CleanControlling®

Online Basic-Seminar
TECHNICAL CLEANLINESS
VDA 19.1 and VDA 19.2



From concept to practice - definition and handling of/with cleanliness limit values

Leander Gihr, CleanControlling GmbH

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Content

Why cleanliness requirements?

The form follows the function!

Outlier handling?

REASONS FOR THE REQUIREMENTS

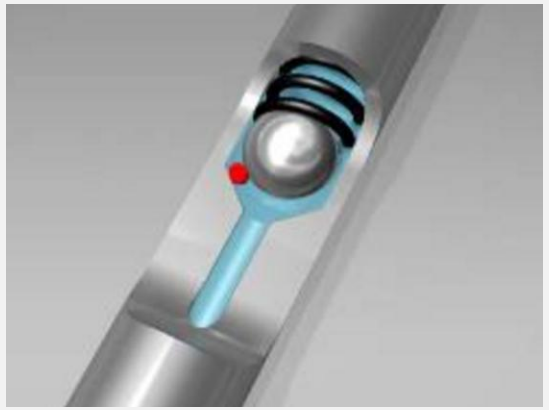
Examples of Damage Mechanisms

Seizing of Bearings and Sliding Surfaces



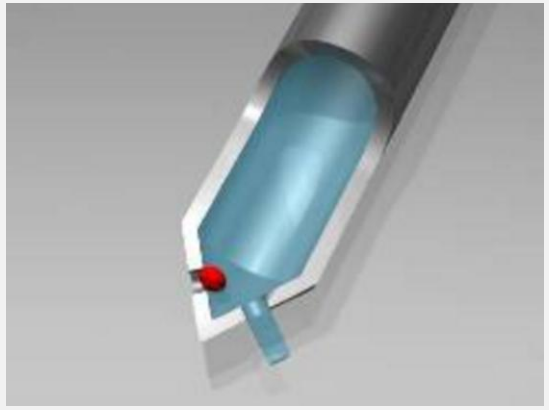
- Turbochargers
- Crankshaft bearings
- Dosing pumps
- Cylinder bores

Valve Blockage



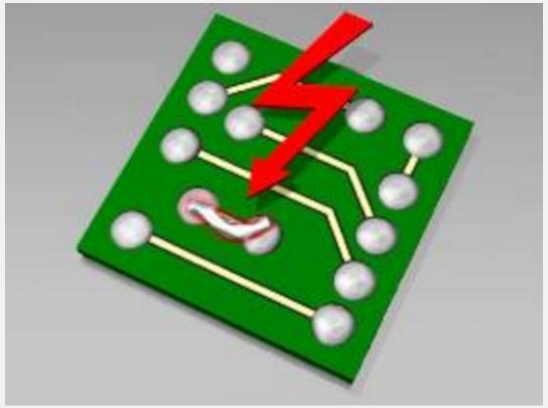
- ABS, ESP
- Hydraulic systems
- Brake boosters

Clogging of Nozzles or Filters



- Injectors
- Fuel injection system

Short Circuits in PCB Traces



- Control electronics
- PCBs, electrical systems

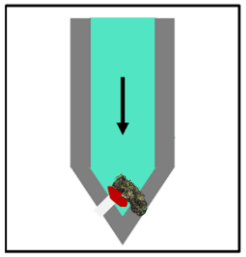
Sources: Unternehmensverbund VDA19/1

Sources: JOMESA Meßsysteme GmbH

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

From damage mechanism to cleanliness requirement

Blocking of nozzles or filters



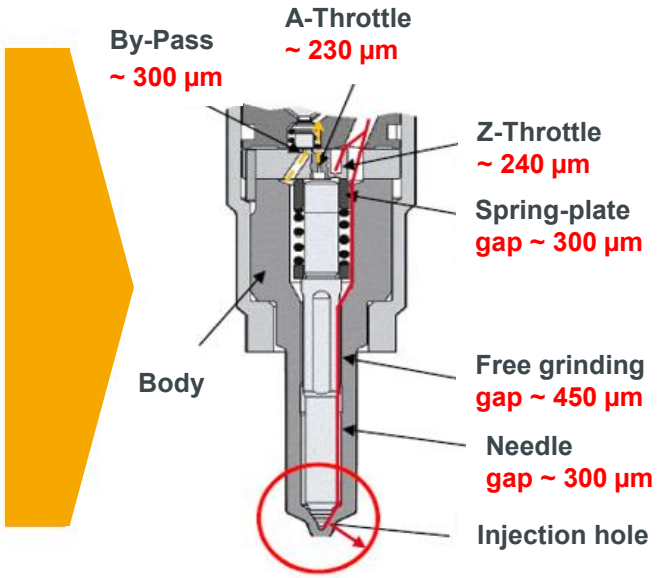
- Fuel supply
- Injectors

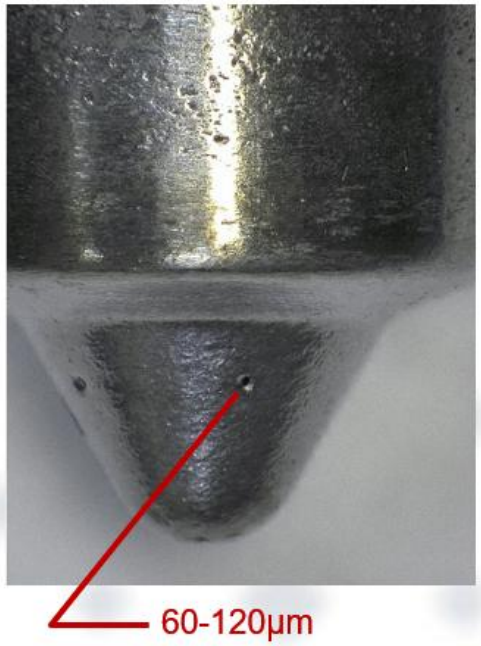


Particles in the injection holes prevent fuel injection



Source: Bosch

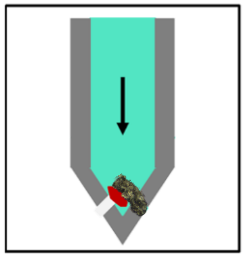




DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

From damage mechanism to cleanliness requirement

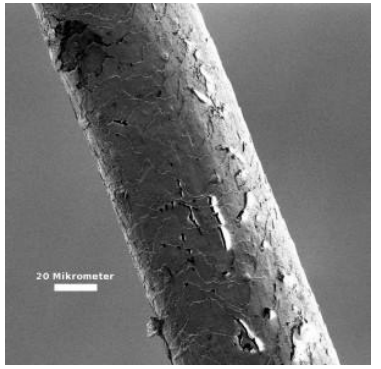
Blocking of nozzles or filters



- Fuel supply
- Injectors



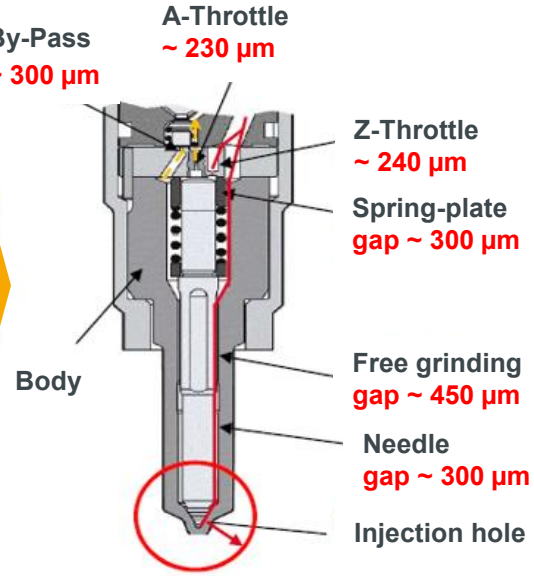
Particles in the injection holes prevent fuel injection

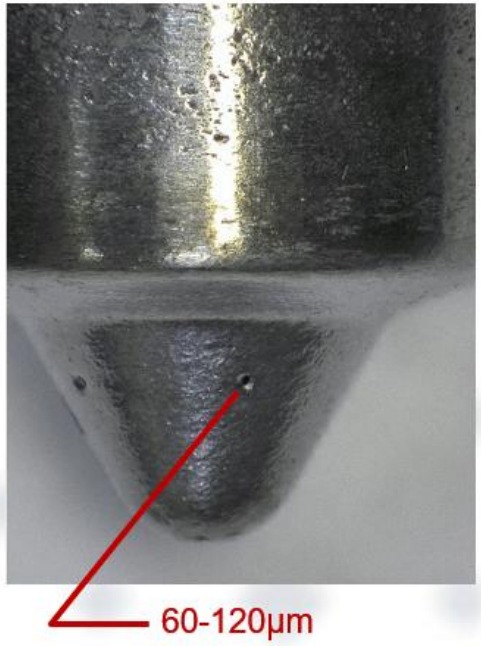


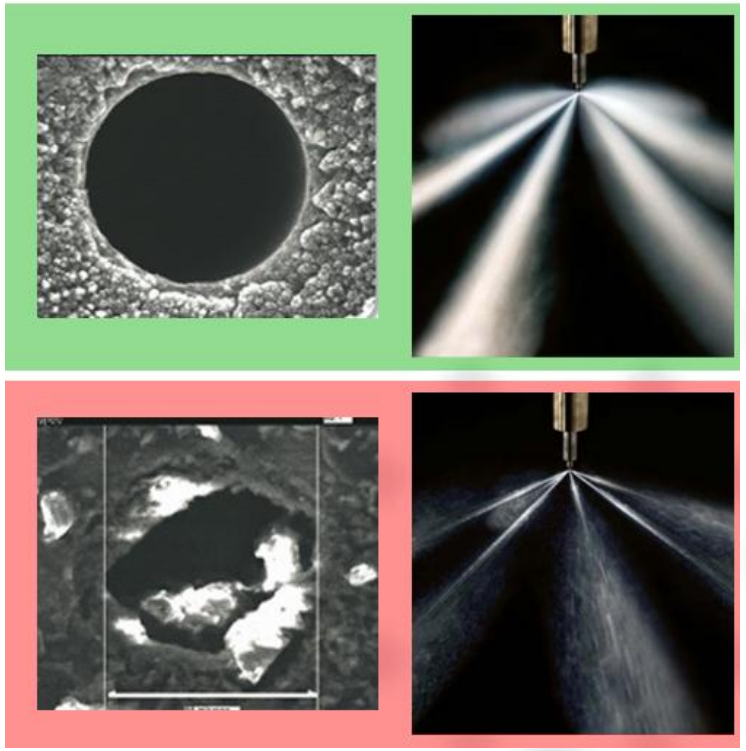
Human hair
60-120 µm



Source: Bosch





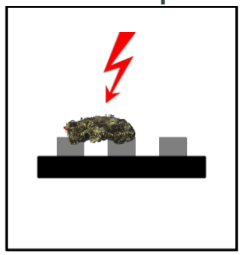


Source: Bosch

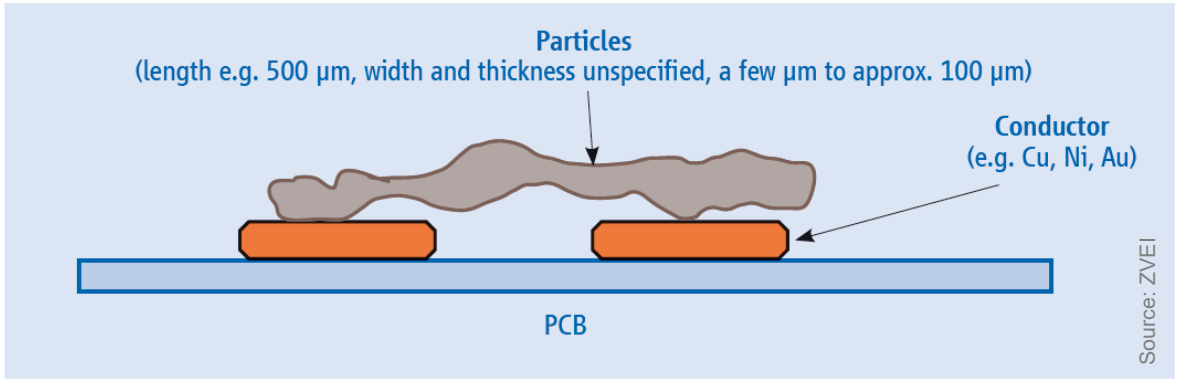
DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

From damage mechanism to cleanliness requirement

Short circuit of conductive paths



- Control electronics





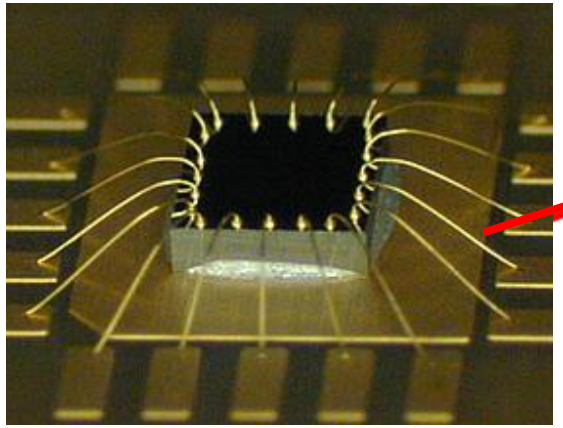
System assembly:
Cleanliness plays a decisive role also in this area



