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Vitreous and porcelain enamels — Terminology —

Part 2: Visual representations and descriptions

Émaux vitrifiés — Terminologie —

Partie 2: Représentations visuelles et descriptions

Reference number
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Foreword

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This document was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*.

A list of all parts in the ISO 19496 series can be found on the ISO website.

Vitreous and porcelain enamels — Terminology —

Part 2:
Visual representations and descriptions

1 Scope

This document establishes a system for the cataloguing of defects in sheet steel enamelling. It serves for a consistent language use concerning the designation and characterization of enamelling defects. This document is limited to detectable defects and does not purport to fully take into consideration all occurring types of defects. It does not evaluate enamelling defects; the classification carried out serves for the conveyance of practical knowledge.

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 Enamelling defects

4.1 Chipping

4.1.1 Further designations

— spalling

— pop-offs

— peeling

— delamination

4.1.2 Description

Chipping (see Figure 1) is surface detachment of the vitreous enamel exposing the layer below or also the substrate.

4.1.3 Origin and causes

Chipping occurs if the stress in the vitreous enamel layer is too great or the adhesion between the vitreous enamel and the substrate is too low.

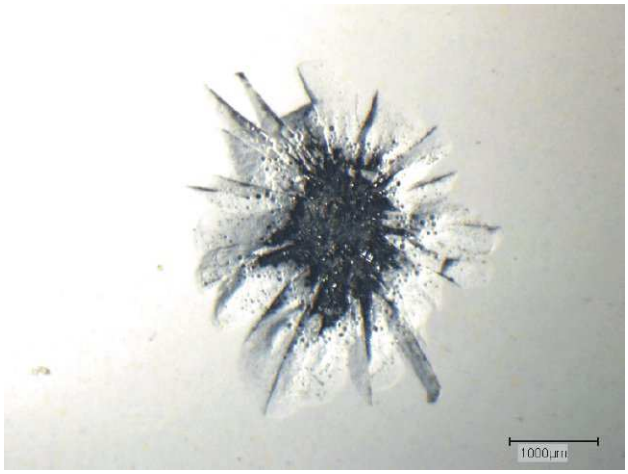
Possible causes are

— compressive stress in the enamel layer which is too high, due to incorrect material combination or a construction not suitable for enamelling,

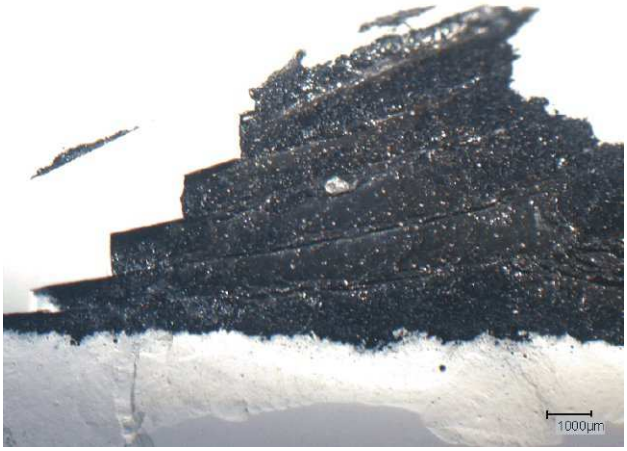
— poor adherence of the vitreous enamel layer on the sheet steel,

— mechanical stress, and

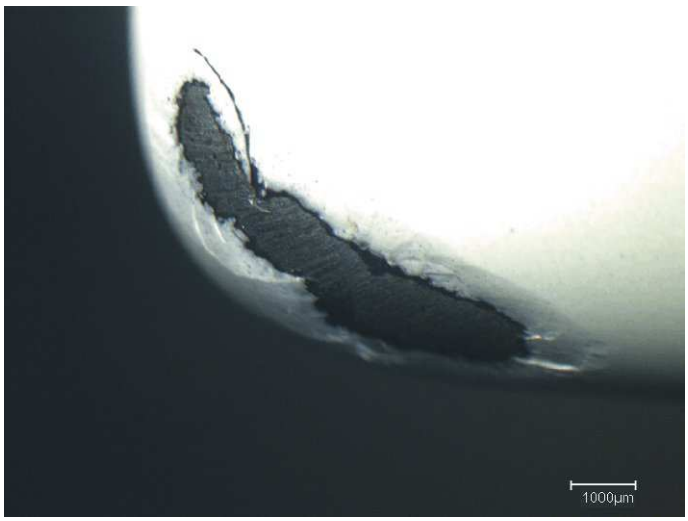
— thermal stress.



a) Pop-off resulting from impact on the rear side



b) Chipping resulting from too high a compressive stress



c) Chipping resulting from too high a compressive stress and poor adherence

Figure 1 — Spalling

4.2 Lines

4.2.1 Hairlines

4.2.1.1 Further designations

— strain lines

— tension lines

4.2.1.2 Description

Continuous, clearly defined line (see Figure 2) in the vitreous enamel surface; single, parallel or concentric.

4.2.1.3 Origin and causes

Hairlines result from reactions during the firing of the vitreous enamel.

