassifizierung der chemischen Oberflächenreinheit (ISO 14644-10:2013); Deutsche Fassung EN ISO 14644-10:2013*

DIN EN ISO 14698-1:2004-04, *Reinräume und zugehörige Reinraumbereiche — Biokontaminationskontrolle — Teil 1: Allgemeine Grundlagen (ISO 14698-1:2003); Deutsche Fassung EN ISO 14698-1:2003*

English version

Space product assurance - Ultracleaning of flight hardware

Assurance produit des projets spatiaux -
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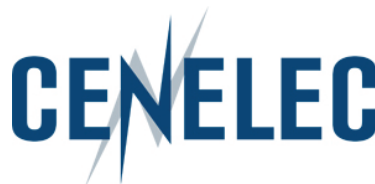
Raumfahrtproduktsicherung - Ultra-Reinigung von
Flug-Hardware

This European Standard was approved by CEN on 9 November 2018.

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Rue de la Science 23, B-1040 Brussels

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European Foreword

This document (EN16602-70-54:2019) has been prepared by Technical Committee CEN-CENELEC/TC 5 "Space", the secretariat of which is held by DIN.

This standard (EN16602-70-54:2019) originates from ECSS-Q-ST-70-54C.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2019, and conflicting national standards shall be withdrawn at the latest by September 2019.

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

This document has been prepared under a standardization request given to CEN by the European Commission and the European Free Trade Association.

This document has been developed to cover specifically space systems and has therefore precedence over any EN covering the same scope but with a wider domain of applicability (e.g. : aerospace).

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This ECSS Standard describes the procedures to be used to clean to a level of cleanliness beyond the scope of the ECSS-Q-ST-70-01, and to control the cleanliness level of flight hardware prior to and following a posteriori to the application of the ultracleaning process. The intended objective of the ultracleaning process is to remove all surface contamination (particulates, biologic material cell debris and chemical molecular contamination) on flight hardware, with no specific limit in geometric dimension or contamination levels. This includes removal of biological material for avoidance of false positive results during investigation of extra-terrestrial samples or environments.

1 Scope

This standard addresses process descriptions, process validation, cleanliness control and monitoring, recontamination prevention, quality assurance as follows:

PROCESSES DESCRIPTIONS, including

- Detergent cleaning
- Alcohol cleaning
- Ultrapure water cleaning
- Liquid boundary layer disruption cleaning
- Multiple solvent cleaning (JPL procedure)
- Vacuum bakeout
- Supercritical fluids cleaning
- Carbon dioxide snow cleaning
- Plasma cleaning
- Pyrolysis
- Criteria for selecting other/novel processes

PROCESS VALIDATION

- Test material selection
- Preparation of test materials for process application
- Deposition of contaminants
- Description of test conditions
- Verification of cleanliness level

CLEANLINESS CONTROL AND MONITORING, including

- Micro/nano imaging techniques
- Spectrometry techniques
- Spectroscopy techniques
- Chromatography techniques

RECONTAMINATION PREVENTION

- Packaging systems
- Protective covers
- Storage

QUALITY ASSURANCE

This standard may be tailored for the specific characteristic and constraints of a space project in conformance with ECSS-S-ST-00.

2

Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system - Glossary of terms
EN 16602-10-09	ECSS-Q-ST-10-09	Space product assurance - Nonconformance control system
EN 16602-20-08	ECSS-Q-ST-20-08	Space product assurance - Storage, handling and transportation of spacecraft hardware
EN 16602-70	ECSS-Q-ST-70	Space product assurance - Materials, mechanical parts and processes
EN 16602-70-01	ECSS-Q-ST-70-01	Space product assurance - Cleanliness and contamination control
	ISO 14644-9: 2012	Cleanrooms and associated controlled environments - Part 9: Classification of surface cleanliness by particle concentration
	ISO 14644-10: 2013	Cleanrooms and associated controlled environments - Part 10: Classification of surface cleanliness by chemical concentration

Terms, definitions and abbreviated terms

3.1 Terms from other standards

- a. For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply, in particular for the following terms:
 - 1. cleanliness
 - 2. qualification
 - 3. test
 - 4. validation
 - 5. verification
- b. For the purpose of this Standard, the terms and definitions from ECSS-Q-ST-70-01 apply, in particular for the following terms:
 - 1. cleanroom
 - 2. off-gassing

3.2 Terms specific to the present standard

3.2.1 bioaerosol

dispersed biological agents in a gaseous environment
[ISO 14698-1:2003]

3.2.2 biological contamination

contamination of materials, devices, individuals, surfaces, liquids, gases or air with viable particles.