PCBA-Production:
Few hundred micrometers

In the field of nano- and micro-electronics - especially non-lacquered PCBs - short-circuit risks play a decisive role

Avoidance:
- Protect sensitive areas
- Design-Principles
- Pin-FMEA



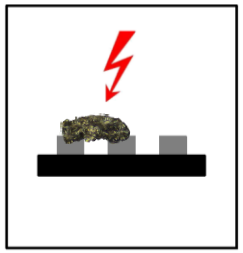
Chip-Production:
Few 10 Nanometer large particles

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

From damage mechanism to cleanliness requirement

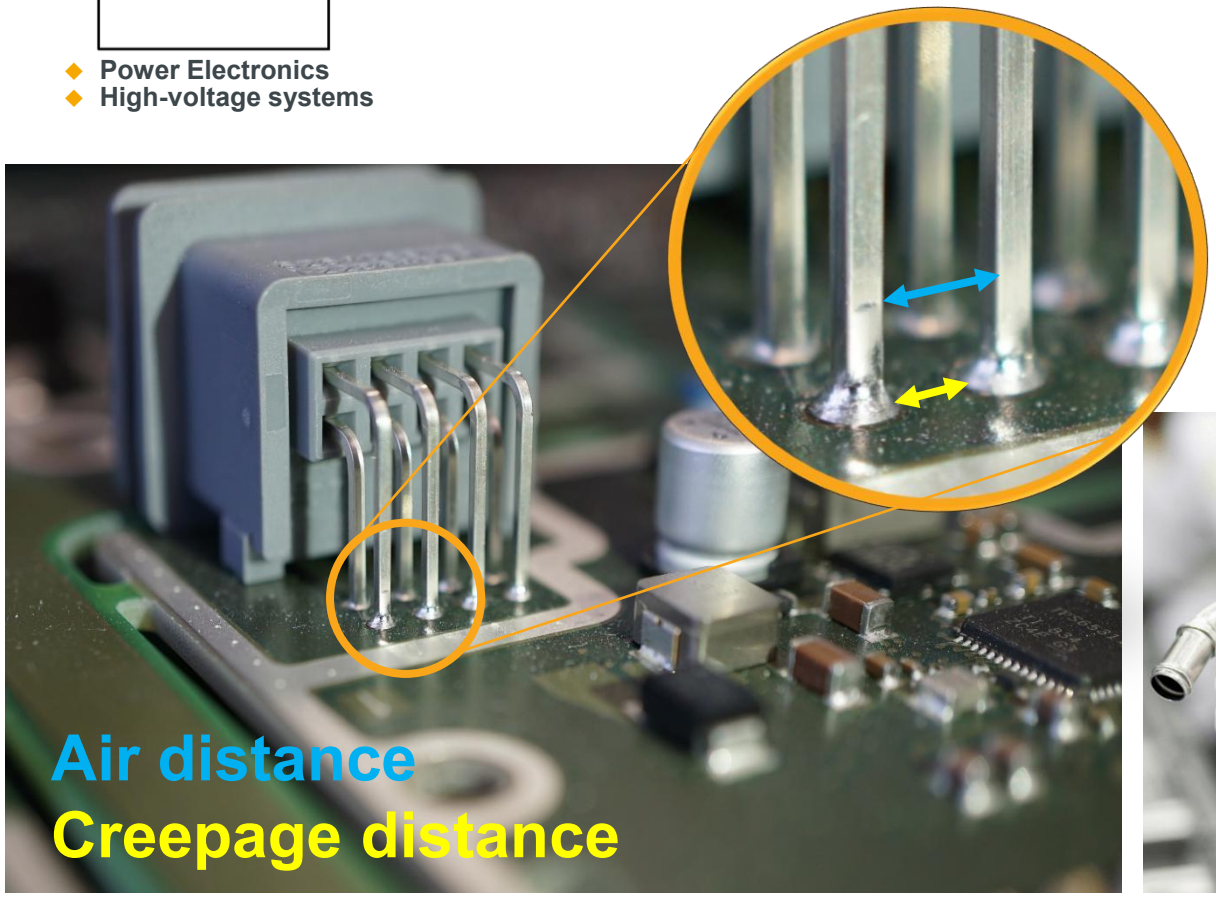
CleanControlling®

Shortening of electrical insulation



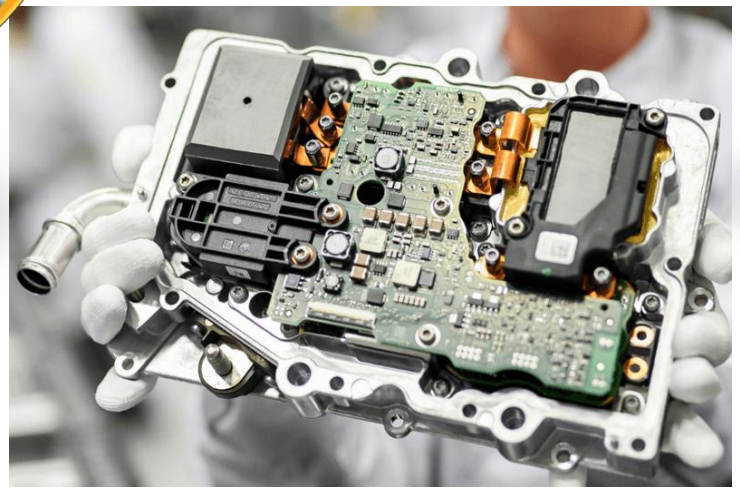
- Power Electronics
- High-voltage systems

In the field of high-voltage power electronics (high voltages / high currents), clearances and creepage distances play a decisive role

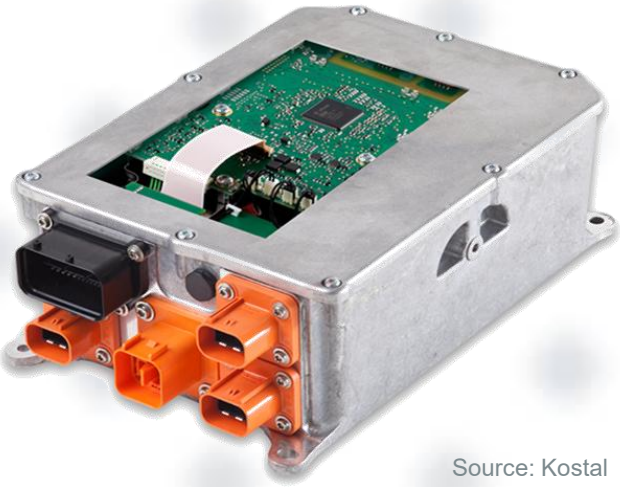




Source: VW



Source: Continental

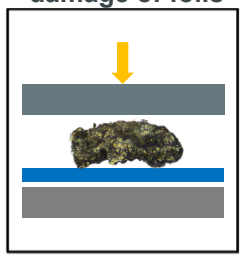


Source: Kostal

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

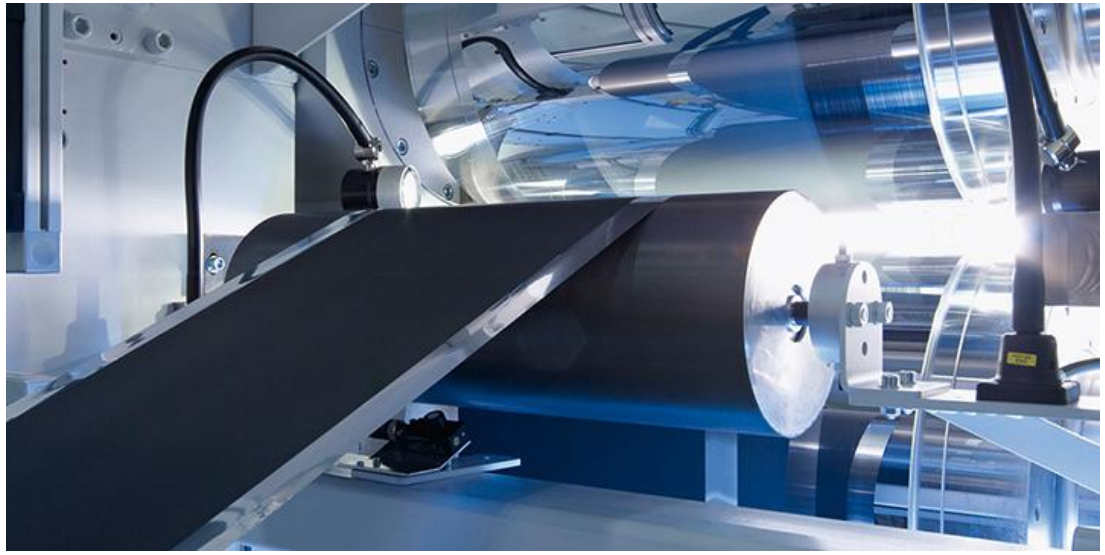
From damage mechanism to cleanliness requirement

