Industrial Enamel

Foundations, production, applications and CERN-tests

Düker

ECL2 Workshop
CERN Geneva

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Eisenwerke Fried. Wilh. Düker GmbH & Co. KGaA
Laufach

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Industrial Enamel

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- Classification of Industrial Enamel:
  „... enamelling used in processes in which physical and chemical stress are in a main consideration..."
- Basic features of industrial enamel
- Enamel optimized design and different illustrative examples based on industrial enamelling
- Applications aside from the general known ones in plant construction of chemical industry, examples
- ELC2 – first steps, open questions

Enamel

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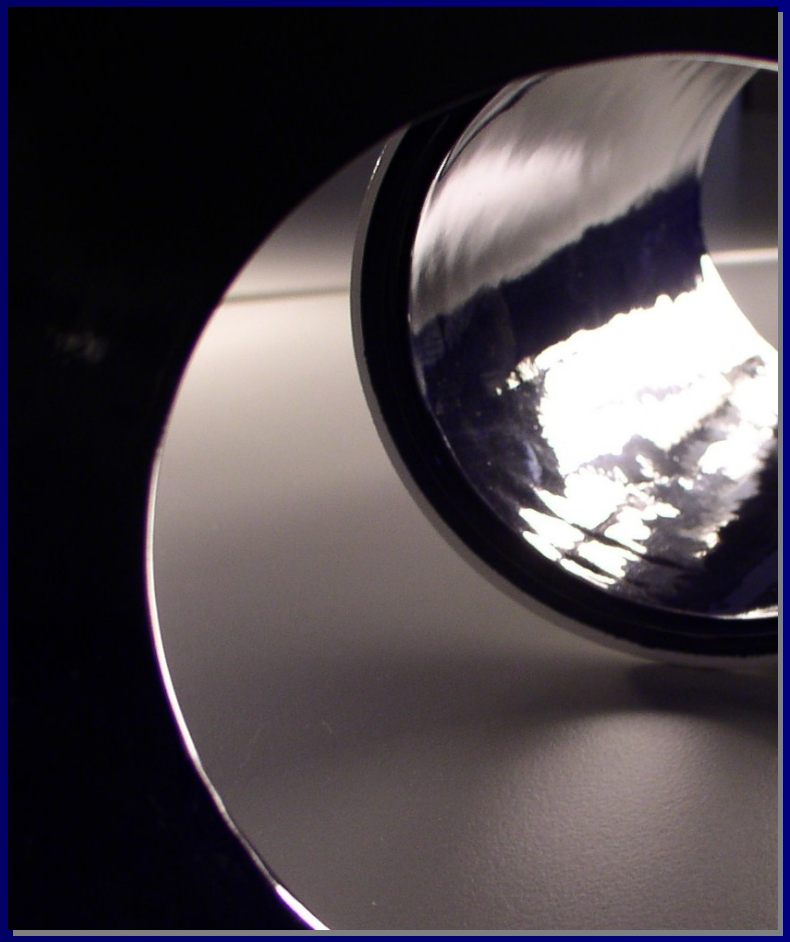

- Vitreous material, generated in melting process, contents a number of anorganic and oxidic-silicatic fractions
- Melting on metal- or glassubstrate, chemical and micromechanical connection between the layer and metall surface
- Universal dissolver for anorganic, metallic oxides
- Countless possibilities of variaty
- Generally free from any organic material

Appearance properties

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- Color permanence
  - Stable in presence of rain, snow, dust, heat, sunlight, oxidizing agents and corrosive fumes
  - Unaffected by ultraviolet and infrared radiation
- Gloss
  - Specular reflectance in a span of 50 up to 60 °
  - Extremely in a range of 10 to 85 °
- Light reflectance
  - White enamels have a reflectance of ca. 75% to 80%

Electrical properties

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- Dielectric strenght
  - Range from 200 to 500 V/mil (total thickness 4 – 6 mils)
  - 16 – 20 kV/mm (Biscardi et al., J. Vac. Sci. Tech. A, 2000)
  - Increasing with dense, decreasing with bubble structure
- Dielectric constant
  - 6 to 12, sharp increase in the temperature range 120 to 150 °C
- Volume resistivity (at 400 cycl/s)
  - 10^{13} to 10^{16} Ω/cm at rt
  - function of temperature
- Dissipation factor (at 400 cycl/s)
  - 1 to 2 %, increase above 93 °C
  - Decrease with increases frequency

High temperature properites

- Resistance to oxidation and corrosion
  - Barrier to diffusion of oxygen
  - Protective ability depends on temperature at which it starts to soften (ca. 200 °C below firing temp.)
- Thermal stability
  - Firing-temp. steel enamelling: 750 – 950 °C, thermal stability ranges 450 – 650 °C
- Thermal shock resistance
  - Typical steel enamelling over 200 °C

Typical frit steel – cast iron

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	Cast iron	Steel
SiO_2	30 – 40%	65 – 70%
B_2O_3	12 – 20%	3 – 5%
Alkali-Oxides	12 – 20%	20%
Oxides earth alkali	2 – 6%	3 – 5%
Al_2O_3	3 – 5%	4 – 5%
Ti-, ZnO	15 – 30%	5 – 15%

General properties

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- High resistance against corrosion attack, more especially in the case of acid media even at higher process temperatures
- Stable to diffusion
- Biological and catalytic inert behaviour
- Smooth, glazed surface
- Qualified for vacuum application (out-gassing rate $\approx 10^{-12}$ mbar 1/s cm^2)
- High mechanical stiffness
- Flame resistant
- Physiological harmless
- Dure, pressure and abrasion stable

Werkstoffklassen

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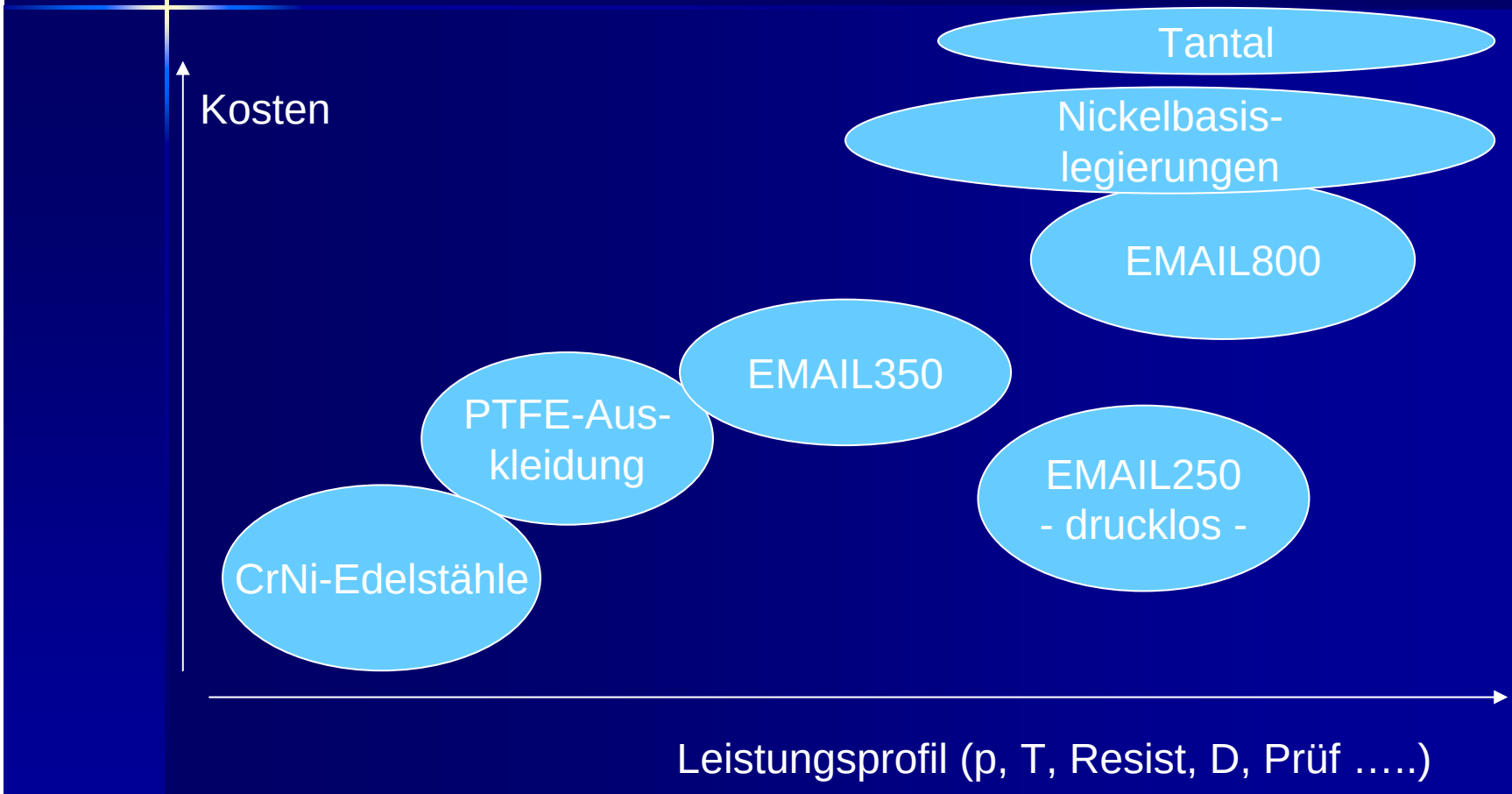