Possible causes are

— lamination or rolled-in scale in the steel (rolling lines),

— pre-treatment residue,

— crazing in vitreous enamel layers underneath,

— uneven heating-up, especially work pieces which have differing wall thicknesses,

— construction of parts which are unsuitable for enamelling,

— vitreous enamel layer too thick,

— vitreous enamel too finely milled,

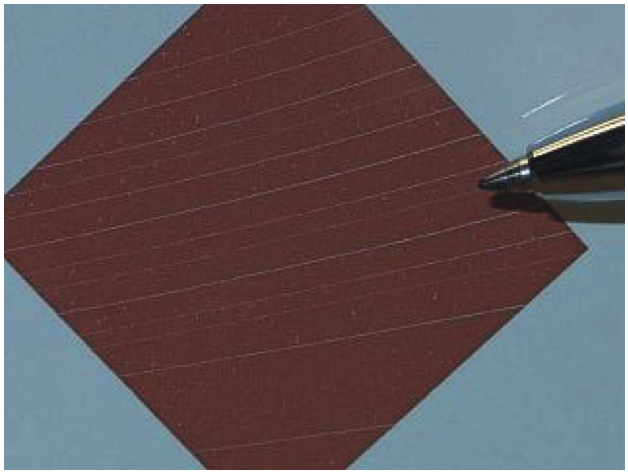
— incorrect matching of ground-coat and cover coat enamel with regard to the smelting behaviour,

— insufficient firing grate supports,

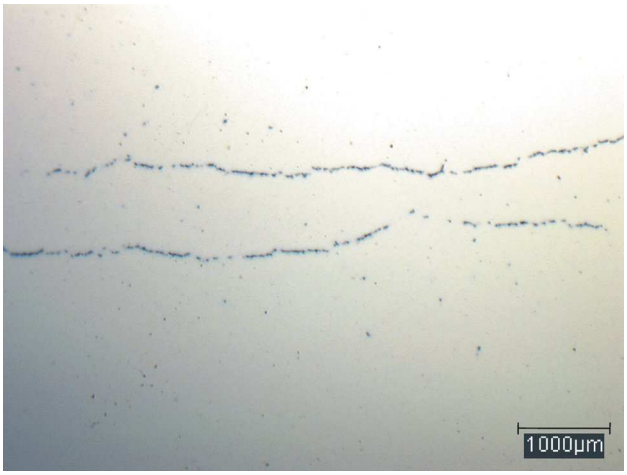
— unequal temperature distribution in the furnace,

— use of outdated steel despite low deformation, and

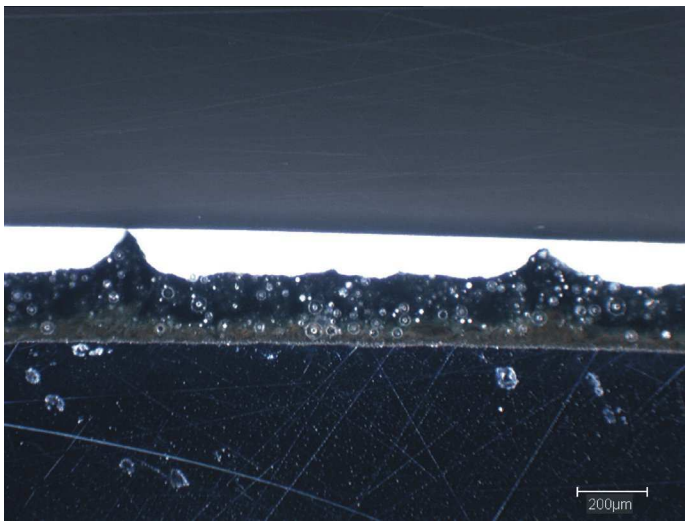
— too low a yield strength of the substrate.



a) Hairlines, top view



b) Hairlines, top view [corresponding cross section; see Figure 2 c)]



c) Cross section of two hairlines which result from too soft or too finely milled ground-coat

Figure 2 — Hairlines

4.2.2 Bubble lines

4.2.2.1 Further designations

— pearl lines

4.2.2.2 Description

Linearly open or closed blisters located in the vitreous enamel surface (see Figure 3).

4.2.2.3 Origin and causes

Bubble lines are a result of gas-forming reactions in the firing of the vitreous enamel.

Possible causes are

— lamination or rolled-in scale in the steel (rolling lines),

— pre-treatment residue,

— contamination of the substrate surface,

— crazing in the vitreous enamel layers underneath,

— vitreous enamel layer too thick,

— poor weld seam production, and

— incorrect filler material for weld seam.

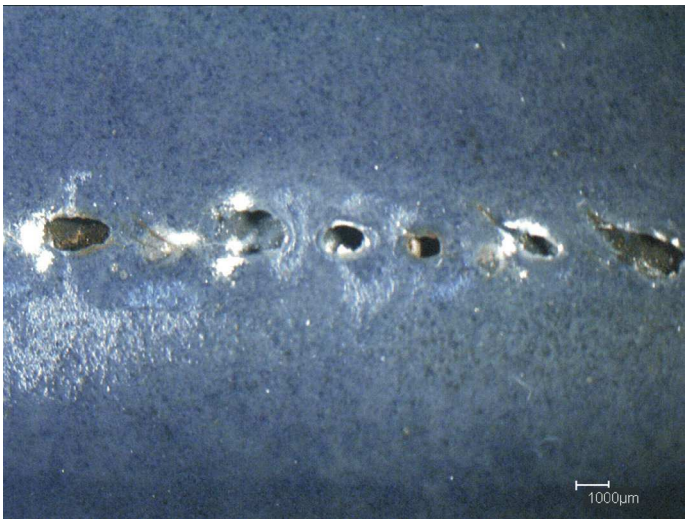


Figure 3 — Bubble line as a result of lamination

4.2.3 Watermarks

4.2.3.1 Further designations

— shorelines

— water streaks

4.2.3.2 Description

Continuous, not clearly defined line (see Figure 4) in the vitreous enamel surface; single, parallel or dispersing.