NOTE 1 Depending on the context, biological contamination can be considered as organic or as particulate contamination. A bacterial cell has about $1\text{E-}13$ g (organic content of one cell is below the detection limit of most chemical methods).

NOTE 2 Problem is that, apart from growing, cells and spores often have

extracellular material that can be more mass than the cell itself.

3.2.3 cleanliness (of a solid surface)

condition of a solid surface where the amount of contamination is controlled to a specific level

NOTE Example of amount of contamination include particle, chemical molecular or viable

3.2.4 contaminant

any particulate, chemical molecular, non-particulate and biological entity that can adversely affect the product or process

3.2.5 decontamination

reduction of unwanted matter to a defined level

3.2.6 direct measurement method (DMM)

measurement method where the contamination that is to be determined is being assessed without any intermediate steps

[adapted from ISO 14644-9:2012]

3.2.7 indirect measurement method (IMM)

measurement method where the contamination that is to be determined is being assessed with intermediate steps

[adapted from ISO 14644-9:2012]

3.2.8 surface cleanliness of chemicals (SCC)

presence on the surface of a product or instrument of molecular, chemical, non-particulate, species in the adsorbed or deposited state which can have a deleterious effect on the product, process or equipment in the cleanroom or controlled environment

[adapted from ISO 14644-10:2013]

3.2.9 surface cleanliness of particles (SCP)

class of surface particle cleanliness is a grading number stating the maximum allowable surface concentration, in particles per m², for a considered size of particles, SPC Classes 1 to 8

[adapted from ISO 14644-9:2012]

3.2.10 surface cleanliness particles (SCP) classification

level (or the process of specifying or determining the level) that represents maximum allowable surface concentrations, in particles per square metre, for considered sizes of particles, expressed in terms of an ISO SCP Class N

[ISO 14644-9:2012]

3.2.11 surface particle concentration

number of individual particles per unit of surface area under consideration
[ISO 14644-9:2012]

3.2.12 thin film contamination

layers of critical contaminants that range from the nanometre scale to the micrometre scale

3.2.13 viable particle

particle that consists of, or supports, one or more live microorganisms

3.2.14 cleaning efficacy

removal of specific contaminants from a surface by a cleaning process, determined by the final accomplished surface cleanliness, in respect to the initial surface cleanliness

NOTE 1 Cleaning efficacy can be expressed in absolute (surface concentration) or relative (percentage) terms.

NOTE 2 In general, repetitive application of the same cleaning process results in consecutive decreasing efficacy.

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms from ECSS-S-ST-00-01 and the following apply:

Abbreviation	Meaning
DRD	document requirements definition
ppm	parts per million (10^{-6})

3.4 Nomenclature

The following nomenclature applies throughout this document:

- a. The word “shall” is used in this Standard to express requirements. All the requirements are expressed with the word “shall”.
- b. The word “should” is used in this Standard to express recommendations. All the recommendations are expressed with the word “should”.

NOTE It is expected that, during tailoring, recommendations in this document are either converted into requirements or tailored out.

- c. The words “may” and “need not” are used in this Standard to express positive and negative permissions, respectively. All the positive

permissions are expressed with the word “may”. All the negative permissions are expressed with the words “need not”.

- d. The word “can” is used in this Standard to express capabilities or possibilities, and therefore, if not accompanied by one of the previous words, it implies descriptive text.

NOTE In ECSS “may” and “can” have completely different meanings: “may” is normative (permission), and “can” is descriptive.

- e. The present and past tenses are used in this Standard to express statements of fact, and therefore they imply descriptive text.

4

Principles

4.1 Cleaning techniques: Contamination removal

4.1.1 Introduction

In the simplest case contamination can be defined as foreign matter, but in relation to this standard is considered any particulate, chemical molecular, non-particulate and biological entity on a surface that can adversely affect the product or process. Increase of contamination leads generally to cumulative build-up.

Surface contamination, such as particles in the micrometre range, microbiological contamination or airborne and surface molecular contamination, has become a significant hazard in many areas of industry.

Figure 4-1 shows schematically typical types of molecular and particulate contamination.