Darstellung nicht maßstäblich

Surface preparation

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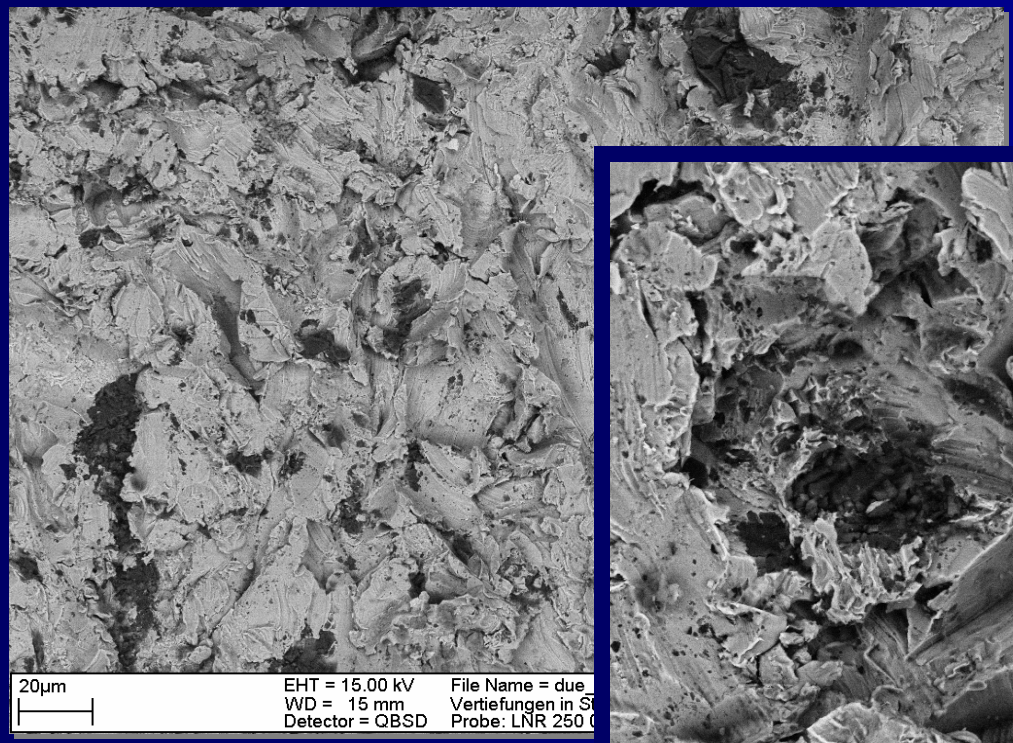

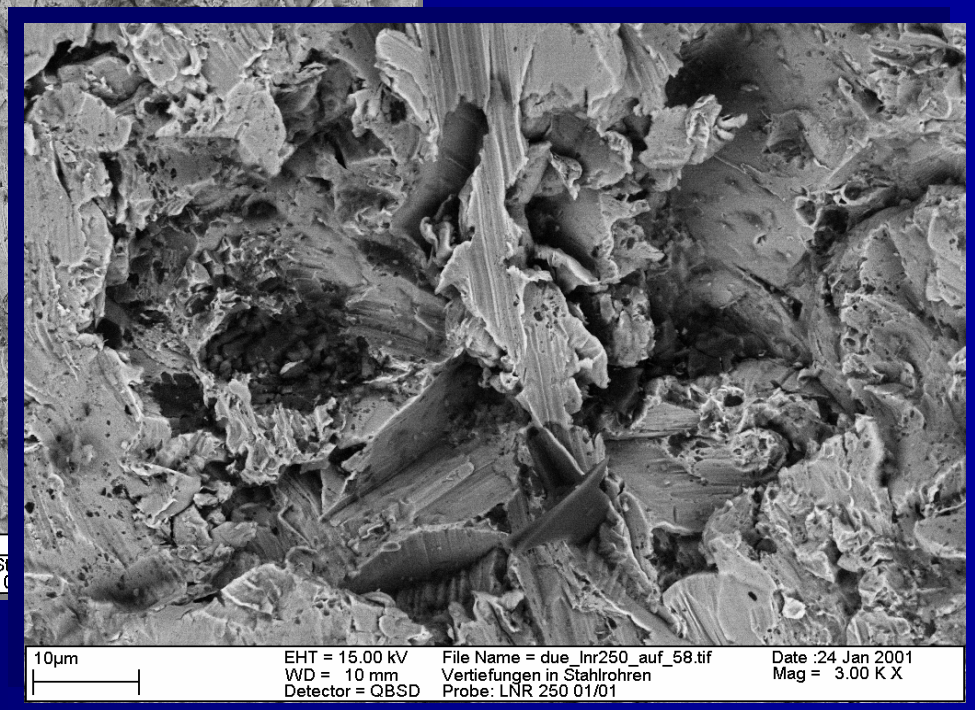

Manufacturing

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- Dipping, pouring, spraying
- Drying (100 °C)
- Firing (850 °C)

Surface mechanism

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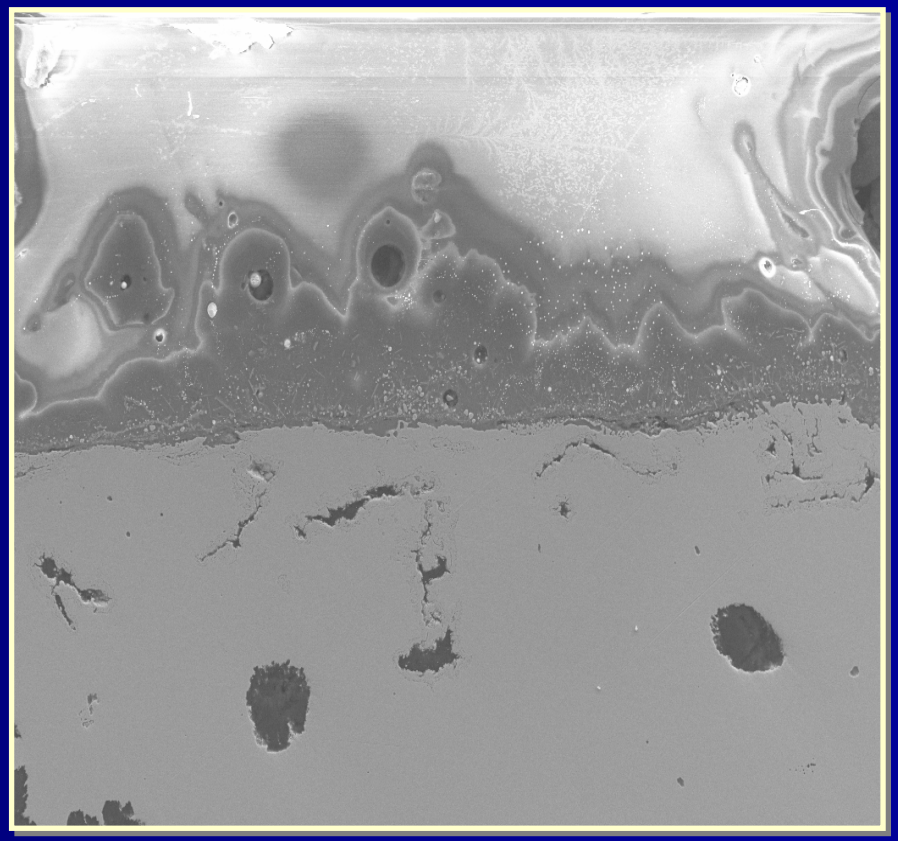
- Solubilize of oxides located close to the prepared surface
- Diffusion process from the basis material towards the enamel region
- Increasing roughness causes enlargement of the specific surface
- Creation of conncetion points and undercuts (dove tails)
- Intermolecular bonding based on Valenz- and Van-der-Waals bonding
- Metallic bonding in the iron-silicium-oxygen system