Mechanical or chemical damage of foils



- Battery electrodes
- Separators
- Insulation foils

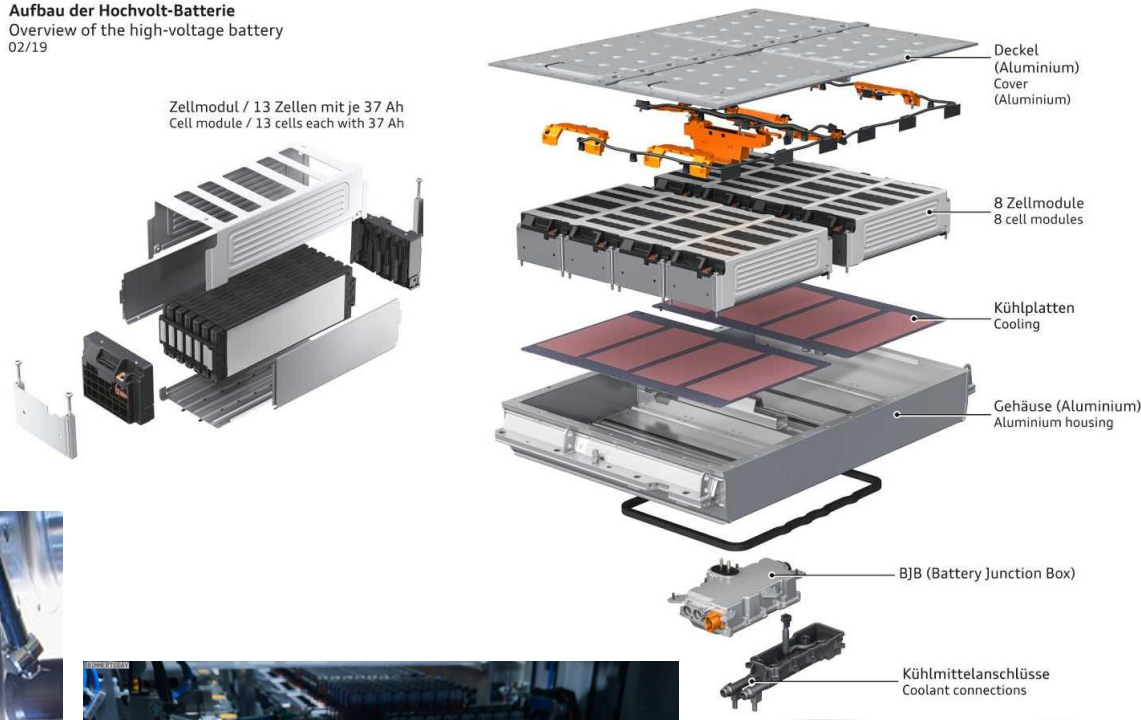




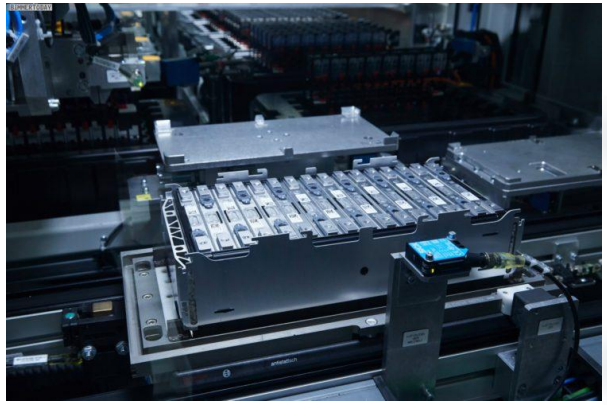
Source: Breyer

Audi A7 Sportback 55 TFSI e

Aufbau der Hochvolt-Batterie
Overview of the high-voltage battery
02/19



Source: AUDI



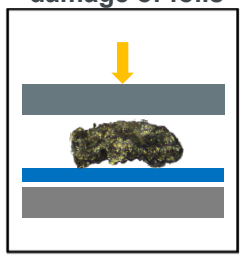
Source: VW

Critical particle sizes:
≥ 10µm

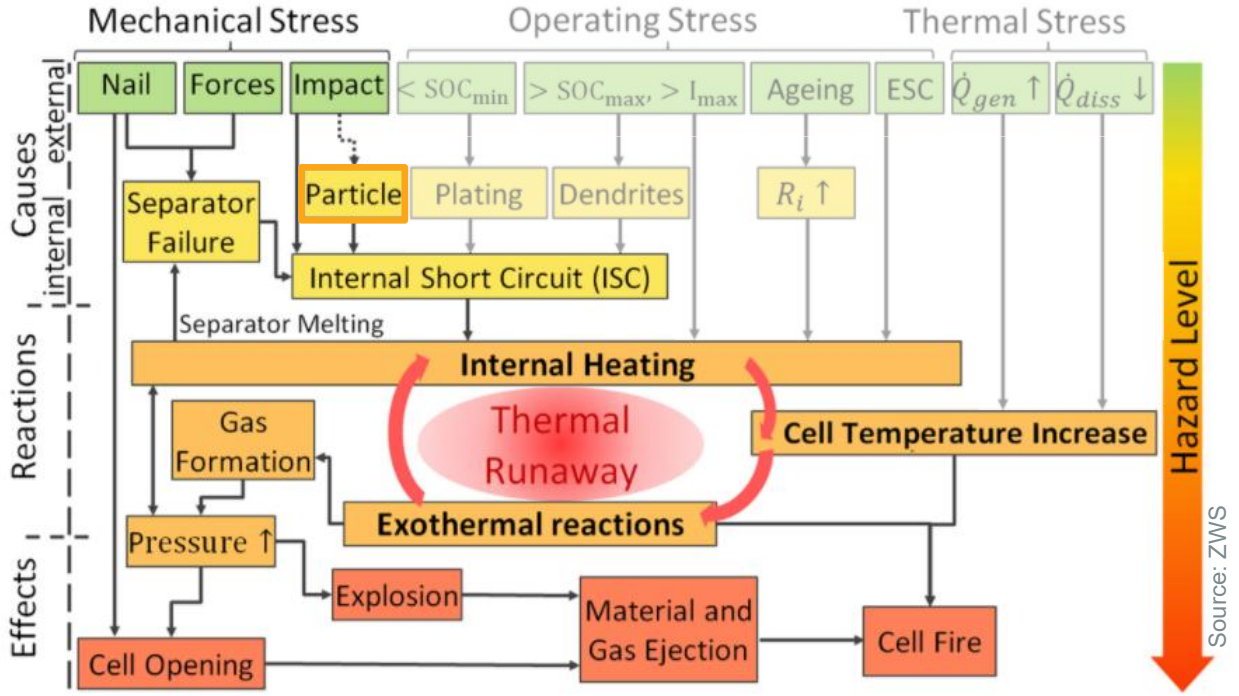
DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

From damage mechanism to cleanliness requirement

Mechanical or chemical damage of foils



- Battery electrodes
- Separators
- Insulation foils



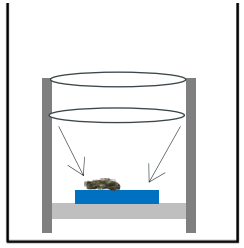


Source: ZWS

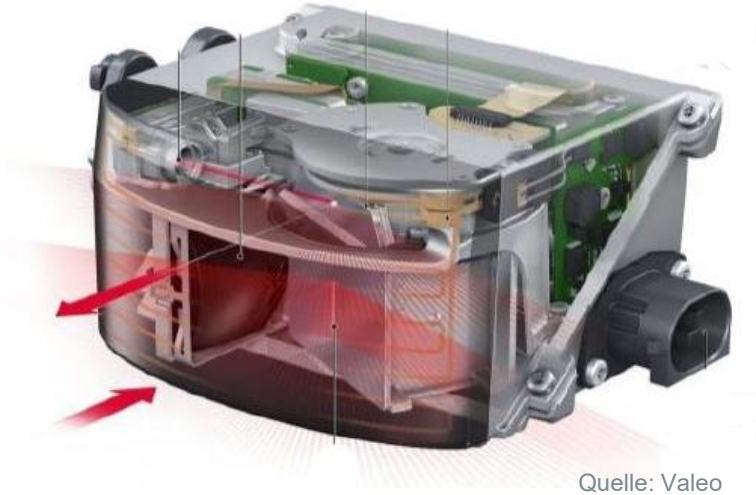
DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

From damage mechanism to cleanliness requirement

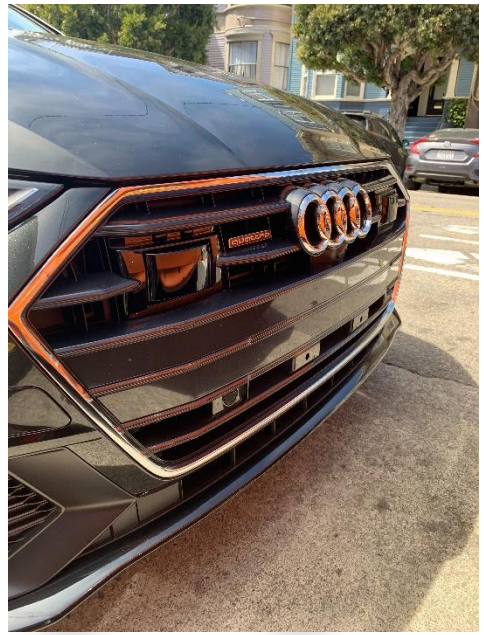
Optical interference of sensors



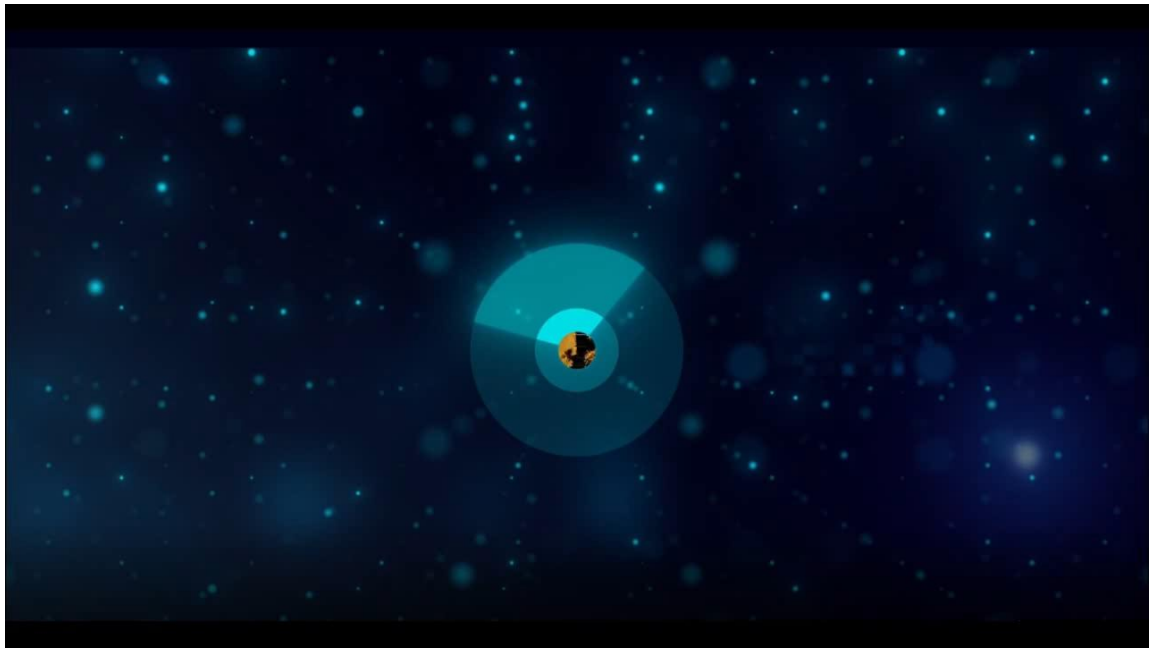
- Camera systems
- LIDAR Sensor Systems
- Optical image acquisition



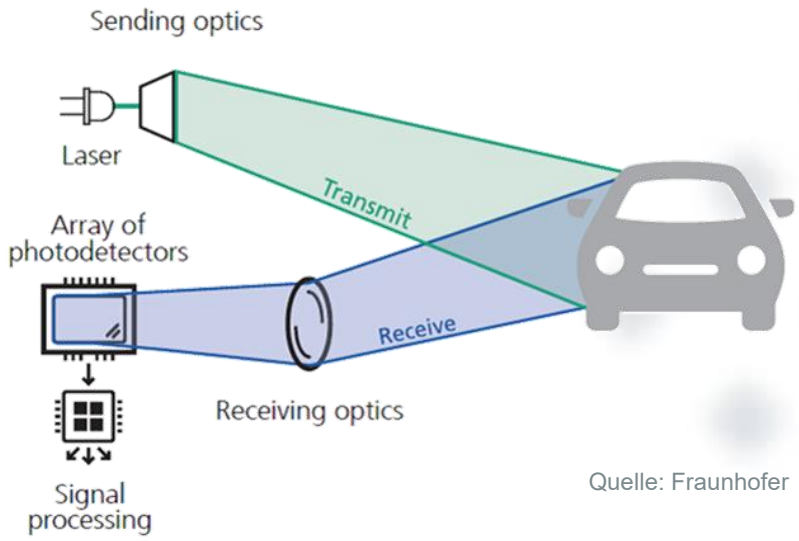
Quelle: Valeo



Source: AUDI



Source: Innoviz



Quelle: Fraunhofer

Critical particle sizes:
≥ 5µm

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Content

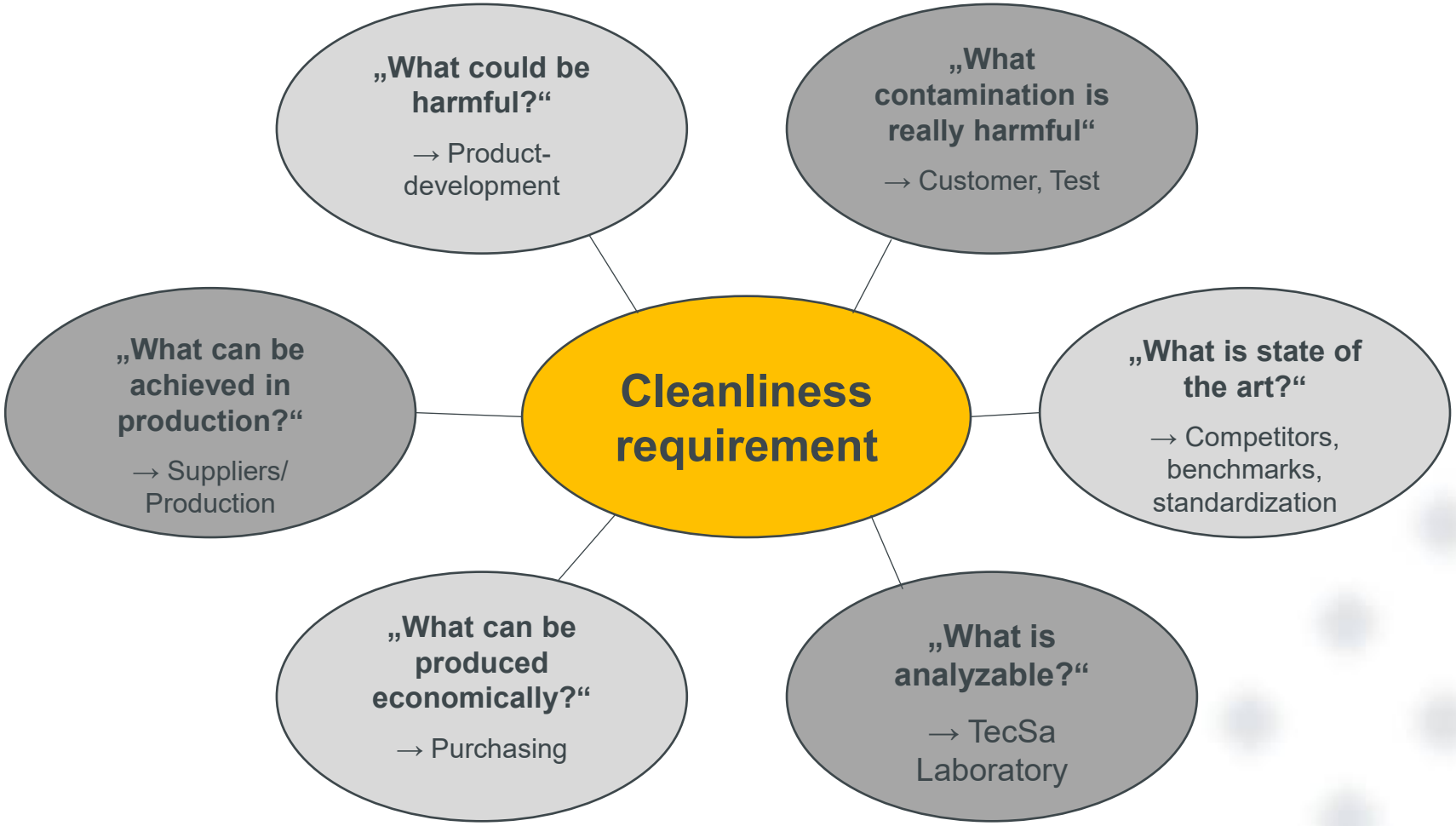
Why cleanliness requirements?