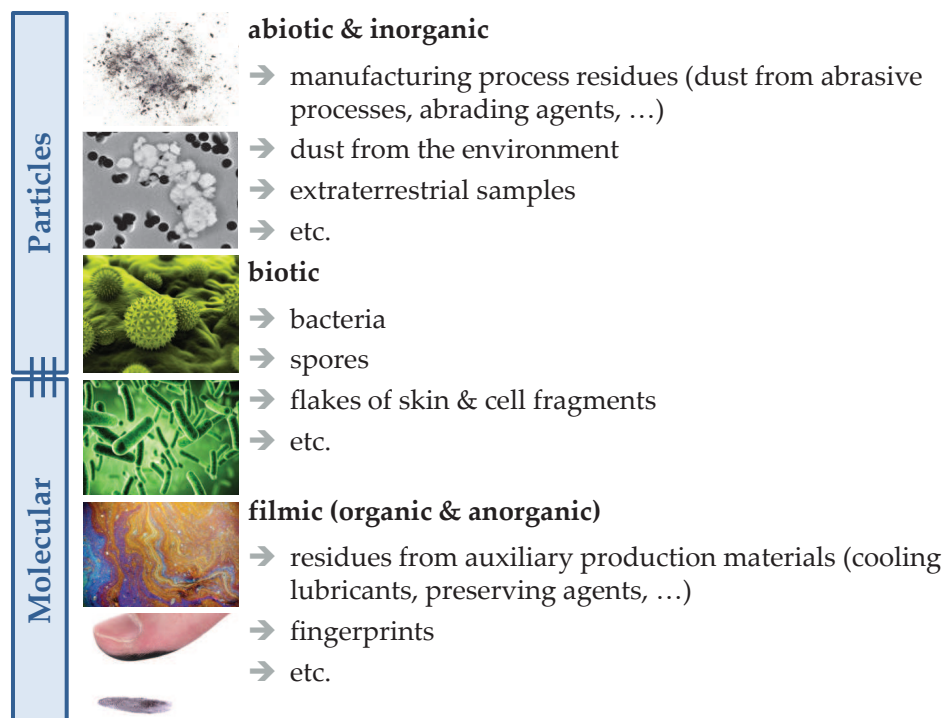


Figure 4-1: Typical types of molecular and particulate contamination

The deposition of contamination on surfaces for example occurs in the following three steps:

- Aerodynamic transportation to the boundary layer
- Transportation inside the boundary layer
- Contamination coming in contact with the surface

Contamination in the micro- and nanometre range can lead to the failure of complete units, impairment of performance, or incorrect test results. Therefore, for many applications, it is essential to ensure that contamination is reliably kept away from component surfaces.

This objective is not easy to achieve, especially if one considers particles smaller than 10 μm . These particles adhere to a surface through very strong bonding interactions: covalent bonding, ionic bonding, van der Waals forces, hydrogen bonding, dipole-dipole and electrostatic interactions, or a combination of these.

By using model approaches, the attractive and adhesive forces occurring between particles and surfaces can be theoretically calculated. The calculations deviate slightly from reality but if, for example, the magnitude of only the van der Waals force is compared with particle weight, essential information about the magnitude of the forces of attraction can still be obtained (see Figure 4-2).