Composite material

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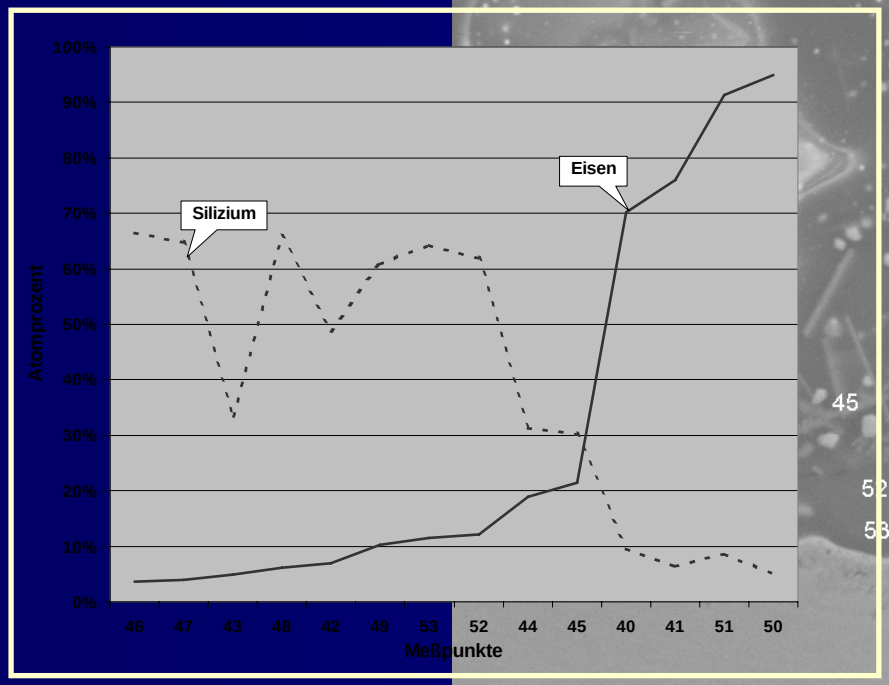
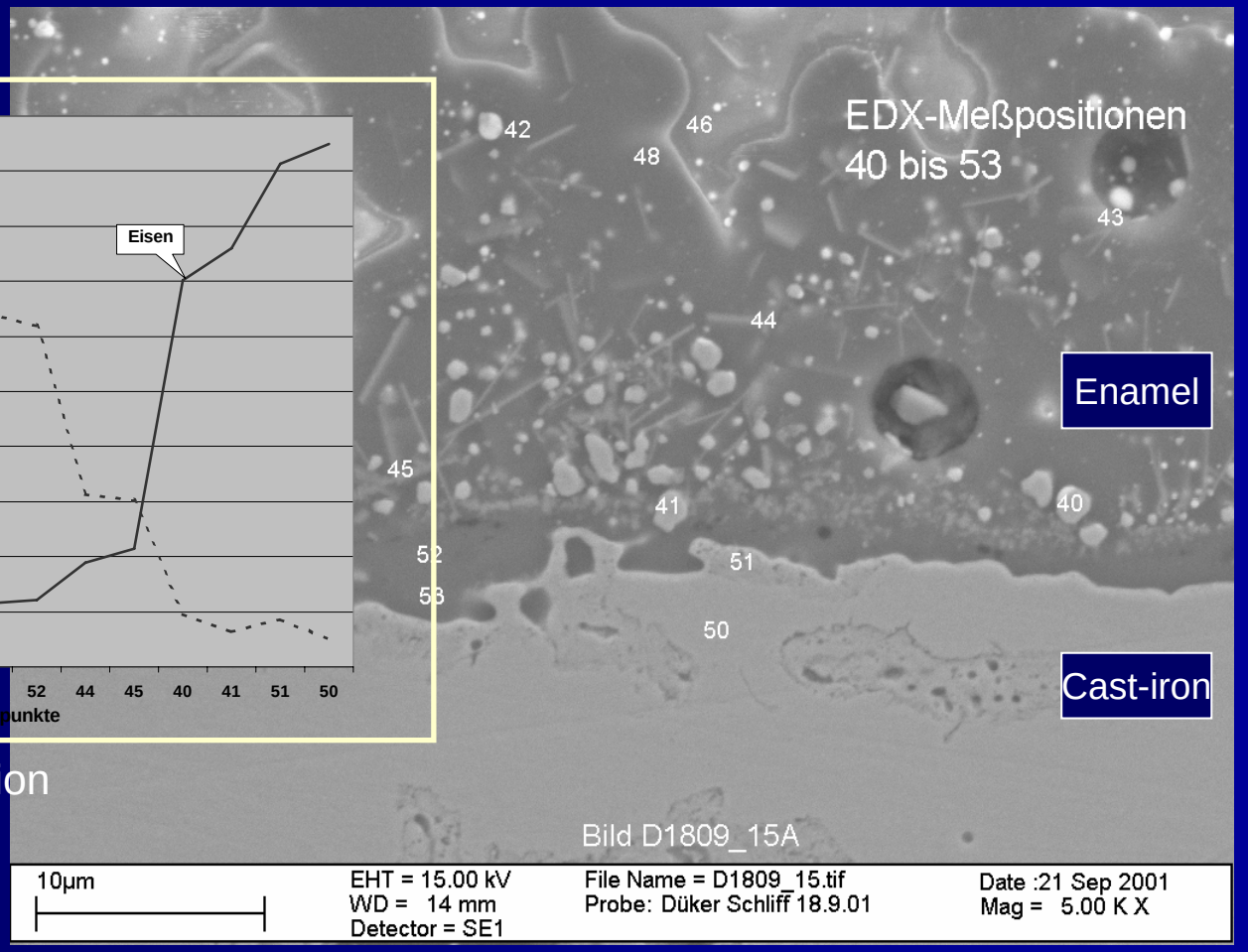


EDX-analysis, allocation measuring points



Tensile and bending stress

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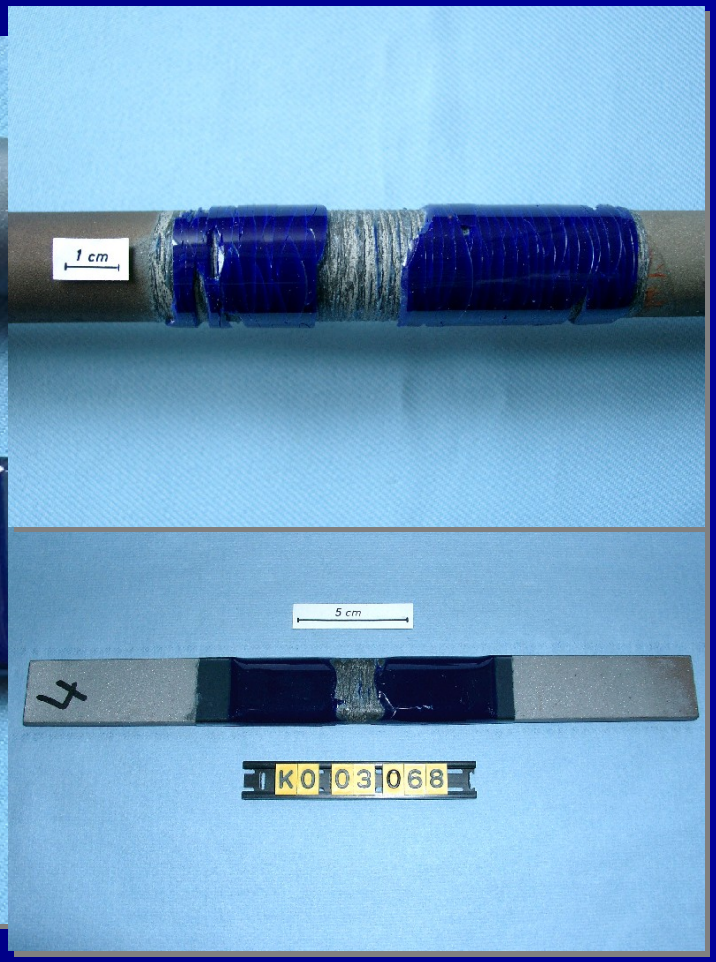