The form follows the function!

Outlier handling?

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

The form follows the function!



Only the right particle at the right time in the right place leads to failure!

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

The form follows the function!

Cleanliness requirements increase effort in all areas

Limit values must be producible (technically feasible and economically justifiable).

High cleanliness requirements cause high costs in production and further processing.

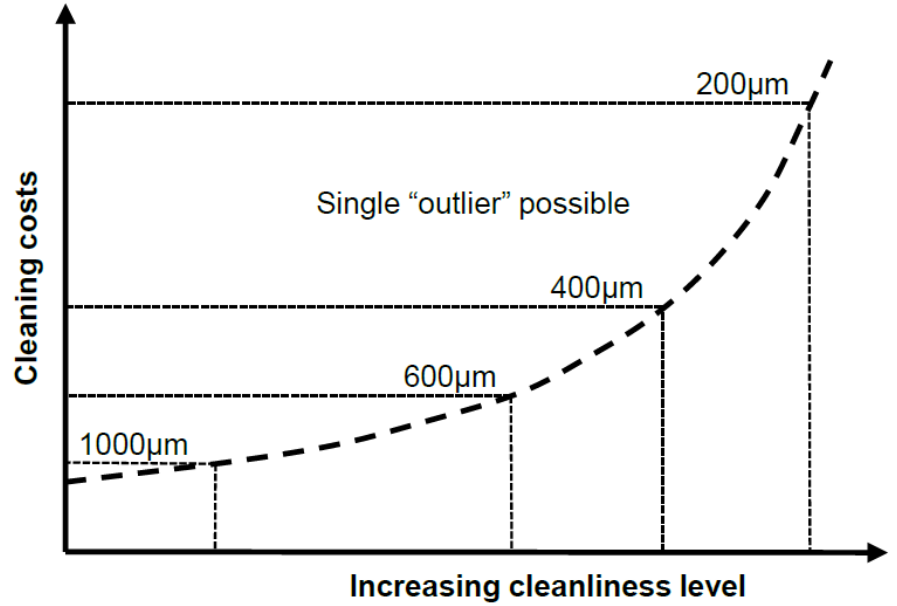
- Material selection or surface coating
- Machining and deburring
- Cleaning
- Logistics
- Production environment
- Personnel
- Assembly equipment and processes

Limit values should be limited to what is necessary for the function.

➡ ***„As clean as necessary, not as possible!“***

➡ ***„Regulate only the components that are really critical!“***





Source: VDA 19

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

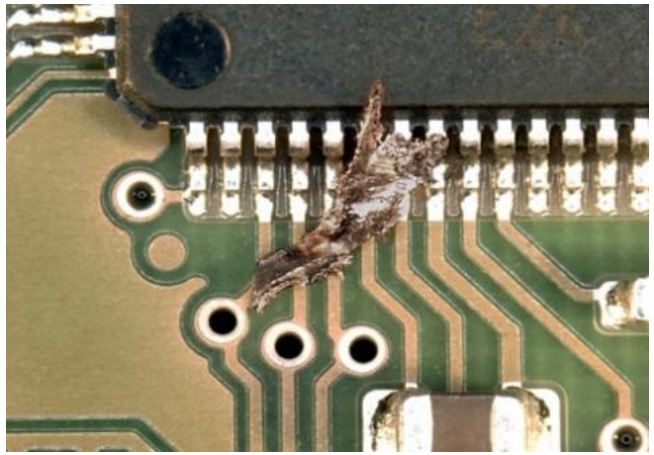
Identification of damage mechanisms

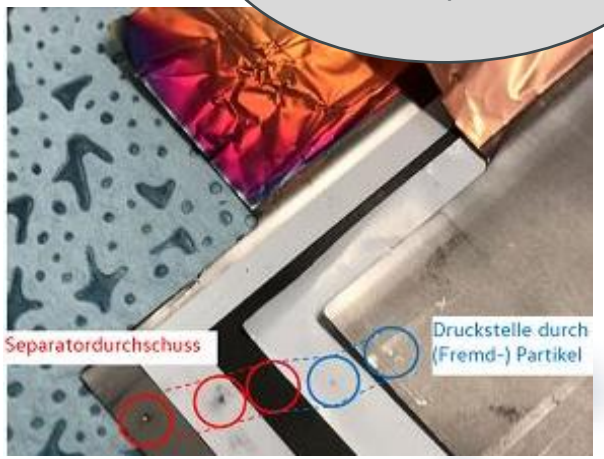
Evaluation of the design features

„What could be harmful?“

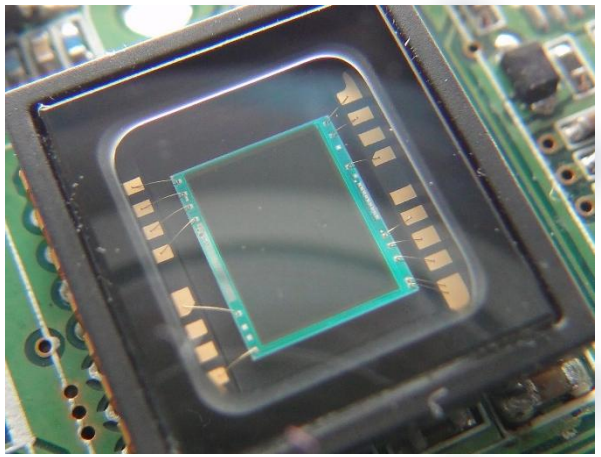
→ Product-development

- Determination of the critical sizes of particles for the function
  - Gap
  - Optical impairment
  - Conductor spacing
  - Sealing lengths
  - Thickness of foils
- Additional data to be noted:
  - Shape of the particles
  - Type/material of the particles









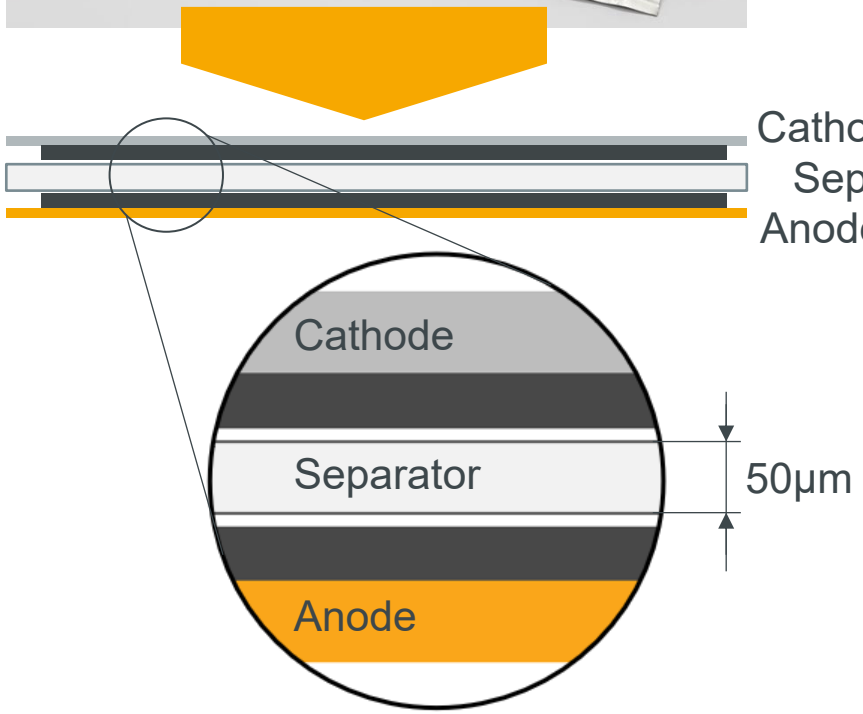
Caution:
This consideration often leads to very highly regulated limits

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Identification of damage mechanisms

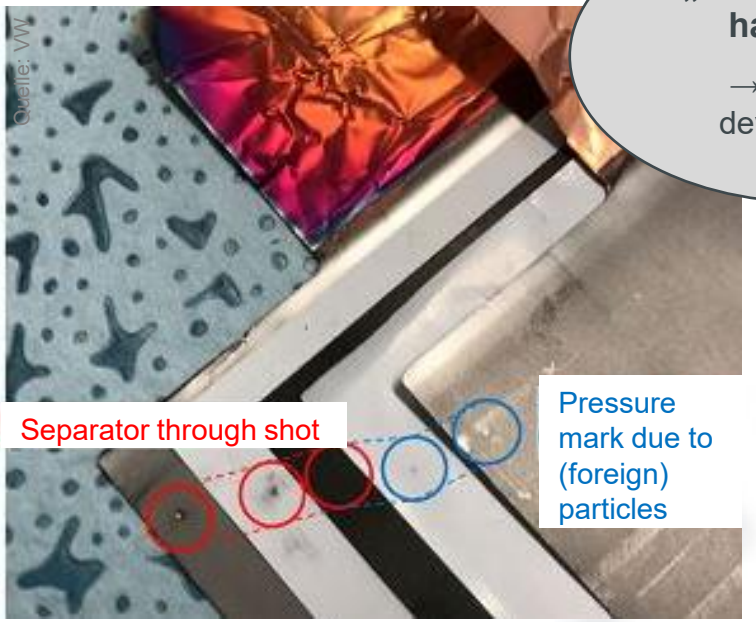
Evaluation of the constructive characteristics - example