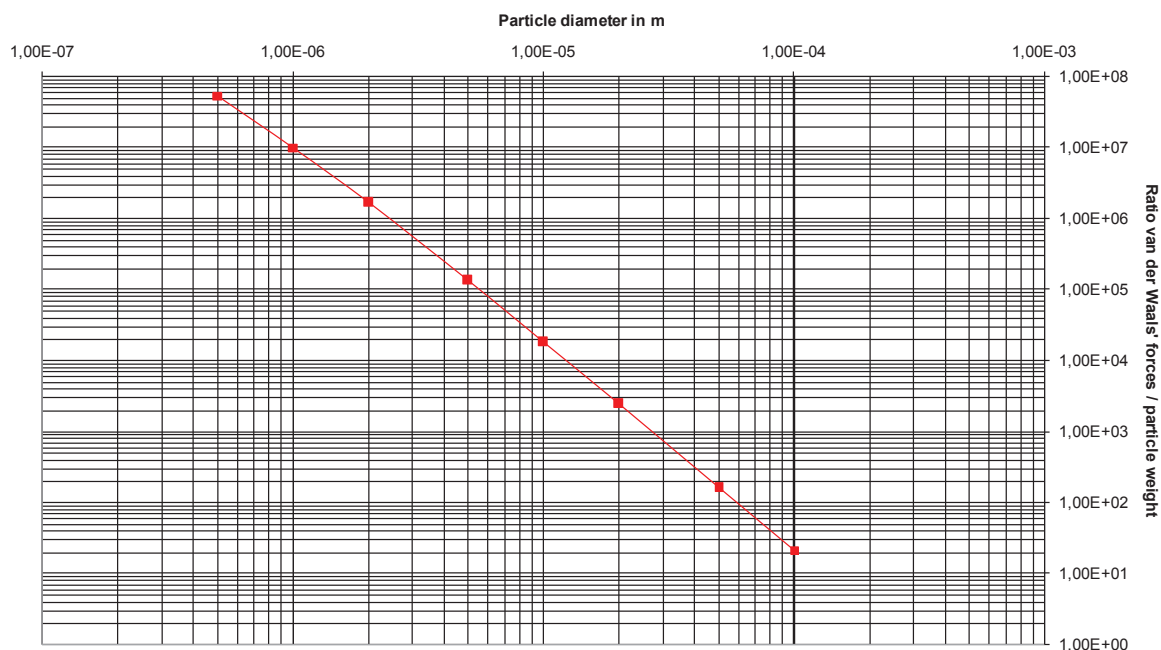


Figure 4-2: Relationship between van der Waals force and weight in dependence upon particle diameter (model according to Hamaker for Al particles on Al substrate)

Van der Waals force exceeds particle weight by a factor of 10^8 for particles of diameter 0,5 μm . Relationships are especially pronounced in the case of small particle diameters (particle diameter of < 10 μm). Whereas van der Waals forces are linearly dependent upon the diameter over several orders of magnitude, particle diameter is cubic to weight.

As the adhesive forces of particles on surfaces are the decisive parameters for cleaning surfaces in contamination-sensitive areas, the choice of cleaning method therefore plays a crucial role.

NOTE The theoretical forces of adhesion are proportional to particle size, while the removal forces varies between the second or third power to the particle diameter thus requiring an increasingly larger force to overcome the adhesion force between the particle and the substrate as the particle size is reduced

At sufficiently thick chemical molecular contamination layers the contaminants will exhibit bulk-like characteristics where the required energy for removal is independent of layer thickness. At low levels (e.g. few molecular layers) the surface of the substrate becomes a significant factor and an increasing amount of energy is required for removal. Consequently it becomes also increasingly difficult to maintain surface cleanliness.

Cleaning principles and related techniques are described in more detail in clause 4.1.3. In general, there are four parameters that influence the cleaning efficacy: Chemical, mechanical, temperature and time. These factors are all inter-correlated, i.e. the change of one factor has an influence on the others. For example the reduction of temperature can be compensated by increase in cleaning time or more aggressive cleaning. This is not limited to the type of cleaning process alone, but also to type of contamination, surface characteristics and process parameters (Figure 4-3).

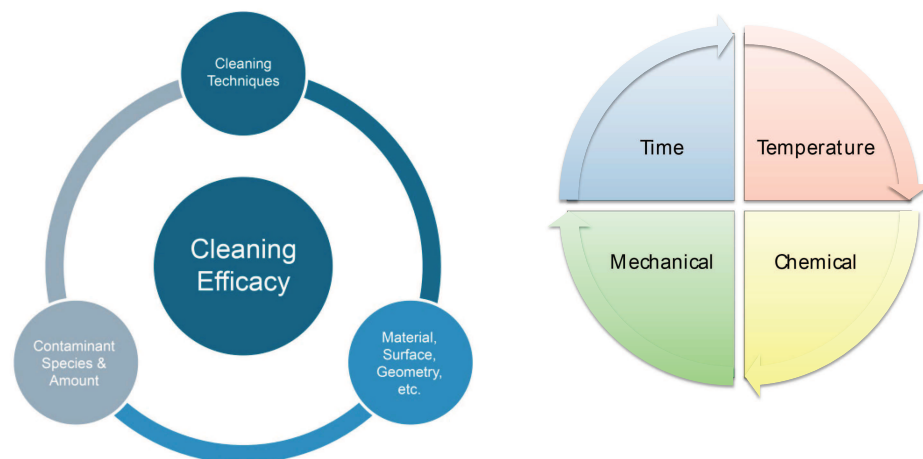


Figure 4-3: Influences on the cleaning efficacy