Mechanical behaviour

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Infraserv Höchst Technik
Werkstofftechnik

Prüfbericht Nr. ME 03 068 vom 02.04.2004

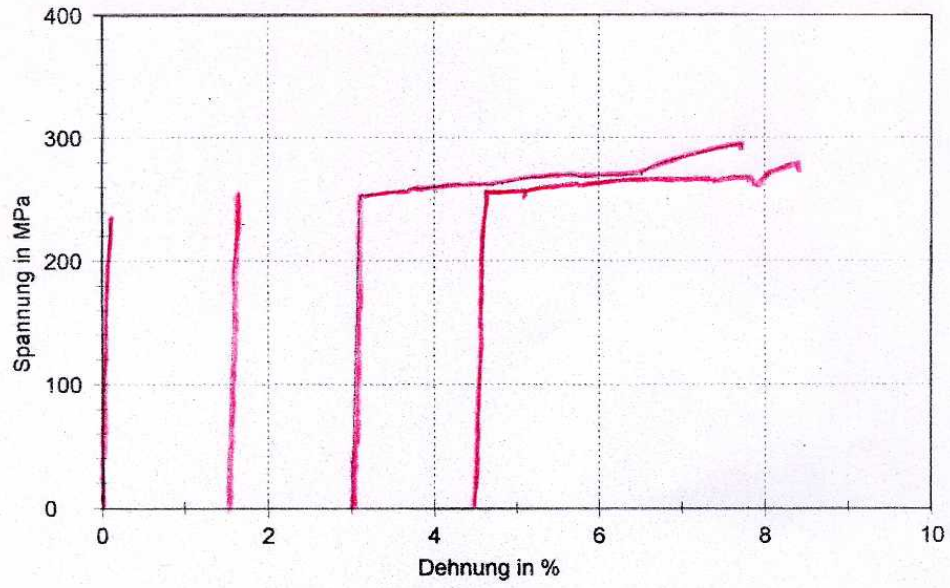

Abb. 17:

Spannungs – Dehnungsdiagramme,
aufgenommen an außen emaillierten Rohrstücken bei RT.

Mechanical behaviour

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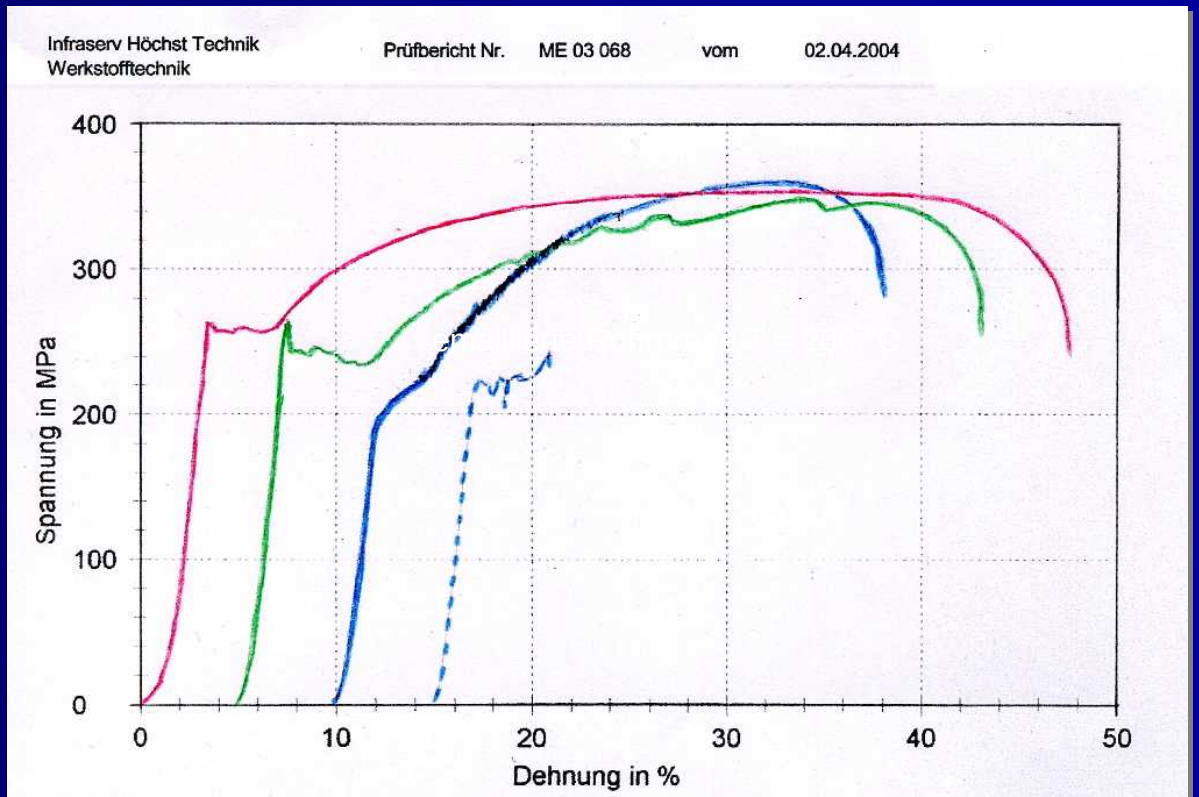

Abb. 18:
Spannungs – Dehnungsdiagramme,
gemessen an Rohrstücken ohne Emailschicht bei 20° C (rot), 100° C (grün) und 200° C (dunkelblau) sowie an einem außen emaillierten Rohrstück bei 200° C (hellblau).

Bending stress

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Three point bending of a flange connection DN 50

- Failure mode local plasticity of the flange in the area of maximum tensile and pressure stress
- Failure also in the area of load transmission by local plastic strain

Fields of application

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- Chemical industry, plant construction
- Pharmaceutical and food industry
- Energy- and environmental engineering
- Specific technical solutions (soldertechnology, general engineering, …)
- Distribution of potable water and gas supply
- Boiler construction

- Agriculture, container construction for liquid manure storage
- Sanitary
- White goods, refrigerators, dish washer
- Building fronts, facades, marker, panels

Different tubesystems

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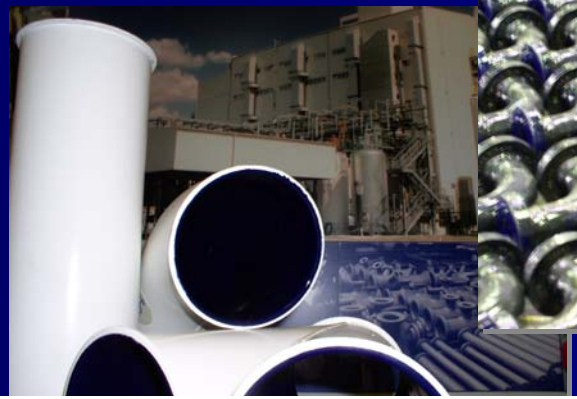