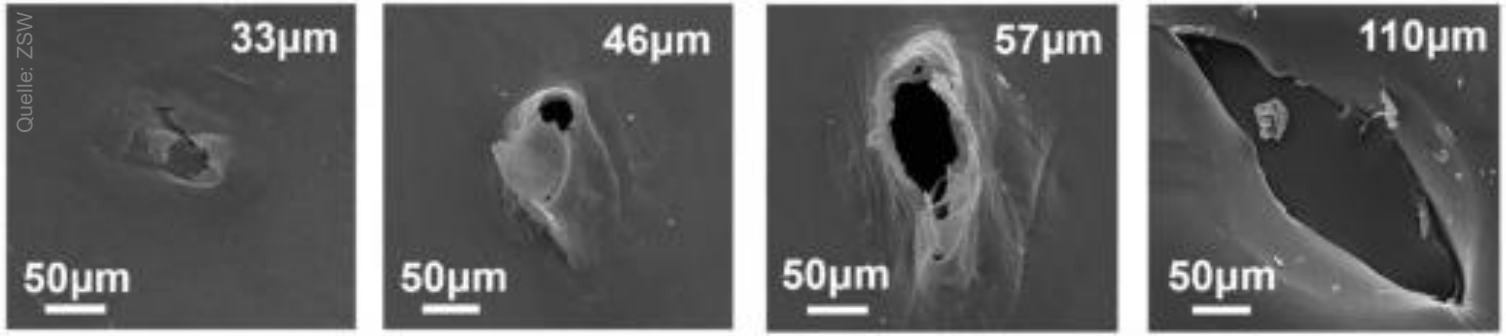




„What could be harmful?“

→ Product-development





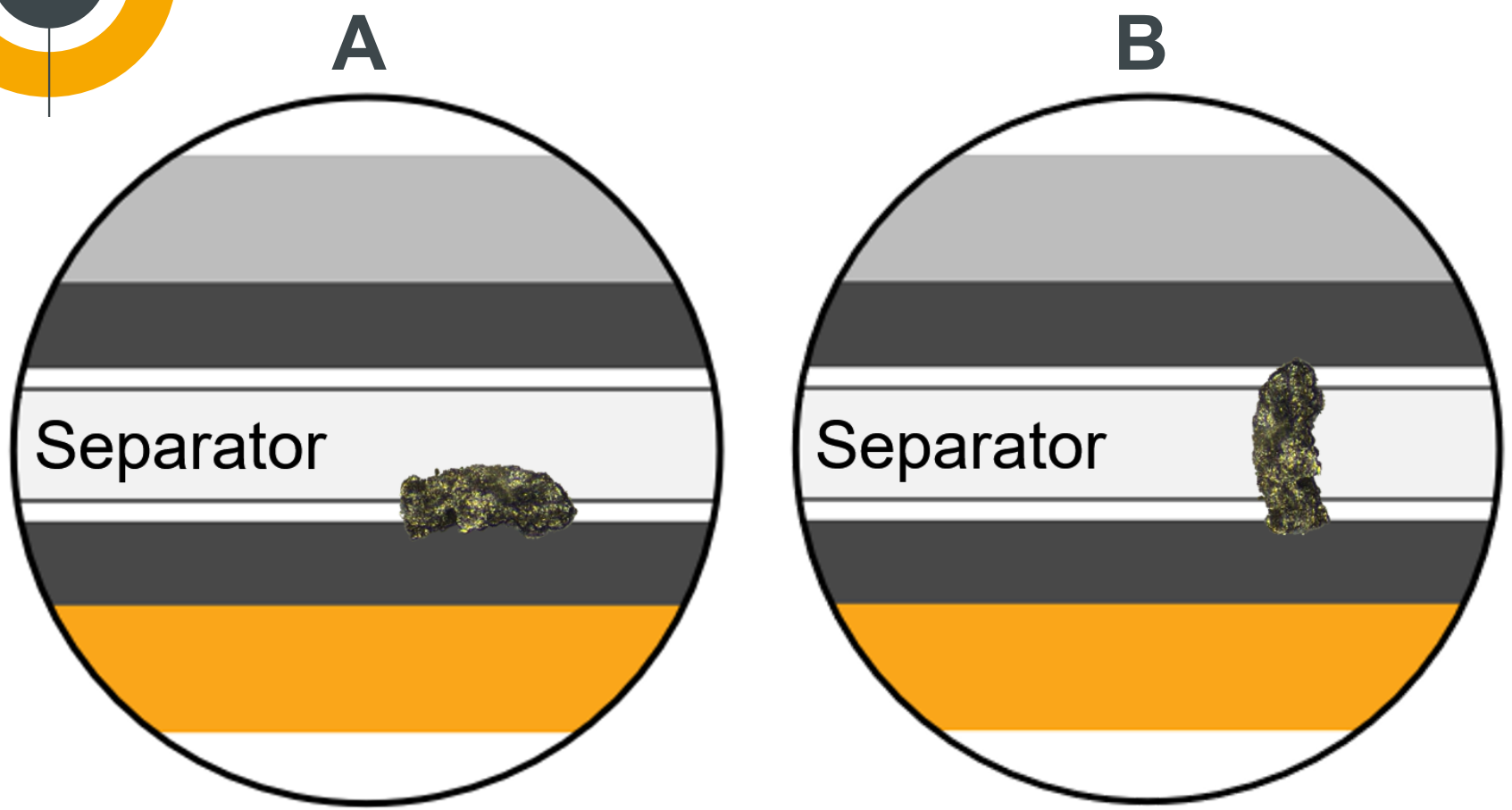
DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Identification of damage mechanisms

Question: How will a sedimenting particle (rather) come to rest on a foil? (SC)

„What could be harmful?“

→ Product-development



DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Identification of damage mechanisms

Answer: It will lay on the surface

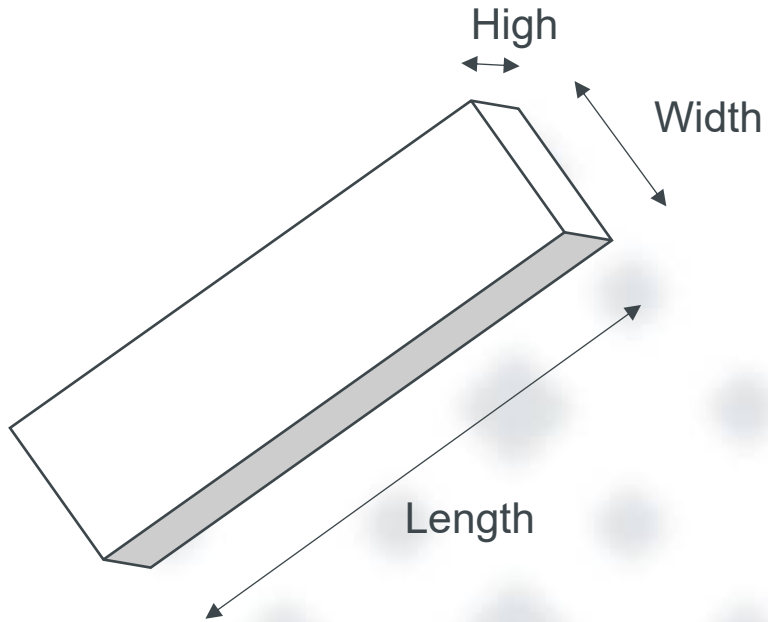


Particle length is therefore not relevant for the damage effect!

Rather the particle height

„What could be harmful?“

→ Product-development

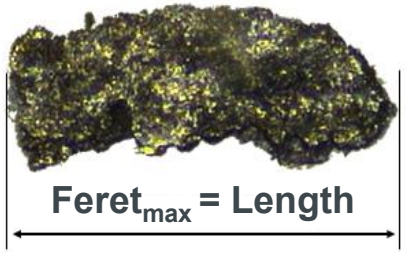


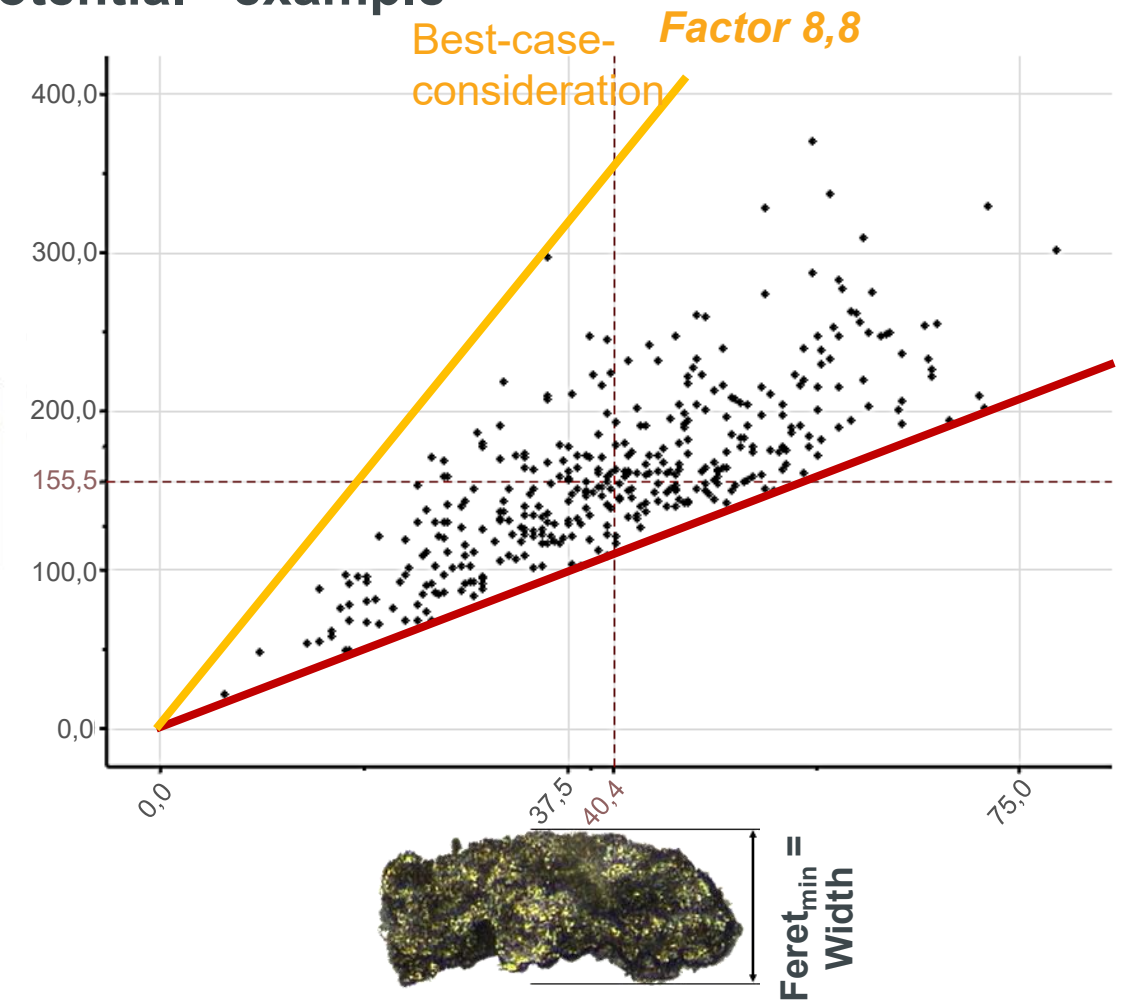
DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Identification of damage mechanisms

Derivation of the damage potential - example

Statistical evaluation of the particle lengths vs. particle widths that can be found on the products.





„What could be harmful?“

→ Product-development

Factor 2,8

Worst-case-consideration

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Identification of damage mechanisms

Derivation of the damage potential - example

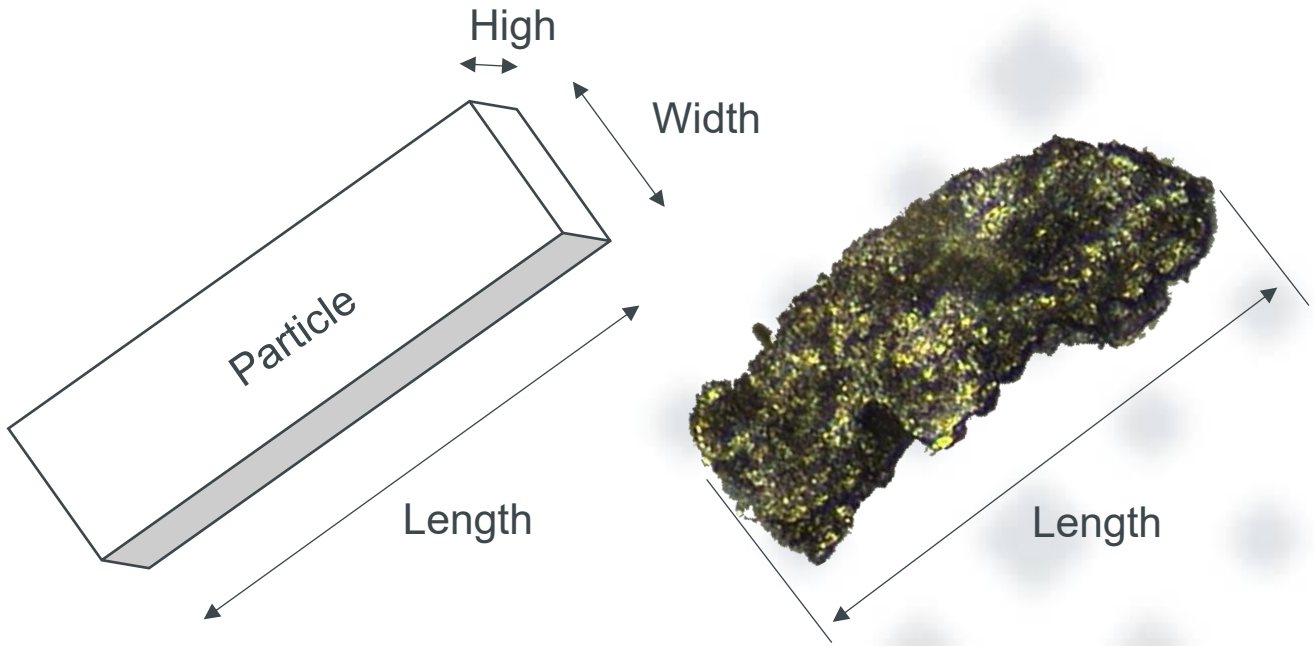
Since there is no sufficient data basis for the height of a particle from the measurement technology, this can be equated (on the basis of empirical experiments) in a worst-case consideration!