4.2.3.3 Origin and causes

Watermarks occur during application of the slip.

Possible causes are

— localized salt accumulation during slip drying,

— recondensation in hollow bodies during uneven drying,

— incorrect slip consistency,

— inappropriate application technique, and

— inappropriate substrate design.

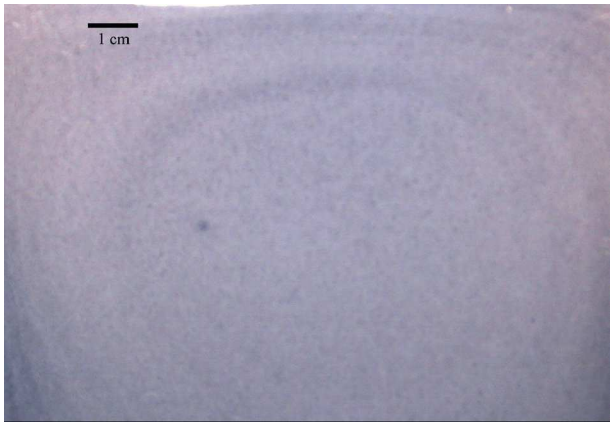


Figure 4 — Drying lines

4.2.4 Linear cracks

See 4.13.

4.3 Lumps

4.3.1 Further designations

— bumps

— pimple

4.3.2 Description

Raised area in the vitreous enamel surface (see Figure 5).

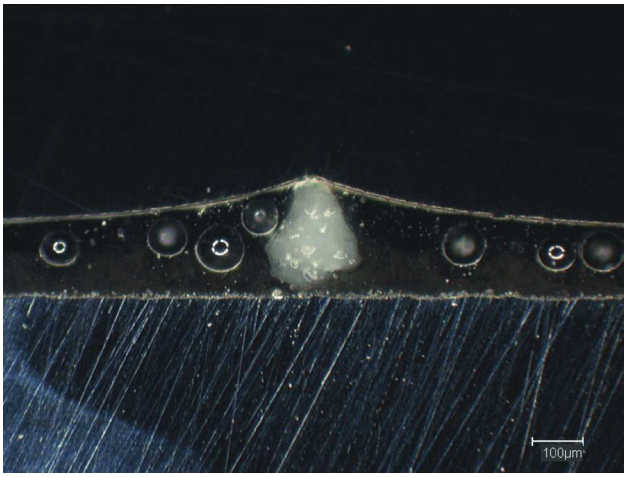
4.3.3 Origin and causes

— contamination of the vitreous enamel slip

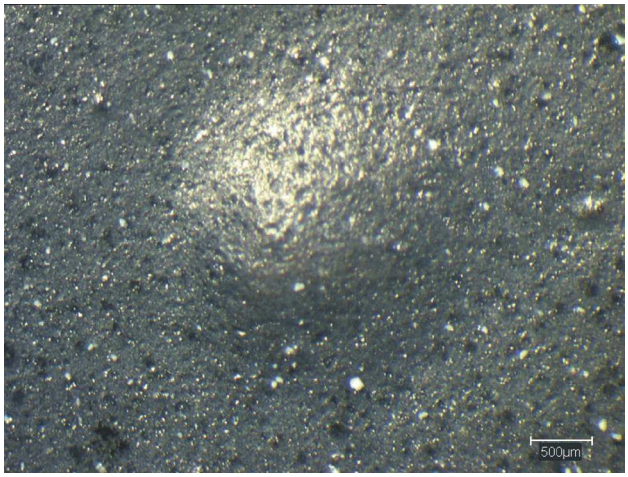
— slip ingredients too coarse

— surface bulged by a closed blister

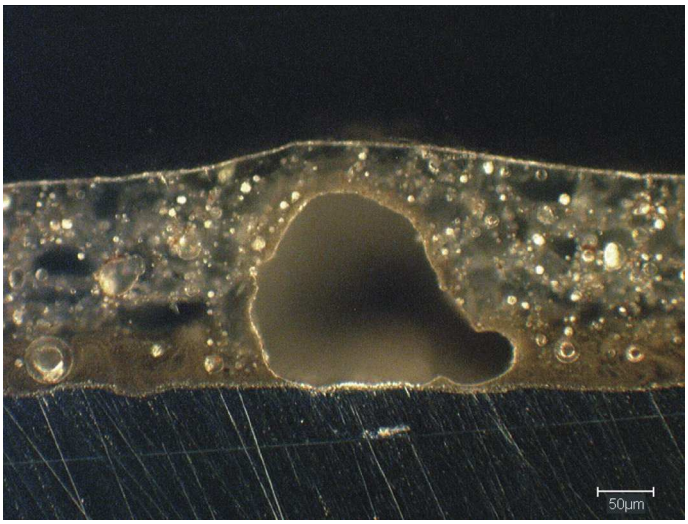
— localized thick enamel application



a) Lump resulting from inhomogeneity



b) Lump resulting from blister, top view



c) Lump caused by a closed blister

Figure 5 — Lump

4.4 Dimples

4.4.1 Further designations

— depression

4.4.2 Description

Shallow depression in the vitreous enamel surface (see Figure 6).

4.4.3 Origin and causes

Dimples result from localized changes in the surface tension and/or viscosity of the vitreous enamel layer, as well as collapsing blisters.