Chemical industry

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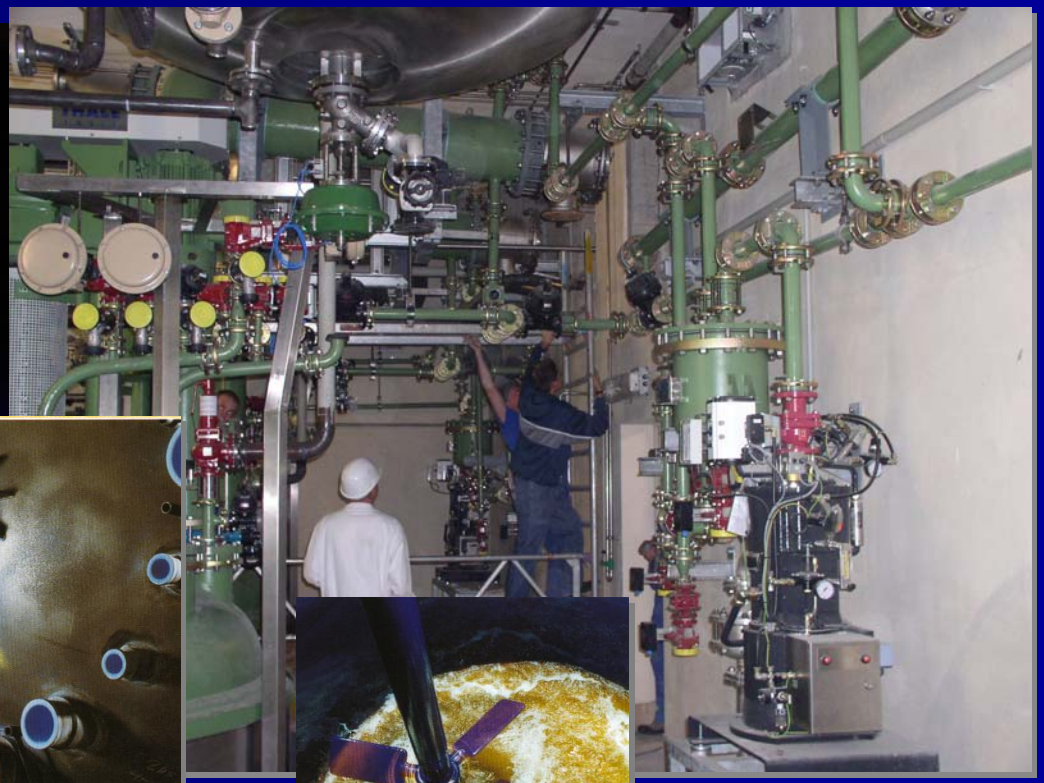

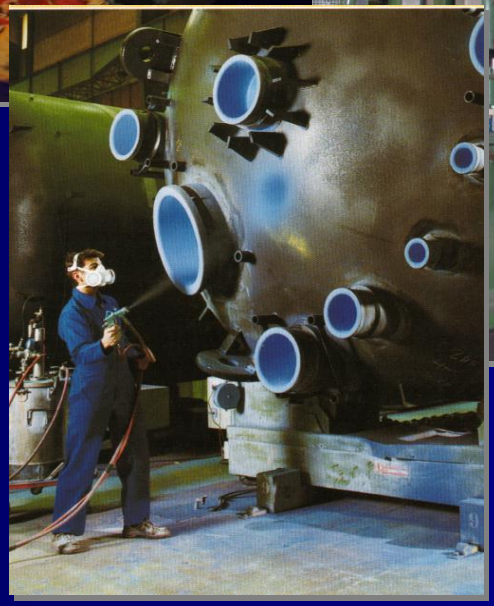

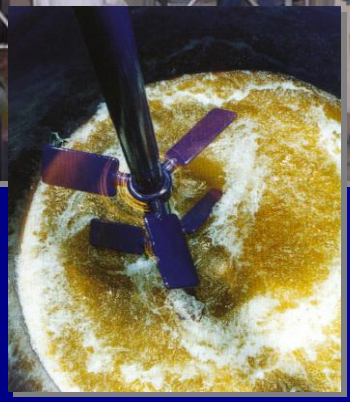

Plant engineering

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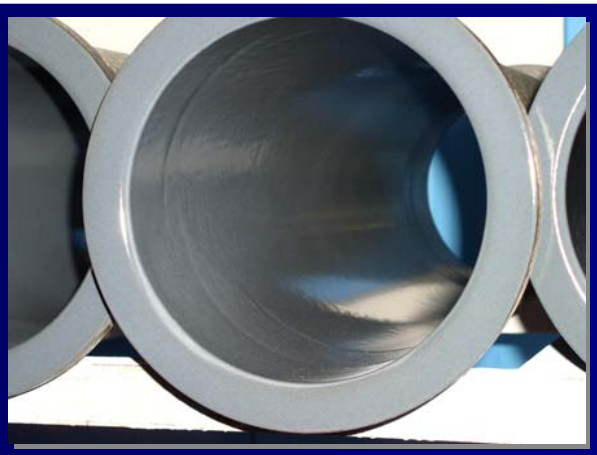
	Email800	Email350
Max. working temperature	250 °C	170 °C
Enamel coat thickness	800 µm up to 2 mm	600 µm up to 1 mm
Corrosion rate, DIN 2743	40 µm/a	80 µm/a



Exhaust air, sewage watersystems

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- Tubes, 2 or 3 mm wallthickness
- Pressure-tight up to 3 bar
- Enamel coat thickness of about 0,5 mm
- Acid-proof
- Free of pores, checked 5KV
- Applicable up to 230°C, unpressurized

Exhaust air, sewage watersystems

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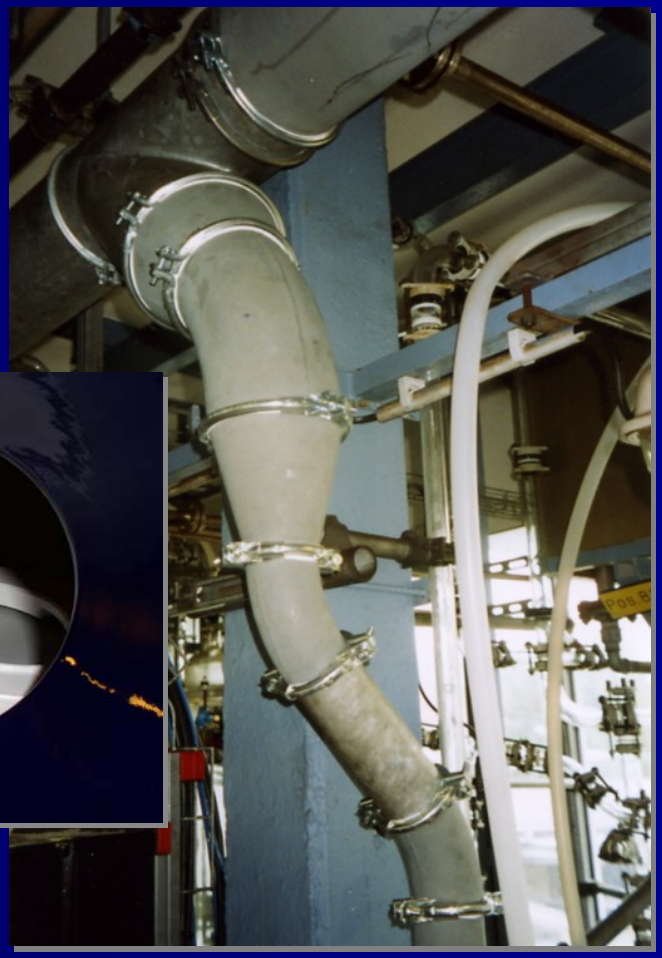

- Modular construction system
- Adapted enamel specific gasket based on PTFE
- Different flange moduli

Bottom outlet valve

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Enamel-adapted design

- Gasket (interface container)
- Bellows (interface handling)

Valve seat

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- Compensation of enamel-typical tolerances at the container outlet (cylindrical, DN 80, 100, 150) by a separated gasket element connected with variable O-ring diameter

- Radial spread of the outer sealing caused by the assembling of the conical sealing body