„What could be harmful?“

→ Product-development

High = Width ***Length***

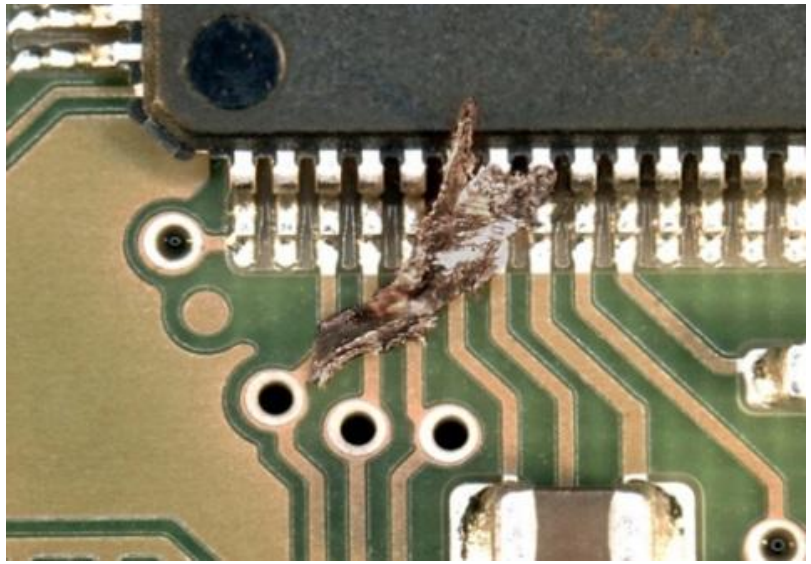
50 µm **Factor 2,8** 140 µm



DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Identification of damage mechanisms

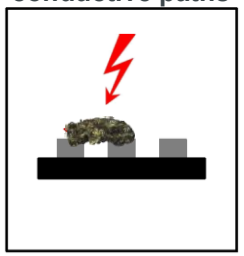
Derivation of the damage potential



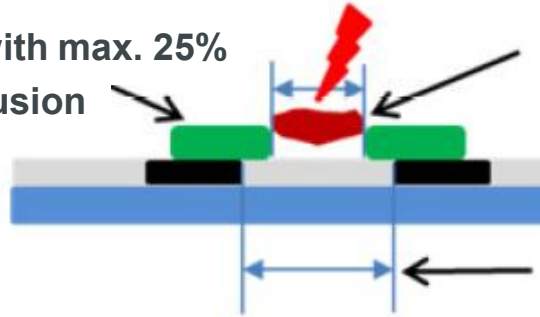
„What could be harmful?“

→ Product-development

Short circuit of conductive paths



- Control electronics



Conductive particles in their largest dimension smaller than half of the smallest electrical distance in the circuits

Open solder contact without solder resist

Printed circuit board with solder resist

Smallest pitch distance of the circuit e.g. 150µm

Source: MBN LV126

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Identification of damage mechanisms

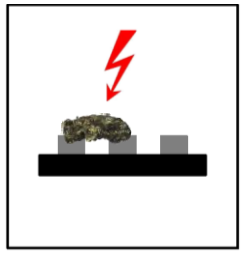
Derivation of the damage potential


Source: DräxImaier

„What could be harmful?“

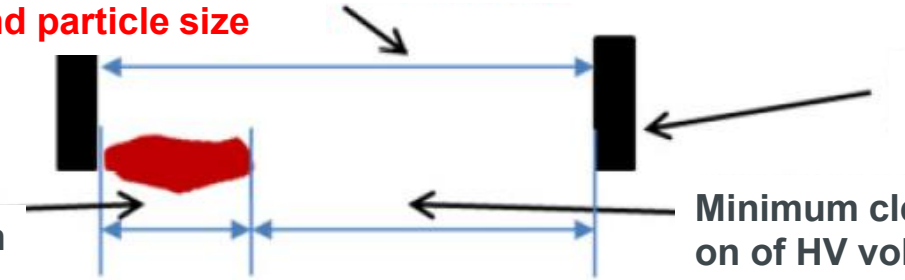
→ Product-development

Shortening of electrical insulation



- Power Electronics
- High-voltage systems

Minimum distance of open HV contacts considering of clearance and creepage distances and particle size



Source: MBN LV126

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

What contamination is effectively harmful?

Take into account experience from functional impairments that have occurred

- Field experience
- Test bench tests
- Endurance tests and gathering tests
- Harmful particle tests

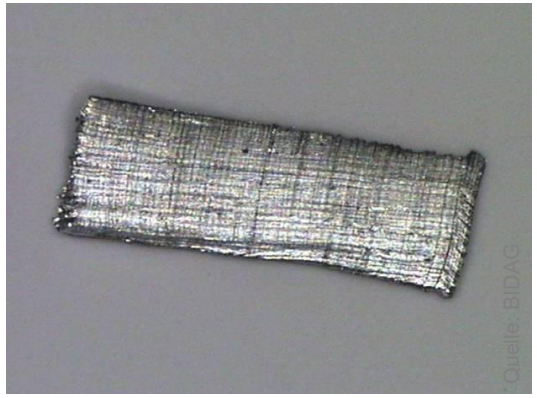
  Apply particles to the system in a targeted manner and investigate the effect under real conditions

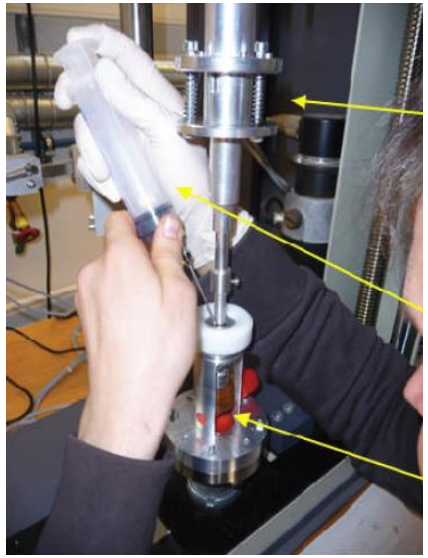
  Test target:

  - Identification particle size / type / number
  - Identification of complete failure / irreversible damage / limitation of life-time

„What contamination is really harmful“

→ Customer, Test





slide oscillation

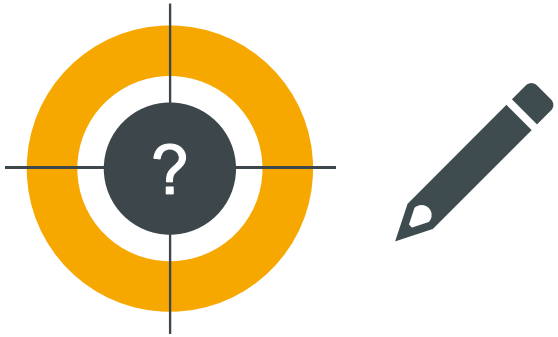
Syringe with reference particles in oil

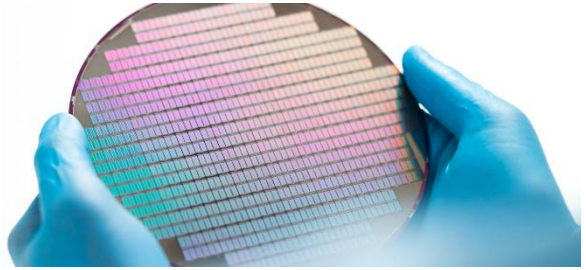
Collecting-tank



DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

What can be achieved internally and externally?





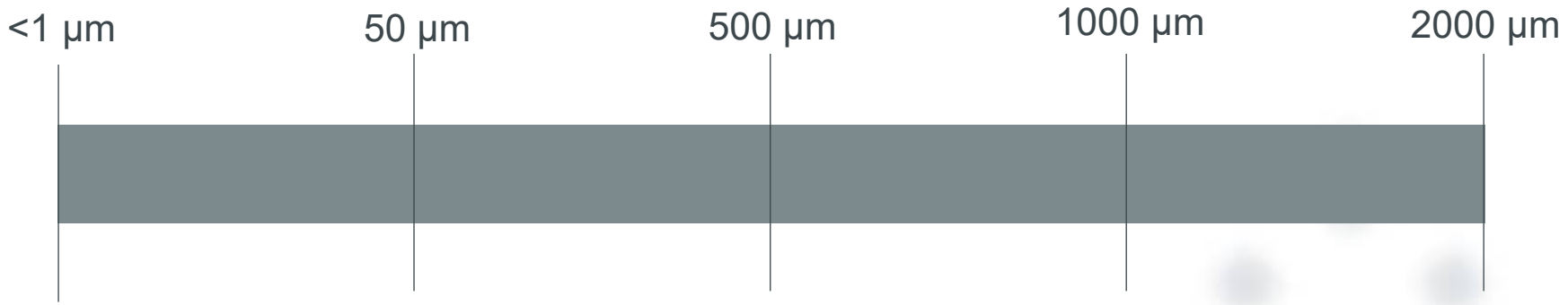
Structured wafers



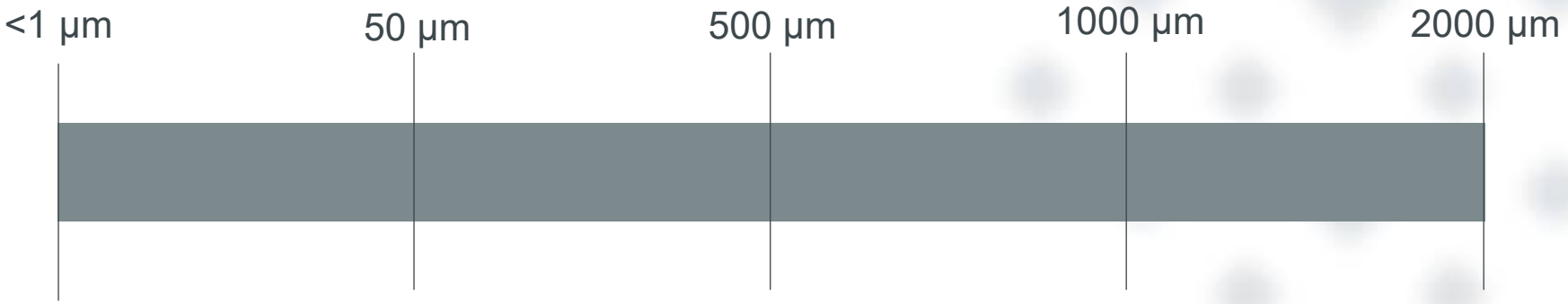
Stamped-bent-components

Question: In which cleanliness qualities can components be produced economically?

No particles larger than



No particles larger than

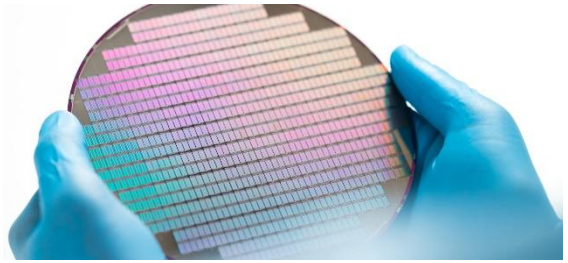


DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

What can be achieved internally and externally?







	Stamped-bent-components	Structured wafers
Processing time	***0,4 s***	***2 hours***
Manufacturing costs	***0,05 Cent***	***200 – 600 €***
Environment	***uncontrolled***	***Cleanroom***
Contamination	***No particles > 600 µm***	***No particles > 1 µm***

„What can be achieved in production?“

→ Suppliers/ Production

„What can be produced economically?“

→ Purchasing

The requirements must be in accordance with the given, economical manufacturing processes!

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Analytical options

According to VDA 19 Part 1 or ISO 16232, following limit value types are possible:

„What is analyzable?“

→ TecSa Laboratory

- Gravimetry limit value

	Soll *rated value*
Gravimetrie / Bauteil *Gravimetric result / Component*	≤ 1 mg

- Gravimetry limit value and specification of largest particles

	Soll *rated value*
Gravimetrie / Bauteil *Gravimetric result / Component*	≤ 1 mg
Größtes metallisch glänzendes Partikel *Largest metallic shining particle*	≤ 400 µm
Größtes nicht glänzendes Partikel [1] *Largest not shining particle* [1]	≤ 1500 µm

- Particle size distribution

I TECHNICAL CLEANLINESS ACC. VDA19/ISO16232-10

CLEANLINESS FOR COMPONENT PART
CCC=N(E200/F100/G50/H25/I1/J-K0)
N=3

VDA 19	
Größe x [µm]	Partikelanzahl
5 < x < 15	
15 < x < 25	
25 < x < 50	700
50 < x < 100	220
100 < x < 150	150
150 < x < 200	
200 < x < 400	10
400 < x < 500	2
500 < x < 1000	0

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Analytical options

According to VDA 19 Part 1 or ISO 16232, following limit value types are possible:

„„What is analyzable?“

→ TecSa Laboratory

- Particle size distribution and particle material

Zul. Partikelanzahl PERMITTED PARTICLE NUMBER						
				Metallische Partikel	nicht metallische Partikel	
PARTIKELLAENGE Definition nach QV11111 - Kap. 3.3.1 PARTICLE LENGTH definition acc. to. QV11111 - chap. 3.3.1				HARTE PARTIKEL keine Härteklasse nach QV11111 - Kap. 3.4 HARD PARTICLES no hardness class H1 and H2 acc. QS11111 - chap. 3.4	WEICHE PARTIKEL ohne Haerteklasse nach QV11111 - Kap. 3.4 SMOOTH PARTICLES w/o hardness class acc. to QS11111 - chap. 3.4	FASERN Def. nach QV11111 - Kap. 3.2 FIBRES def. acc. to QS11111 - chap. 3.2
				Zul. Partikelanzahl PERMITTED NO.	Zul. Partikelanzahl PERMITTED NO.	Zul. Partikelanzahl PERMITTED NO.
E	50	-	100	k.E.	k.E.	
F	100	-	150	k.E.	k.E.	
G	150	-	200	k.E.	100	
H	200	-	400	10	50	
I	400	-	600	0	10	
J	600	-	1000	0	0	
	>1000			0	0	
Zul. Partikelgesamtmasse [mg]: 2 *Permitted particle weight [mg]: t.b.d.*						

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Limit types, effort and level of detail

