
**Vitreous and porcelain enamels —
Terminology —**

**Part 2:
Visual representations and
descriptions**

Émaux vitrifiés — Terminologie —

Partie 2: Représentations visuelles et descriptions

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

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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

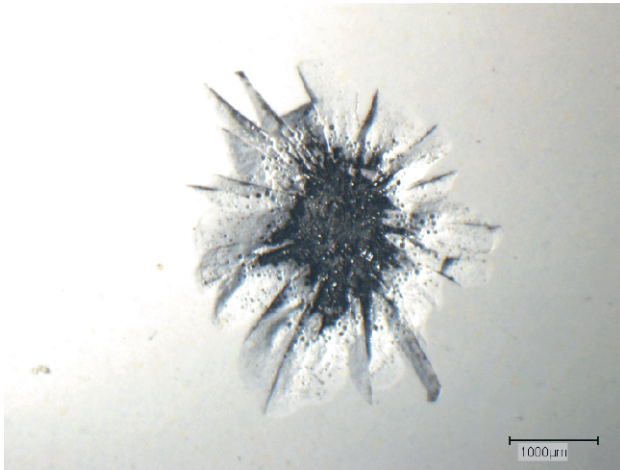
Chipping (see [Figure 1](#)) is surface detachment of the vitreous enamel exposing the layer below or also the substrate.

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

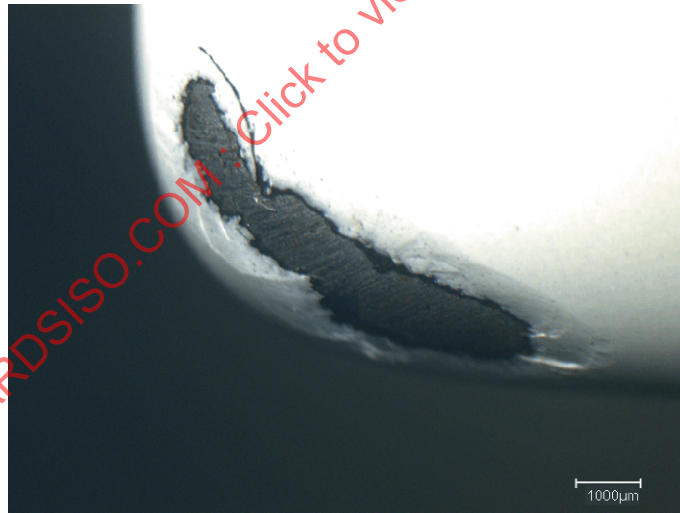
- compressive stress in the enamel layer which is too high, due to incorrect material combination or a construction not suitable for enamelling,
- poor adherence of the vitreous enamel layer on the sheet steel,
- mechanical stress, and
- thermal stress.



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

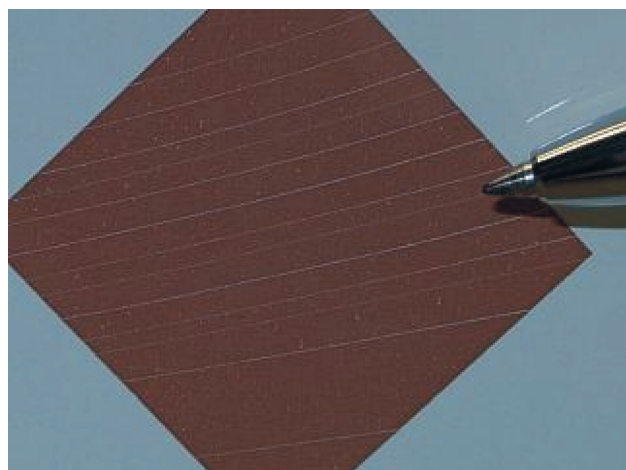
Continuous, clearly defined line (see [Figure 2](#)) in the vitreous enamel surface; single, parallel or concentric.

4.2.1.3 Origin and causes

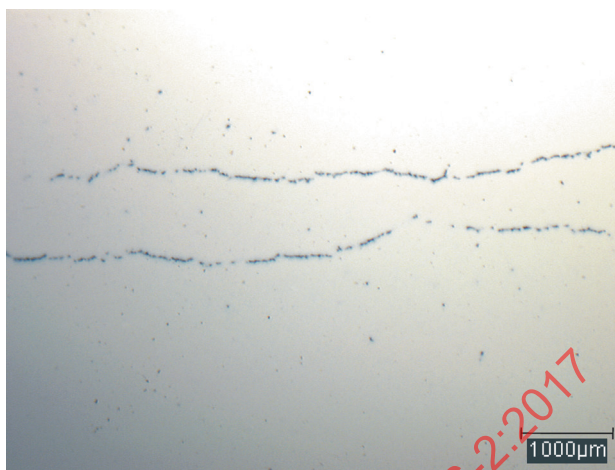
Hairlines result from reactions during the firing of the vitreous enamel.