Assembling steps

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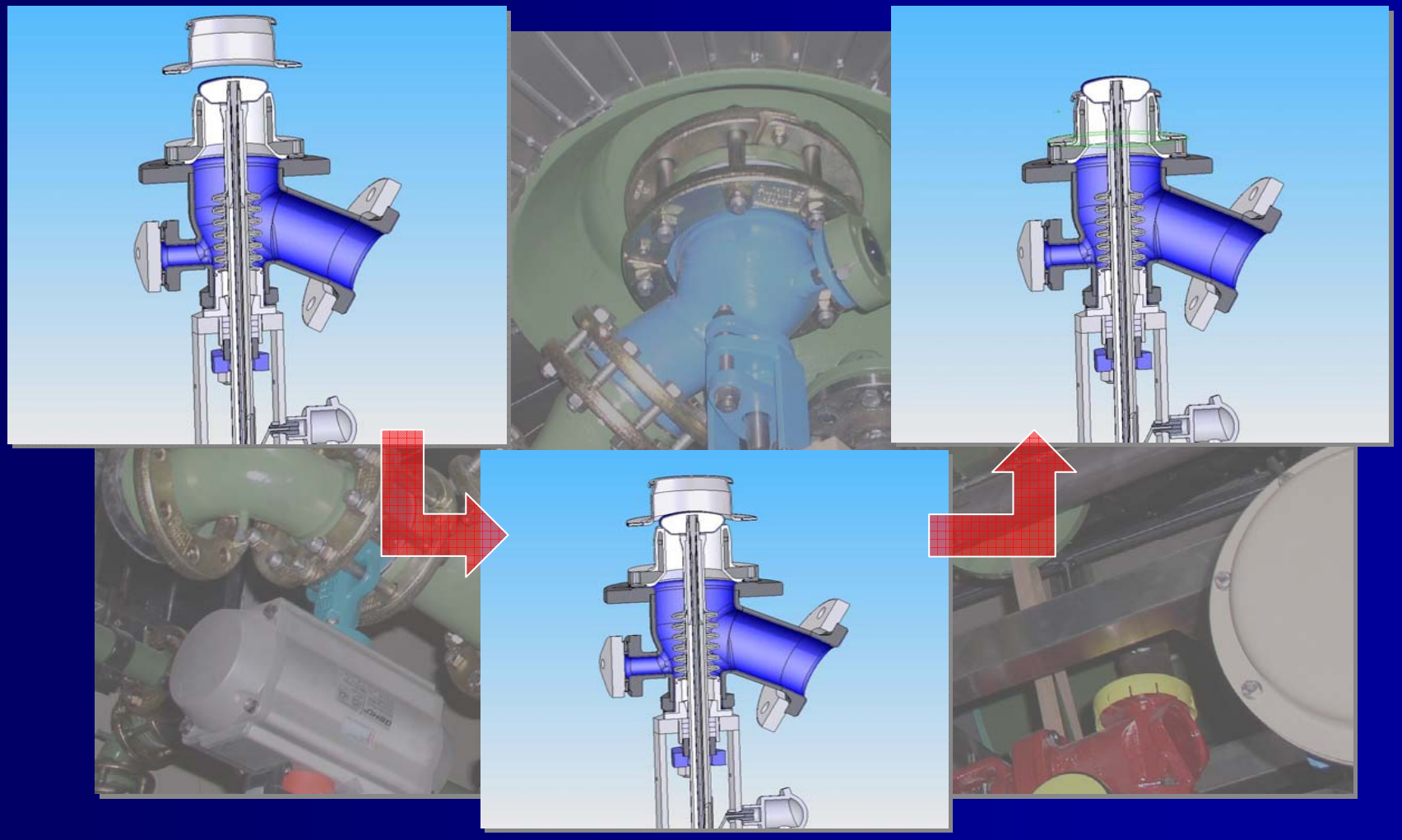

Bellow design

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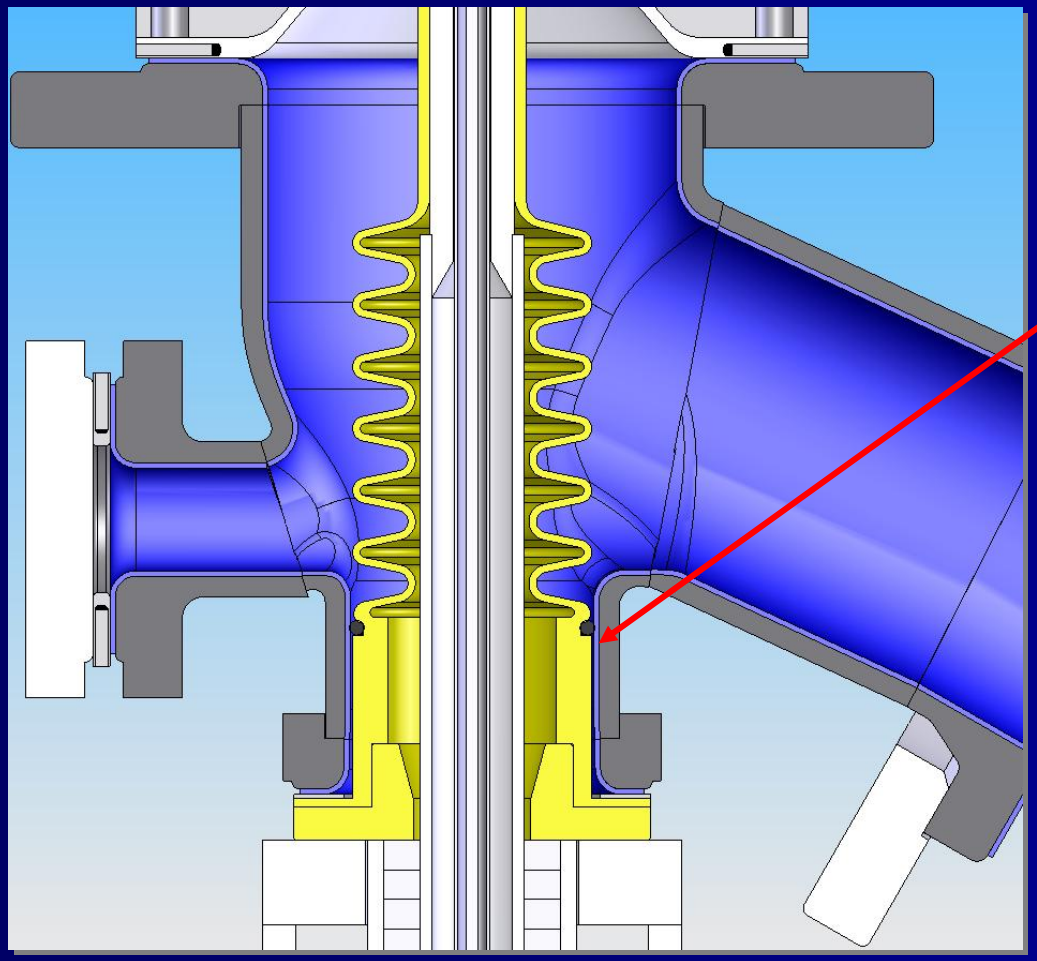

- intension: reduces dead storage volume
- O-ring sealing possible by circular grinding of the enamel surface

Potable water distribution

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- Absperrschieber, Formstücke
- Traditionell innen emailliert
- Neuentwicklung Komplett-Emaillierung
- Anpassung Emailresistenz gegen aggressive Boden-qualitäten
- Vermeidung von Schnittstellenfehlern aus unterschiedlichen Beschichtungssystemen

Solder technology

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Impeller pump

- SnAgCu-solder, legally obligated lead-free European Community 1.7.2006
- Solder-temperature up to 280°C
- Hotspots cause recent higher local temperatures
- Combined flow abrasion depends on pump speed of 500/min

Solder technology

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Counterpart of an axial slide seal ring