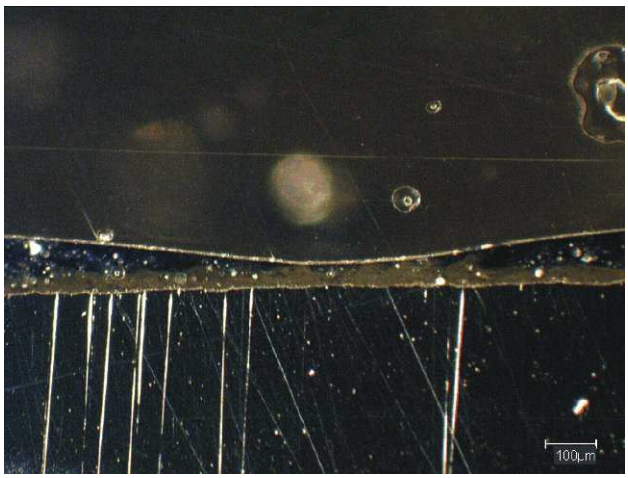
Possible causes are

— borax crystals in the slip,

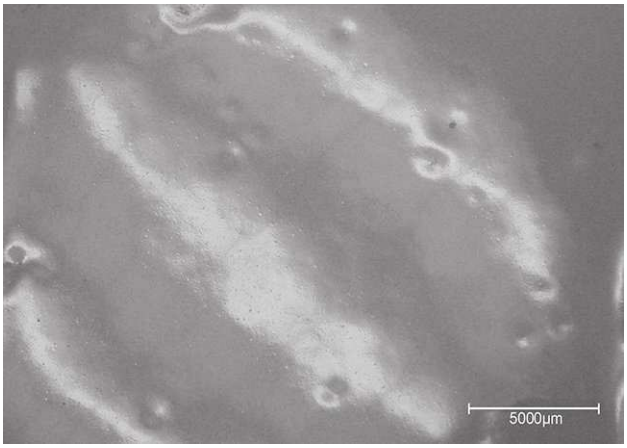
— sulfur compounds,

— iron, molybdenum and tungsten contamination, and

— large blisters which, after firing, are closed but have not smelted to a smooth finish.



a) Dimple resulting from borax crystals



b) Dimples, top view

Figure 6 — Dimples

4.5 Blisters

4.5.1 Further designations

— boiling defect

— scum blisters

— blister groups

4.5.2 Description

Visible, open or closed hollow spaces on the vitreous enamel surface (see Figure 7).

4.5.3 Origin and causes

Blisters are a result of gas formation during the firing of the vitreous enamel.

Possible causes are

— reaction of gas-forming components in the substrate,

— lamination or rolled-in scale in the steel (rolling lines), welding seam defect,

— emission of hydrogen during firing,

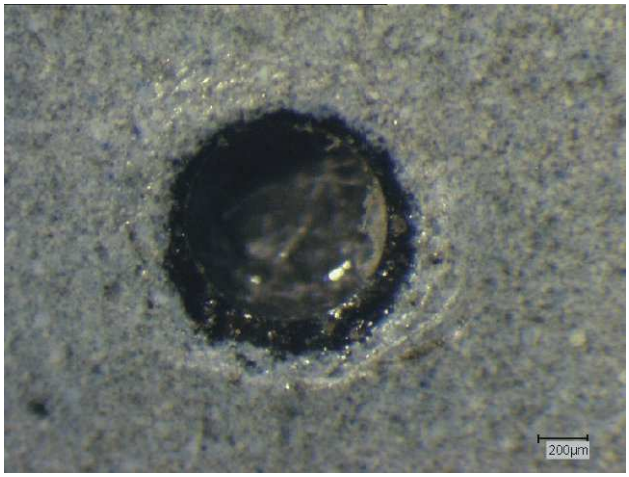
— slip (mill additions, slip too old, incorrect enamel combination),

— pre-treatment residue,

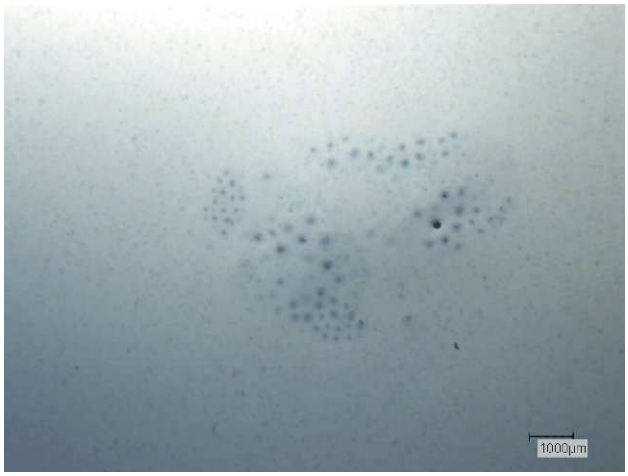
— organic contamination,

— furnace atmosphere (too humid, poor furnace ventilation), and

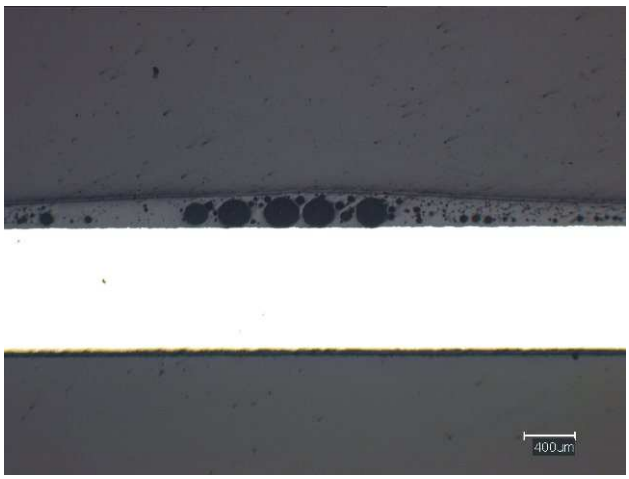
— burnt ground-coat.