„What is analyzable?“

→ TecSa Laboratory

Analytical effort

	Soll *rated value*
Gravimetrie / Bauteil *Gravimetric result / Component*	≤ 1 mg

Gravimetry

Level of detail / informative value

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

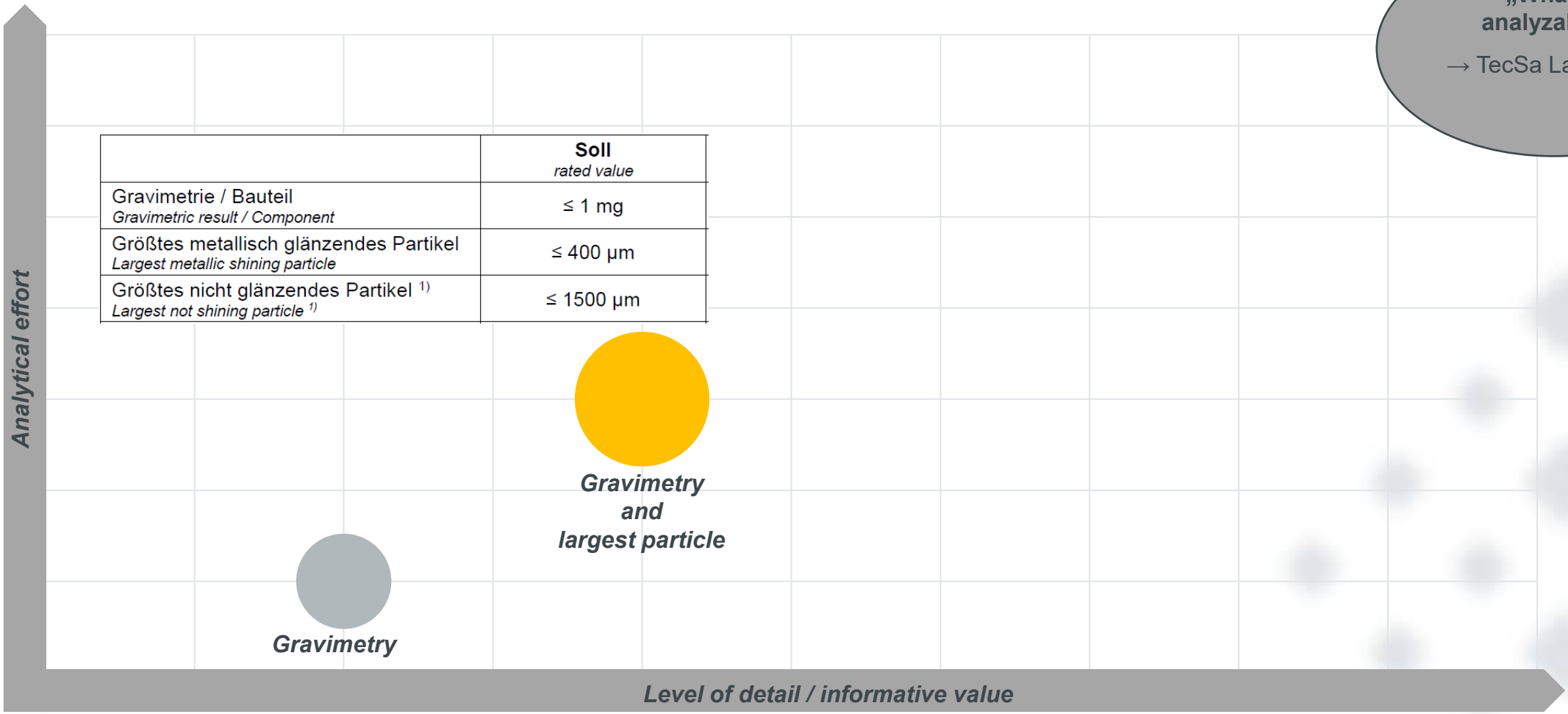
Limit types, effort and level of detail

CleanControlling®

„What is analyzable?“

→ TecSa Laboratory

	Soll *rated value*
Gravimetrie / Bauteil *Gravimetric result / Component*	≤ 1 mg
Größtes metallisch glänzendes Partikel *Largest metallic shining particle*	≤ 400 µm
Größtes nicht glänzendes Partikel [1] *Largest not shining particle* [1]	≤ 1500 µm



DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Limit types, effort and level of detail

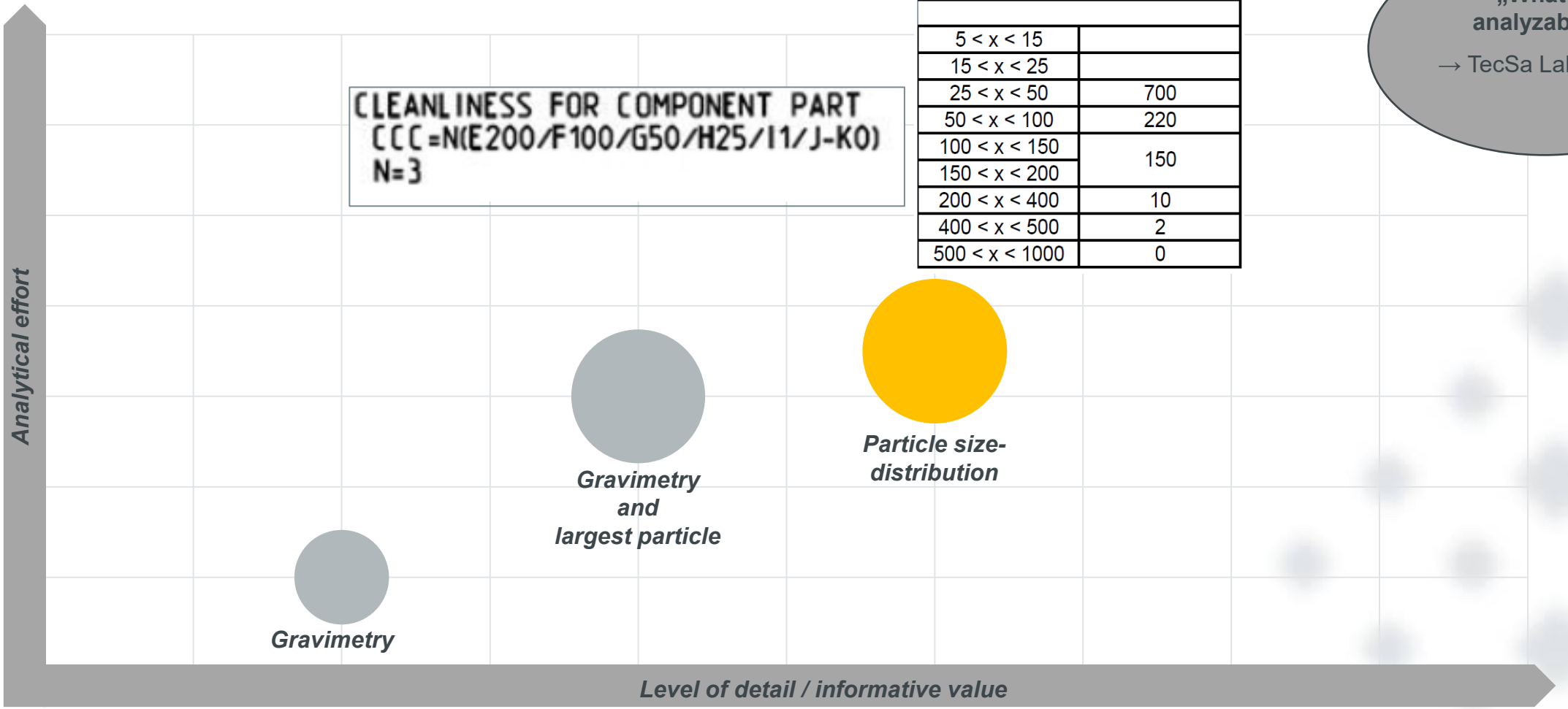
CleanControlling®

CLEANLINESS FOR COMPONENT PART
CCC=N(E200/F100/G50/H25/I1/J-K0)
N=3

VDA 19	
Größe x [µm]	Partikelanzahl
5 < x < 15	
15 < x < 25	
25 < x < 50	700
50 < x < 100	220
100 < x < 150	150
150 < x < 200	
200 < x < 400	10
400 < x < 500	2
500 < x < 1000	0

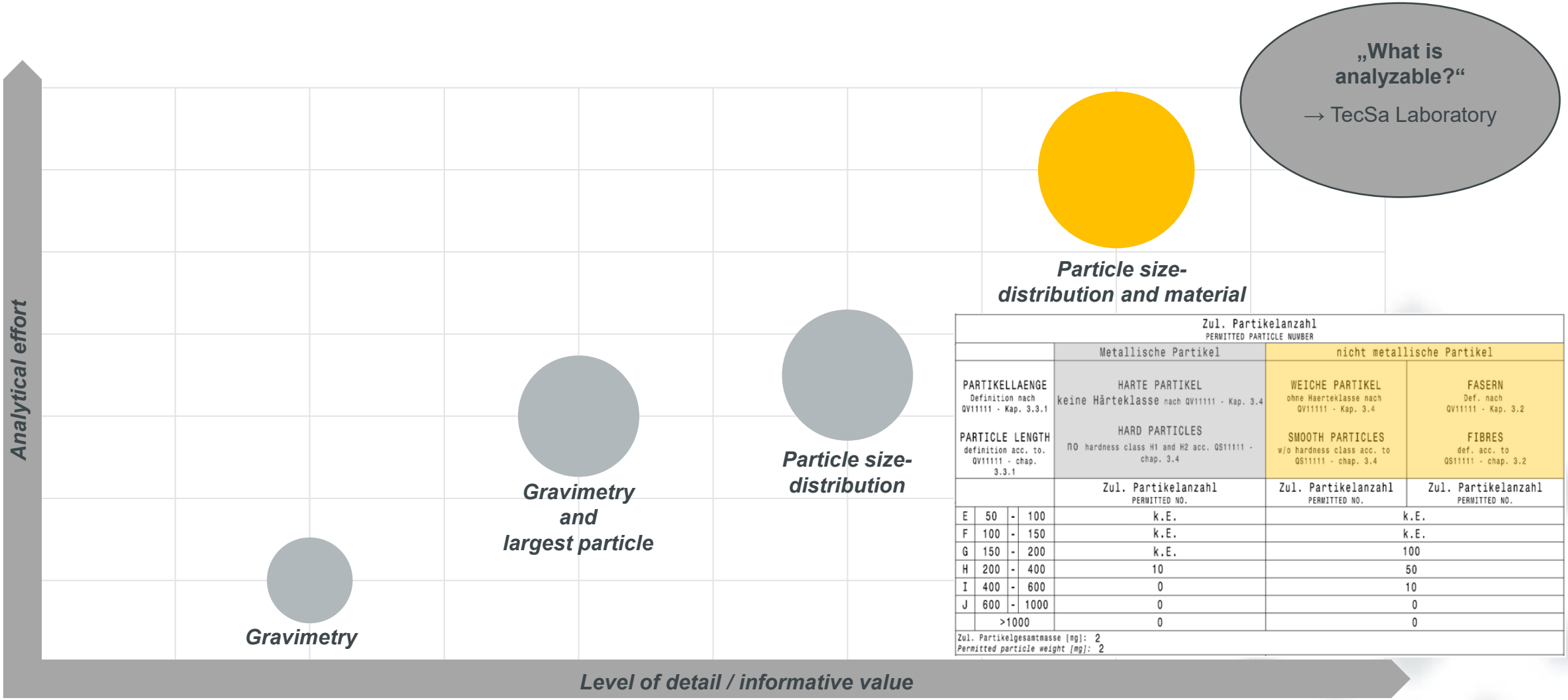
„What is analyzable?“

→ TecSa Laboratory



DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Limit types, effort and level of detail



Zul. Partikelanzahl
PERMITTED PARTICLE NUMBER

				Metallische Partikel	nicht metallische Partikel	
PARTIKELLAENGE Definition nach QV11111 - Kap. 3.3.1 PARTICLE LENGTH definition acc. to. QV11111 - chap. 3.3.1				HARTE PARTIKEL keine Härteklasse nach QV11111 - Kap. 3.4 HARD PARTICLES no hardness class H1 and H2 acc. QS11111 - chap. 3.4	WEICHE PARTIKEL ohne Haerteklasse nach QV11111 - Kap. 3.4 SMOOTH PARTICLES w/o hardness class acc. to QS11111 - chap. 3.4	FASERN Def. nach QV11111 - Kap. 3.2 FIBRES def. acc. to QS11111 - chap. 3.2
				Zul. Partikelanzahl PERMITTED NO.	Zul. Partikelanzahl PERMITTED NO.	Zul. Partikelanzahl PERMITTED NO.
E	50	-	100	k.E.	k.E.	
F	100	-	150	k.E.	k.E.	
G	150	-	200	k.E.	100	
H	200	-	400	10	50	
I	400	-	600	0	10	
J	600	-	1000	0	0	
	>1000			0	0	