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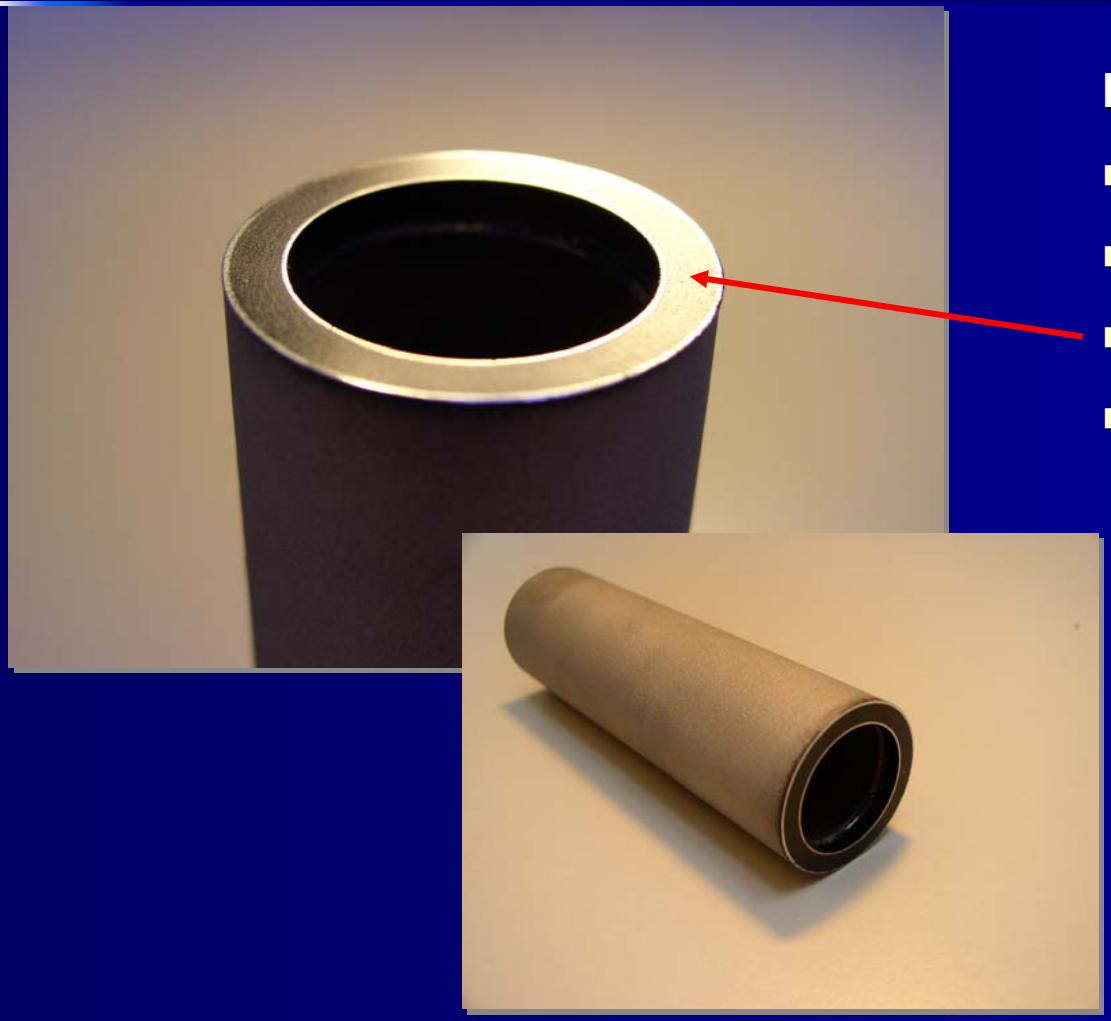

Prototype

- Food technology
- 30 x 120 mm
- Enamelling frontal area
- Manufactoring steps:
  - mechanical treatment,
  - enamelling,
  - fine grinding

Electrical Insulation

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Liquid level sensor,
requirements on insulation
and other electrophysical
features

Enamelling of nickel based alloys

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High acid resistant enamelled component of a ball valve, HHC 22

Sterile union in enamelled quality

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Flange connection system for pharmaceutical production plants

Basic material high-grade stainless steel, inside enalmelled

Different components enamelled

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Prototype enamel coated steel pipe

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Prototype enamel coated steel pipe

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Application of different types of conducting paste Heraeus

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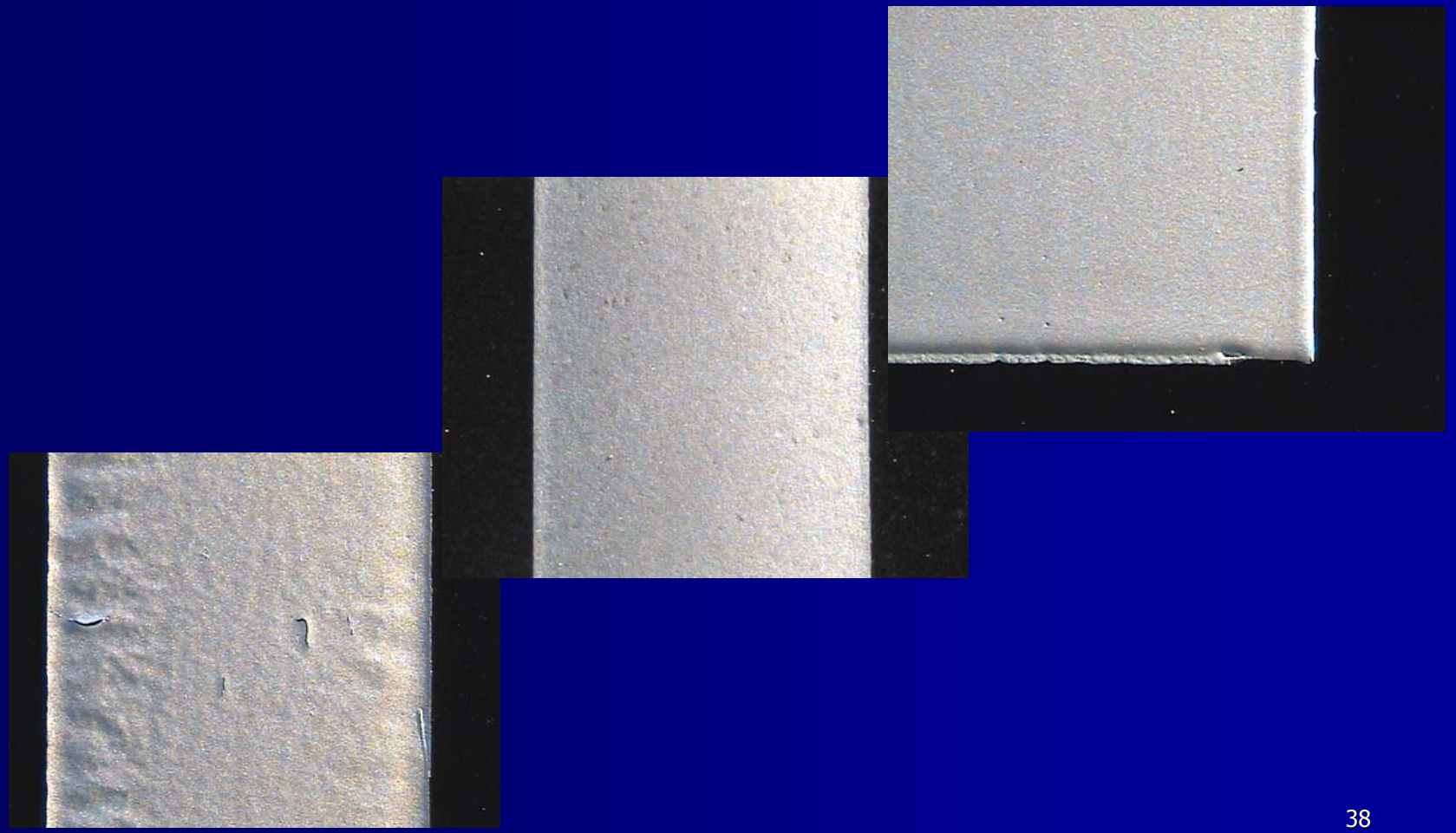