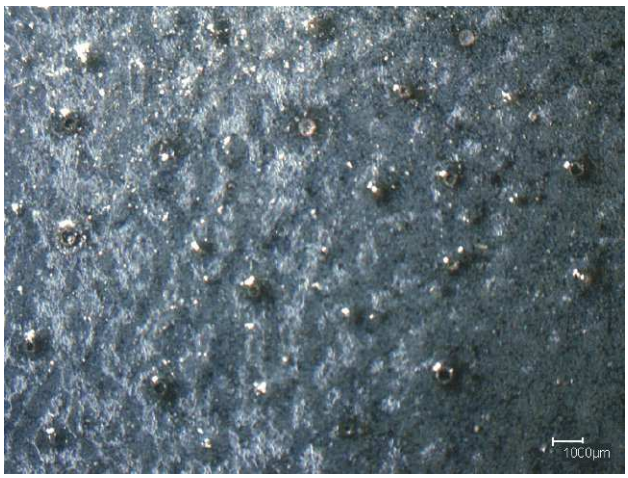
a) Open blister, top view



b) Blister accumulation as a result of organic contamination, top view



c) Cross section through a blister accumulation



d) Closed blisters, top view

Figure 7 — Blisters

4.6 Spots and specks

4.6.1 Further designations

None.

4.6.2 Description

From point-shaped up to extensive colour deviation of the vitreous enamel with varying intensity; isolated or occurring in lines or groups (see Figure 8).

4.6.3 Origin and causes

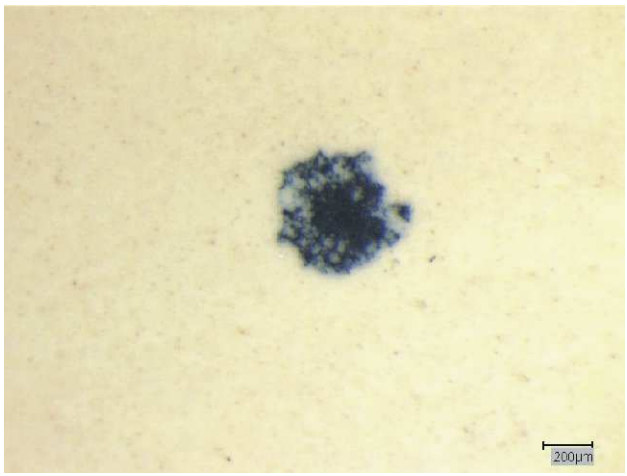
Spots and specks result from inhomogeneity in/on the fired vitreous enamel surface.

Possible causes are

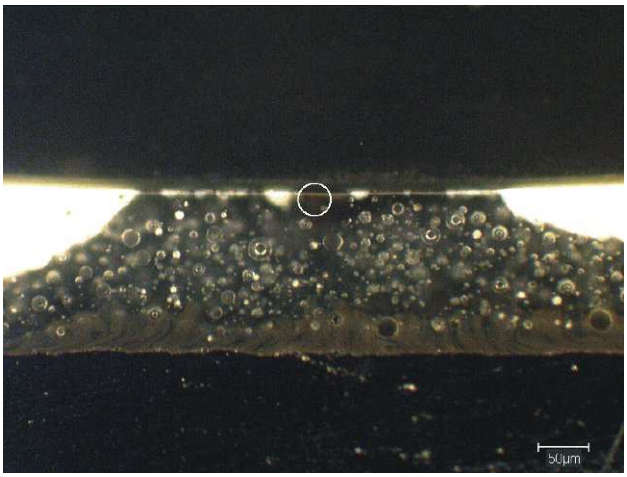
— foreign bodies which are introduced at all stages of the enamelling process, e.g. material to be milled or blasted, infestation,

— boiling of the ground layer into the cover-coat, and

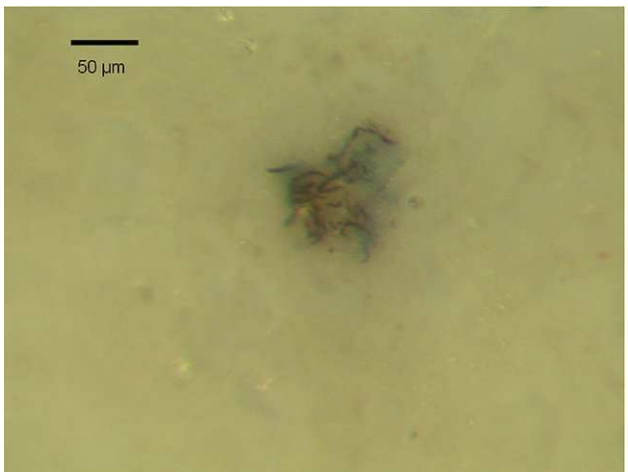
— blister cluster under the surface.