Possible causes are

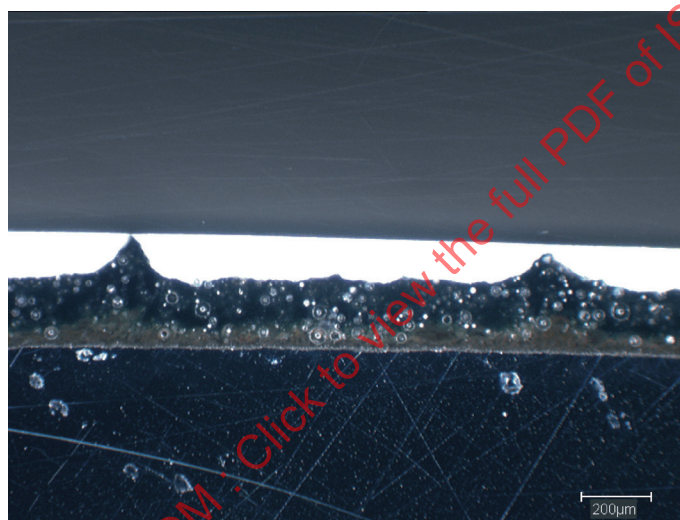
- lamination or rolled-in scale in the steel (rolling lines),
- pre-treatment residue,
- crazing in vitreous enamel layers underneath,
- uneven heating-up, especially work pieces which have differing wall thicknesses,
- construction of parts which are unsuitable for enamelling,
- vitreous enamel layer 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.

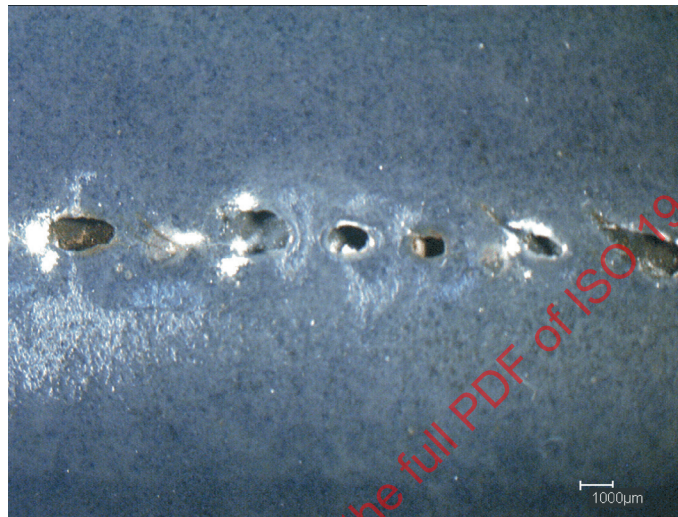


Figure 3 — Bubble line as a result of lamination

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.

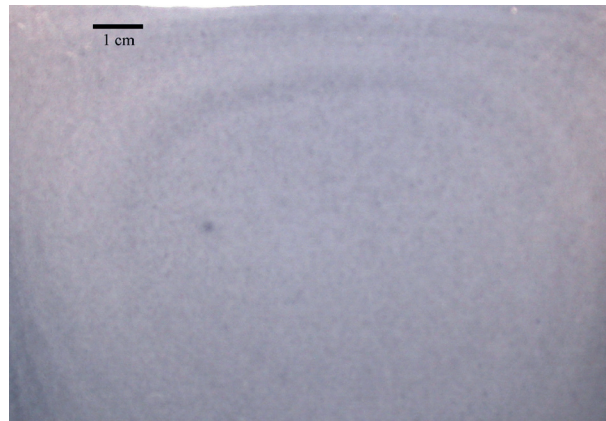


Figure 4 — Drying lines

4.2.4 Linear cracks

See [4.13](#).