Application of Different types of conducting paste Heraeus

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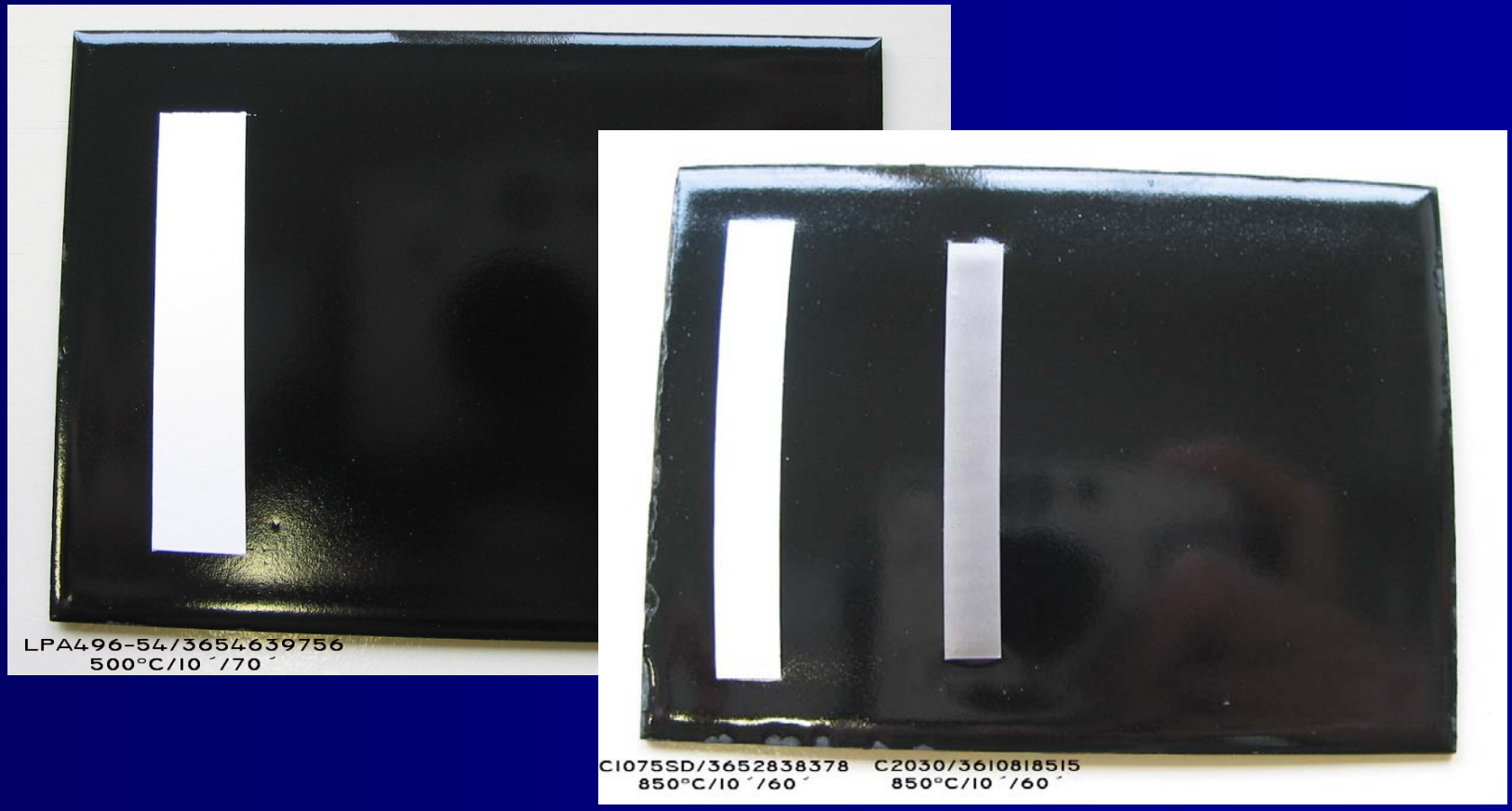

Application of Different types of conducting paste Heraeus

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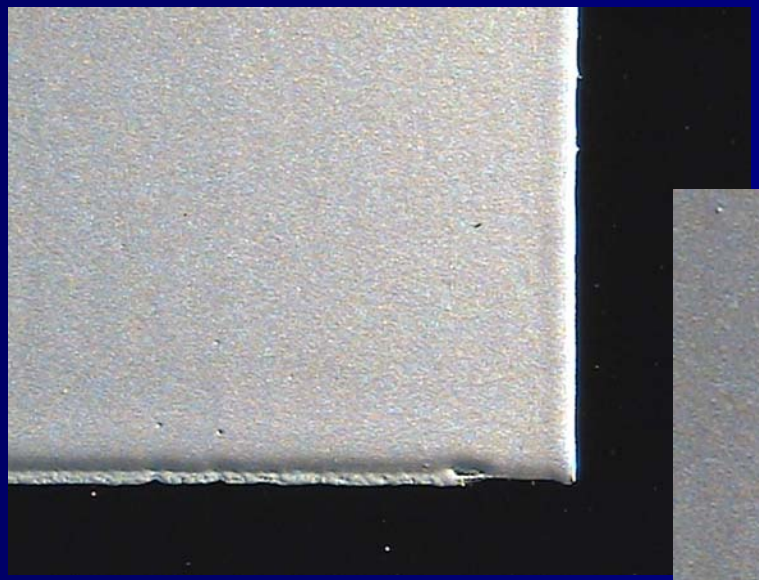

Definition of requirements

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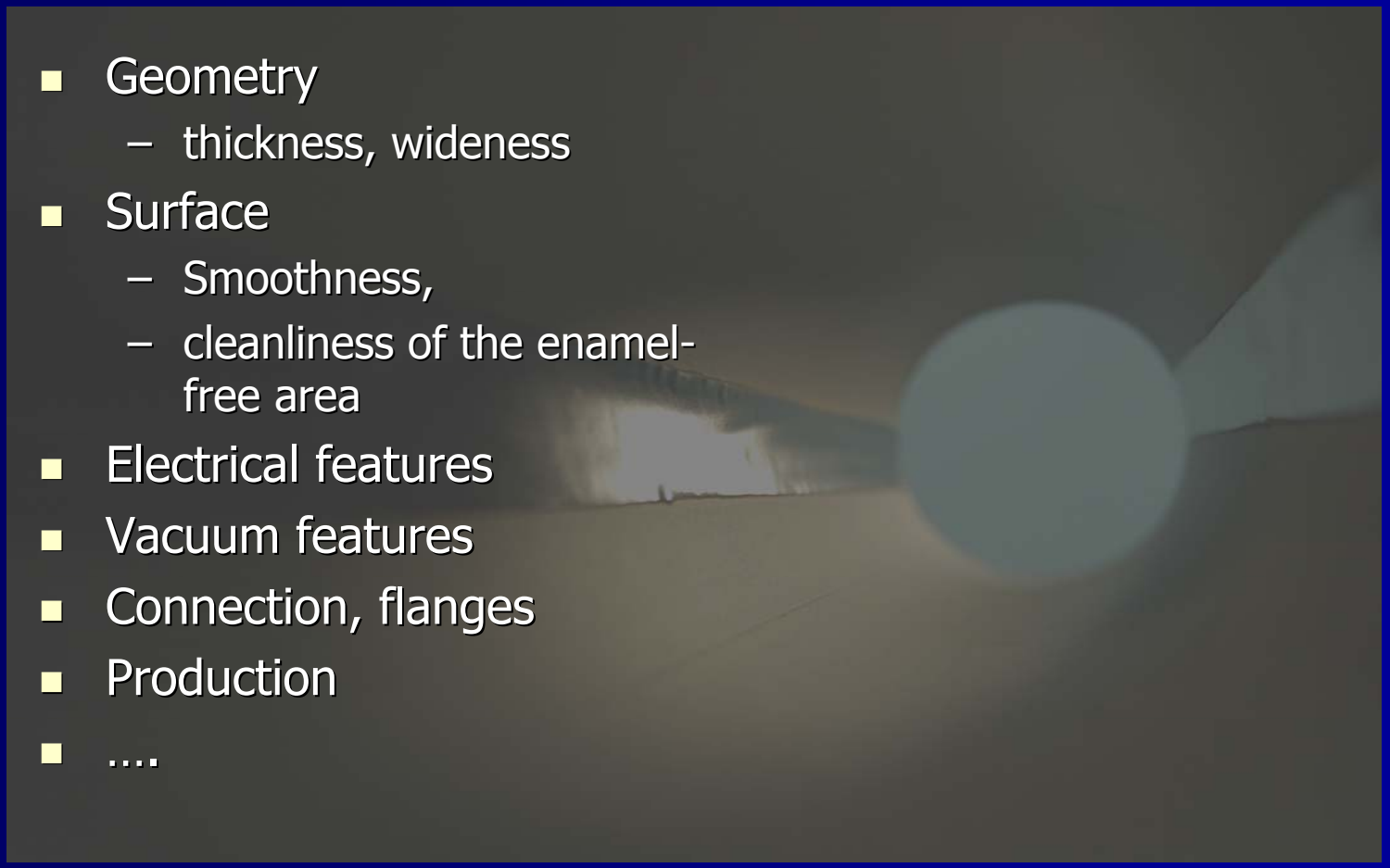

- Geometry
  - thickness, wideness
- Surface
  - Smoothness,
  - cleanliness of the enamel-free area
- Electrical features
- Vacuum features
- Connection, flanges
- Production
- ….

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