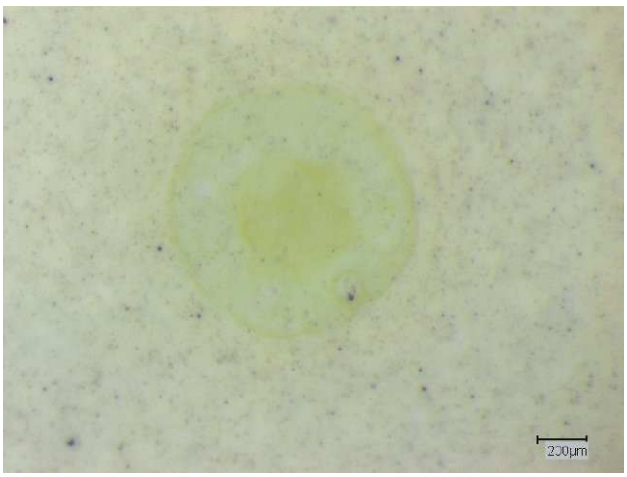
a) Spot as a result of a boiling, top view



b) Spot as a result of a boiling, cross section



c) Speck due to foreign body



d) Speck due to foreign substance

Figure 8 — Spots and specks

4.7 Crawling

4.7.1 Further designations

— curling

— roll back

— wetting defect

4.7.2 Description

Incomplete covering of the work piece by the vitreous enamel layer (see Figure 9).

4.7.3 Origin and causes

Crawling results from inadequate wetting of the substrate surface by the vitreous enamel during application, drying and firing.

Possible causes are

— insufficient degreasing,

— pre-treatment residue,

— oil and/or grease on the surface,

— slip too finely milled,

— surface tension of the vitreous enamel too high,

— inadequate drying,

— incorrect vitreous enamel layer thickness,

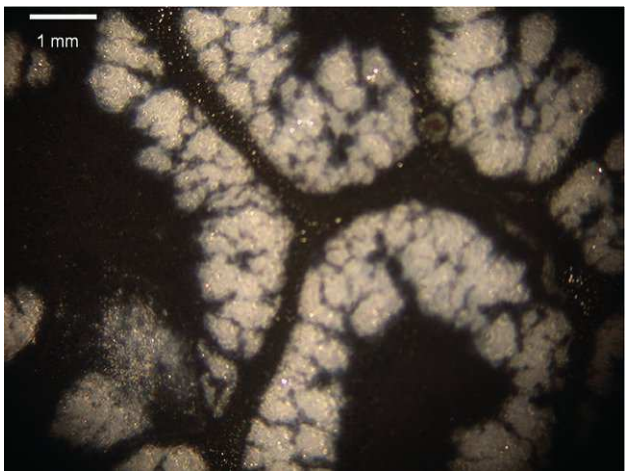
— incorrect slip properties,

— incorrect spray conditions (e.g. spray mist too dry),

— damage of bisque, and

— mechanical stress to substrate.

a) Crawling defect as a result of oil or grease



b) Crawling defect as a result of incorrect vitreous enamel layer thickness and too high a surface tension

Figure 9 — Crawling defects

4.8 Copperheads and burn-offs

4.8.1 Further designations

— oxidation

4.8.2 Description

Vitreous enamel areas supersaturated with iron oxide. These areas have a matt, rough, non-glassy appearance. When the burn-off is shaped like a point, it is called a copperhead (see Figure 10).

4.8.3 Origin and causes

Copperheads and burn-offs are a result of the vitreous enamel absorbing too much iron during firing.