Zul. Partikelgesamtmasse [mg]: 2
Permitted particle weight [mg]: 2

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

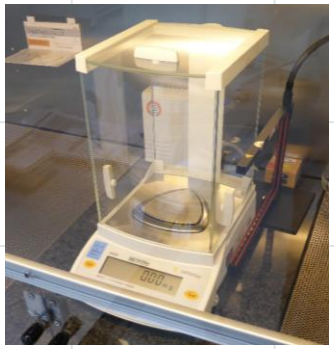
Limit types, effort and level of detail

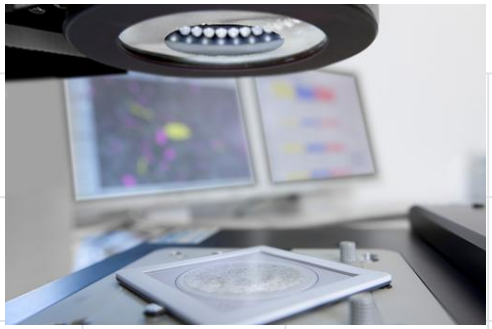
CleanControlling®

„What is analyzable?“

→ TecSa Laboratory







Particle size-distribution and material

Gravimetry and largest particle

Particle size-distribution

Gravimetry

Analytical effort

Level of detail / informative value

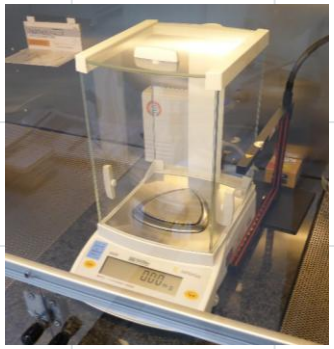
DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

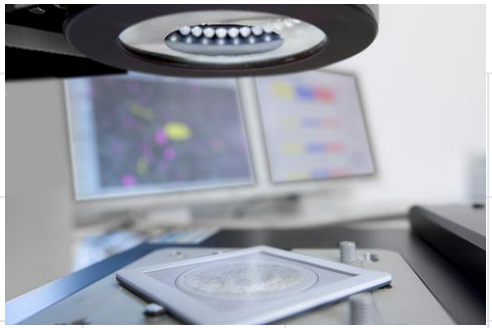
Limit types, effort and level of detail

„What is analyzable?“

→ TecSa Laboratory







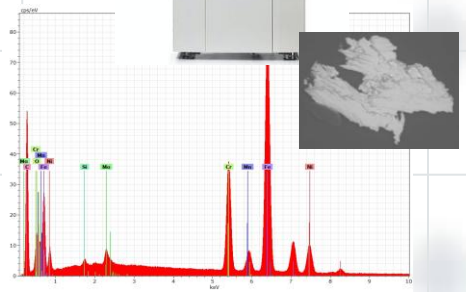
Gravimetry

Gravimetry and largest particle

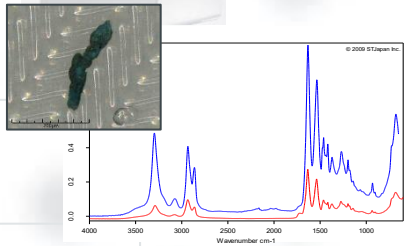
Particle size-distribution

Particle size-distribution and material









Analytical effort

Level of detail / informative value

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

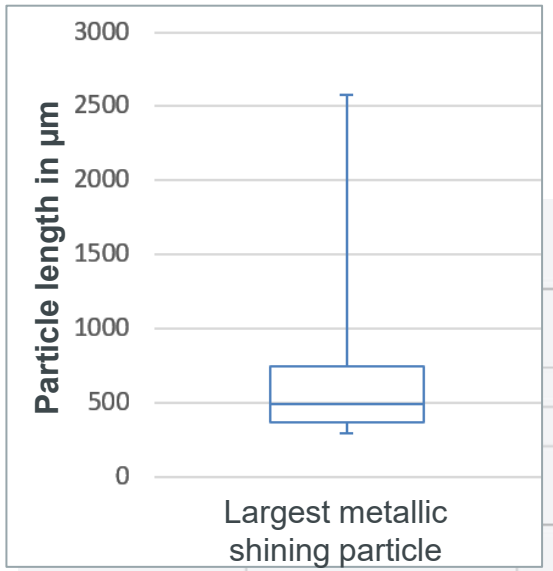
Content

- Why cleanliness requirements?
- The form follows the function!
- Outlier handling?

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Technical cleanliness vs. process capability

Cleanliness results often show large variations!

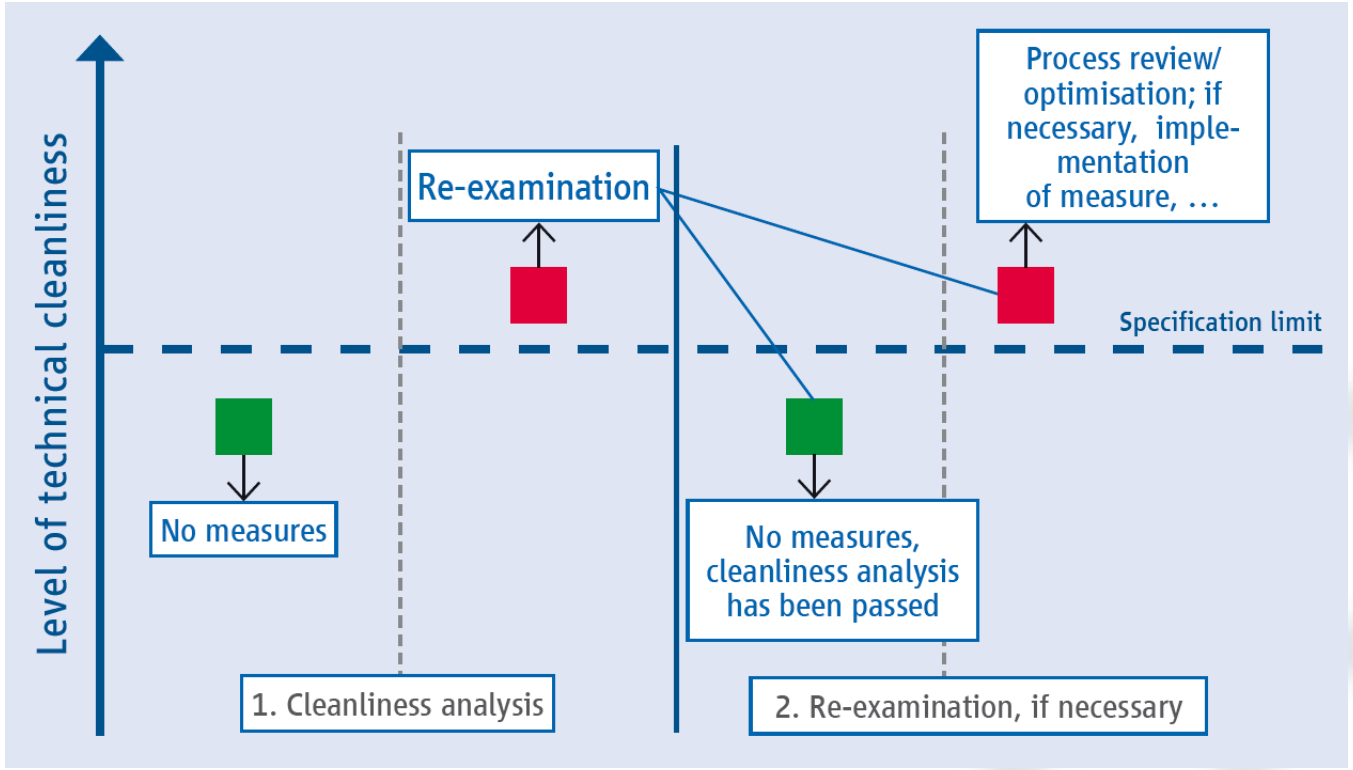




DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Outlier-rule and escalation strategy

- Since - due to the high variance - there are always outliers from the limit value in the area of technical cleanliness, an escalation strategy is recommended in case of deviations
- Examples of outlier rules:
  - Repeat measurement on components of the same batch
  - Statistical approaches
  - In case of repeated deviations, initiation of root cause analyses and implementation of optimization projects

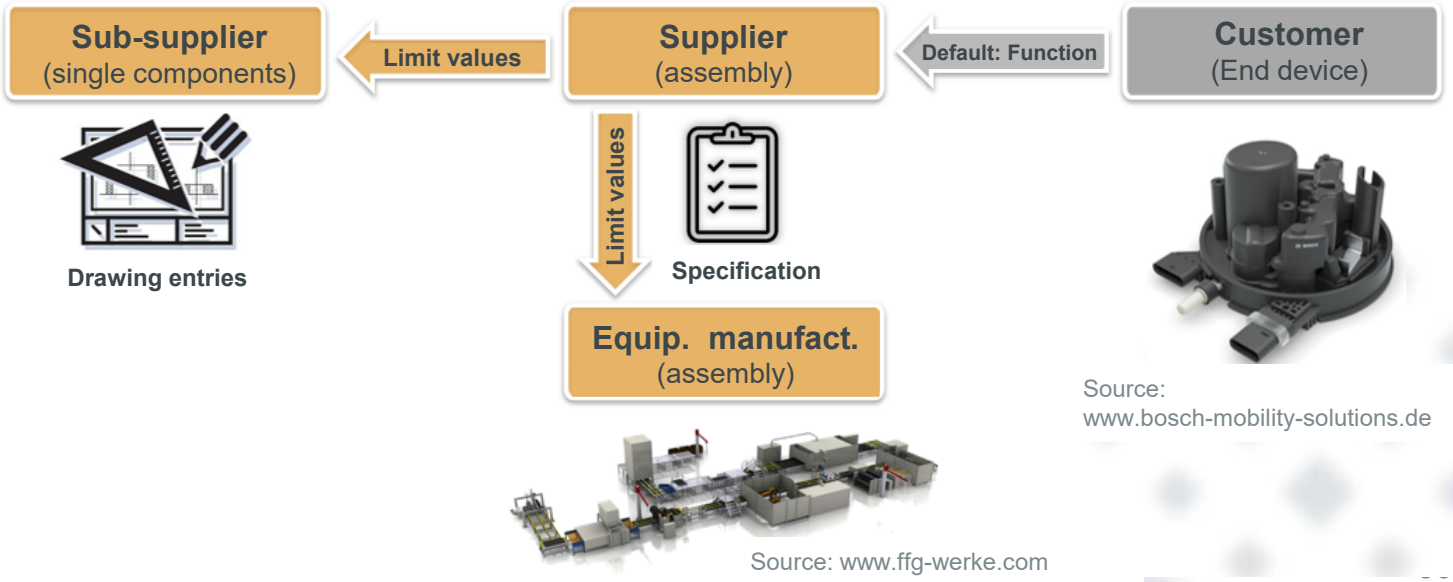


Source: ZVEI

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Basic recommendations for the definition of limit values

- Limit setting based on the procedure:
  „***as clean as necessary***“ and not „***as clean as possible***“
- The possibilities of production and analytics should be considered as well!
- A verification of the process capability for characteristics of the TecSa via a process capability code cpk can basically not be carried out!
- Important: Creation of an escalation strategy in case of deviations from the limit value!



DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Basic recommendations for the definition of limit values

PROJEKT

Bauteilreinigung und technische Sauberkeit – Teil 1: Verfahren für die Herleitung und Erstellung einer Sauberkeitsspezifikation

Kurzreferat

Dieses Dokument legt ein Verfahren zur Herleitung und Erstellung einer Sauberkeitsspezifikation für Bauteile entlang der Prozesskette. Dieses Dokument wurde für metallische Bauteile entwickelt; das beschriebene Verfahren ist jedoch auch auf Bauteile anderer Werkstoffe und Baugruppen anwendbar. Dieses Dokument richtet sich insbesondere an Planer, Qualitätsverantwortliche und Produktionsverantwortliche in industriellen Produktionsprozessen metallischer Bauteile. Dieses Dokument erläutert die Herleitung von Grenzwerten, legt jedoch keine Grenzwerte für einzelne Verunreinigungen oder Verunreinigungsklassen innerhalb oder am Ende der Prozesskette fest.

Beginn

2025-02-03

Geplante Dokumentnummer

DIN 4878-1

Projektnummer

06236603

Zuständiges nationales Arbeitsgremium

NA 062-01-81 AA - Bauteilreinigung und Sauberkeit von metallischen Komponenten im Herstellungsprozess >

IHR KONTAKT

Steffen Jenkel

Am DIN-Platz, Burggrafenstr. 6
10787 Berlin

Zum Kontaktformular >

DEFINITION AND HANDLING OF/WITH CLEANLINESS LIMITS

Basic recommendations for the definition of limit values



Particle count per size class

Critical area per size class

Total internal surface area

Mounting orientation

Weighting factors



QUESTIONS

CleanControlling®



Do you have any questions!

Chat



E-Mail

seminar@cleancontrolling.de

Thank you for your attention



TECHNISCHE SAUBERKEIT

CleanControlling®

Leander Gihr
Consulting

CleanControlling GmbH
Gehrenstr. 11a
D-78576 Emmingen-Liptingen

Phone +49 74 65 / 92 96 78-21
Fax +49 74 65 / 92 96 78-10

l.gihr@cleancontrolling.de
www.cleancontrolling.de