Possible causes are

— enamel layer too thin,

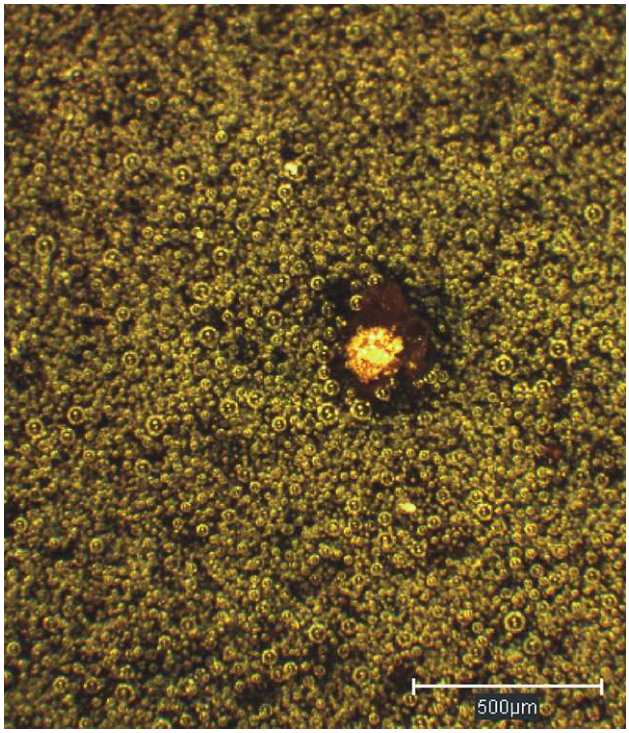
— incorrect firing,

— steel surface too reactive (over-pickling),

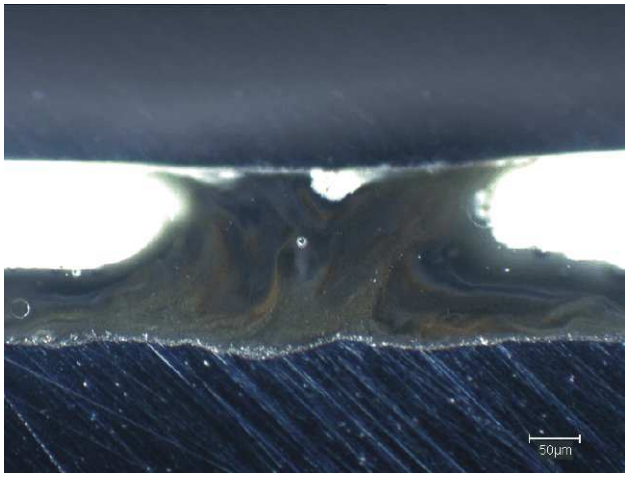
— incorrect slip properties,

— residue from the pre-treatment, and

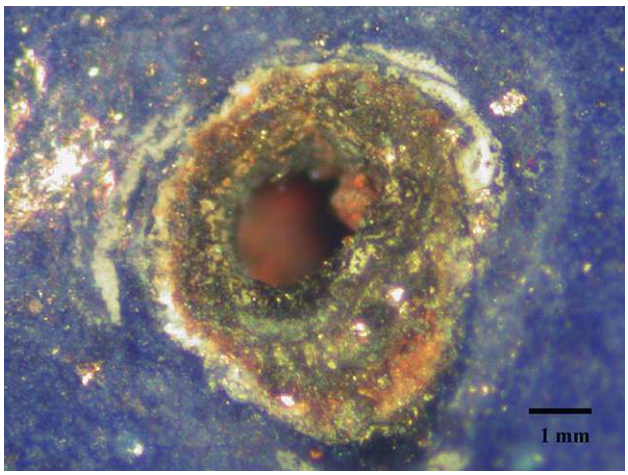
— steel surface metallic contamination.



a) Copperheads, top view



b) Burn-off as a result of substrate decomposition, cross section



c) Copperhead, top view (standard)

Figure 10 — Copperheads

4.9 Fish scales

4.9.1 Further designations

— whale scale

— process fish scale

— shiner scale

4.9.2 Description

Scale-like chippings originating from the steel/vitreous enamel interface in the vitreous enamel which occur immediately after firing or time-delayed (see Figure 11).

4.9.3 Origin and causes

Fish scales are a result of too high a hydrogen pressure out of the steel on the boundary layer steel/vitreous enamel.

The causes are

— sheet steel with too few hydrogen traps, and

— incorrect pre-treatment to steel surface.

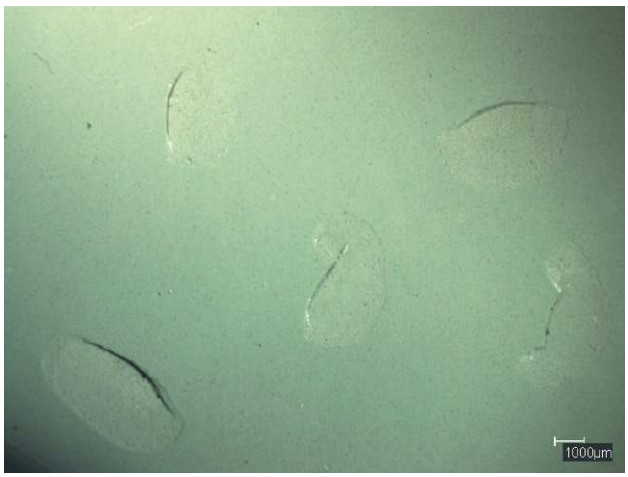
Further negative influences are

— poor adherence,

— firing temperature too low or too high,

— furnace atmosphere humidity too high, and

— incorrect pre-treatment of steel substrate.



a) Fish scales, top view

b) Fish scales, cross section

Figure 11 — Fish scales

4.10 Pinholes

4.10.1 Further designations

— holidays

— pores

4.10.2 Description

Fine, pinhole-shaped depression in the almost smooth vitreous enamel surface; isolated or occurring cumulatively in groups (see Figure 12).

4.10.3 Origin and causes

Pinholes are a result of a release of gas, also as a blister, during the final firing.

Pinholes can have various causes; this is difficult to classify explicitly.

Possible causes are

— inadequate furnace ventilation,

— incorrect firing of the vitreous enamel,

— vitreous enamel applied too thick,

— vitreous enamel slip is too old,

— inadequately dried slip application, and

— contamination of substrate surface or enamel slip.

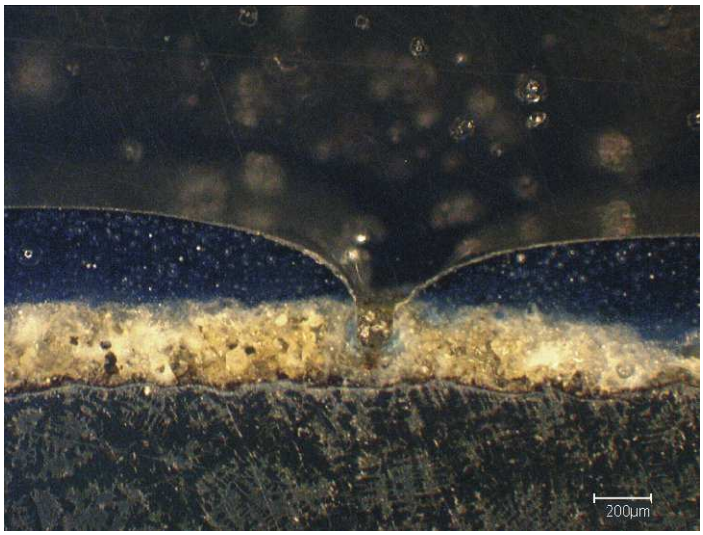


Figure 12 — Pinhole, cross section

4.11 Ripples

4.11.1 Further designations

— orange-peel

— crocodiling

— leather

4.11.2 Description

Rippled surface after firing of the vitreous enamel (see Figure 13).

4.11.3 Origin and causes

Ripples are the result when the vitreous enamel surface does not flow smoothly during firing.

Possible causes are

— poor matching of the vitreous enamel ground and cover coat enamels,

— incorrect frit combination,

— slip (density, milling fineness),

— application of vitreous enamel (spray pressure, spray application too dry, spray application too dense), and

— firing of the vitreous enamel (temperature, time, atmosphere).

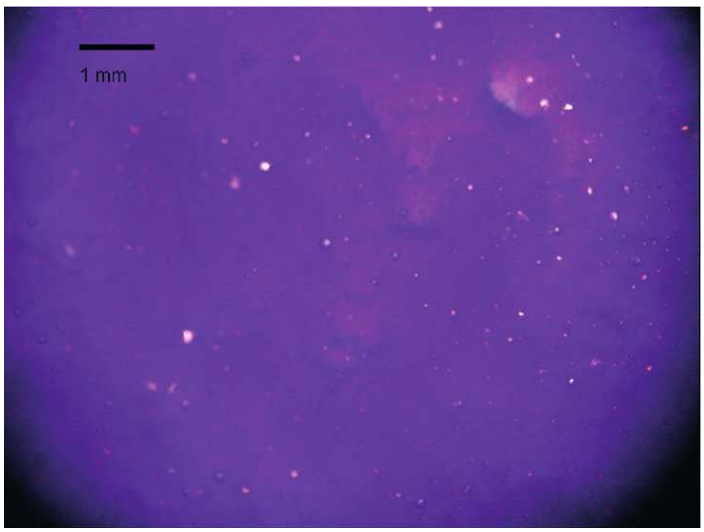


Figure 13 — Ripples

4.12 Poor adherence

4.12.1 Further designations

— silver metal

4.12.2 Description

Insufficient bond between substrate and vitreous enamel (see Figure 14).

4.12.3 Origin and causes

— insufficient reaction between steel and vitreous enamel during firing

— reactivity of the steel too low

— reactivity of the vitreous enamel too low

— improper pre-treatment

— incorrect firing conditions

— contamination of substrate surface

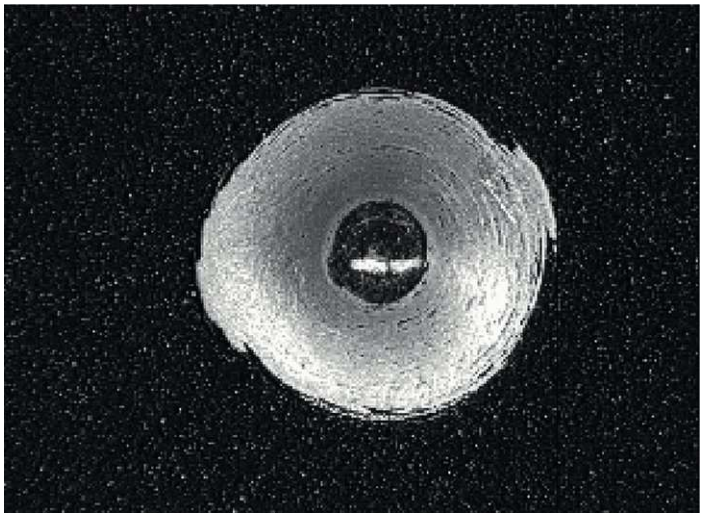


Figure 14 — Poor adherence

4.13 Cracks

4.13.1 Further designations

— crazing

4.13.2 Description

Fissure-shaped fracture in the vitreous enamel which can appear linear or star-shaped (see Figure 15).

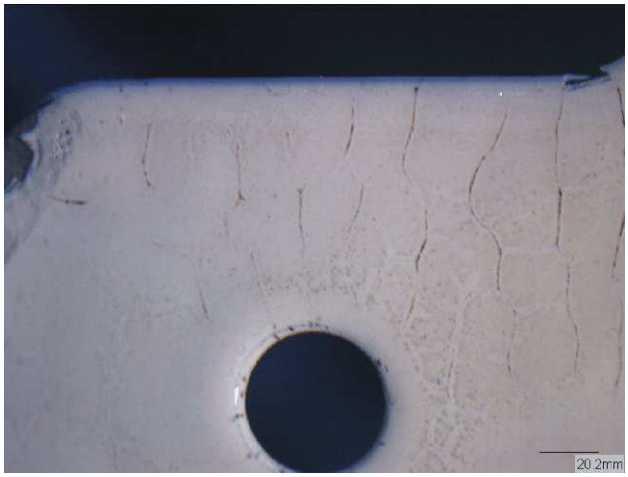
4.13.3 Origin and causes

— design not suitable for enamelling

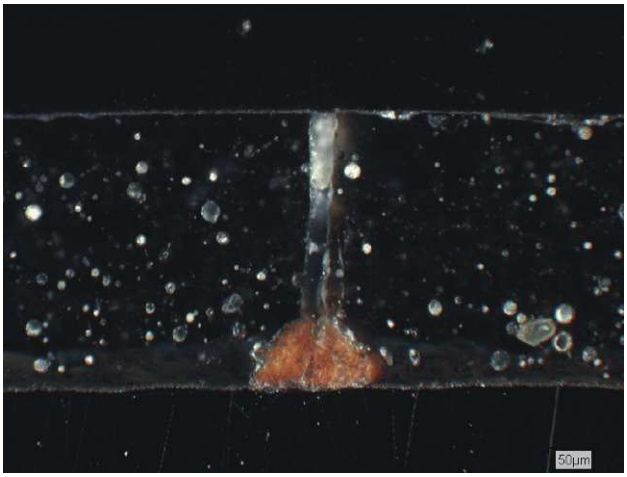
— manufacturing defect in the work piece

— mechanical load on the enamelled part too high

— expansion coefficient of the vitreous enamel too high



a) Cracks, top view



b) Cracks, cross section

Figure 15 — Cracks

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