4.3 Lumps

4.3.1 Further designations

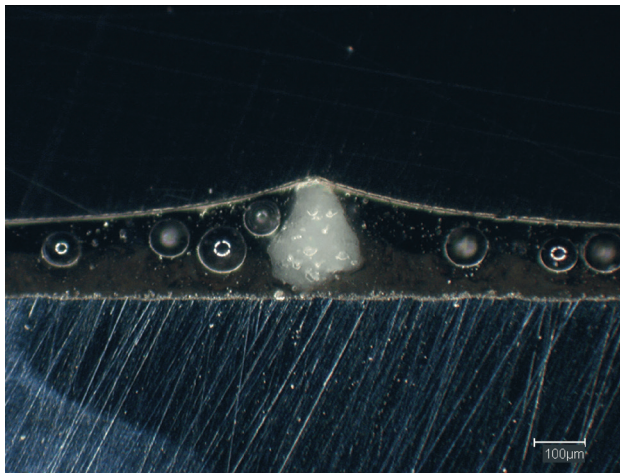
- bumps
- pimple

4.3.2 Description

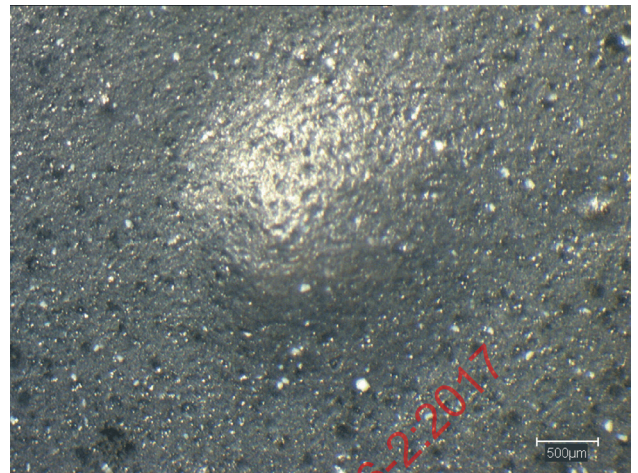
Raised area in the vitreous enamel surface (see [Figure 5](#)).

4.3.3 Origin and causes

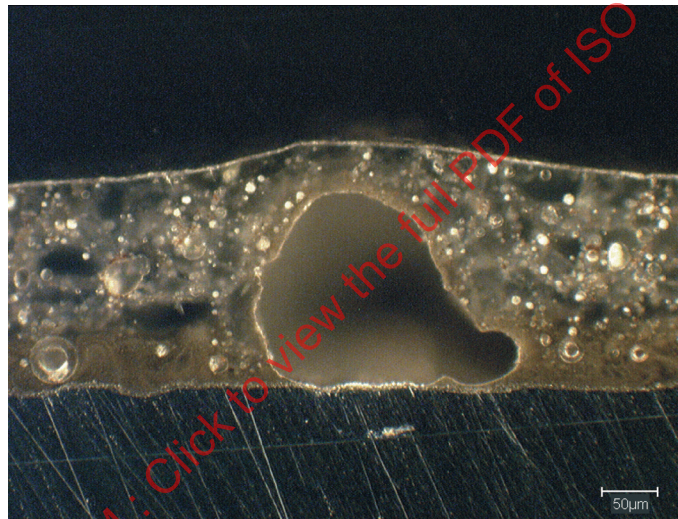
- contamination of the vitreous enamel slip
- slip ingredients too coarse
- surface bulged by a closed blister
- localized thick enamel application



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](#)).

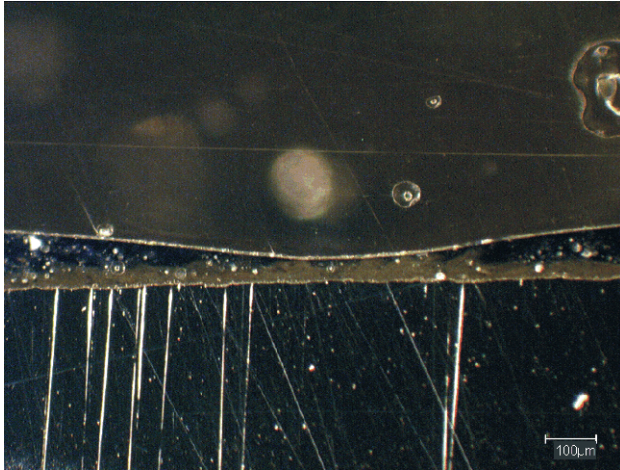
4.4.3 Origin and causes

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

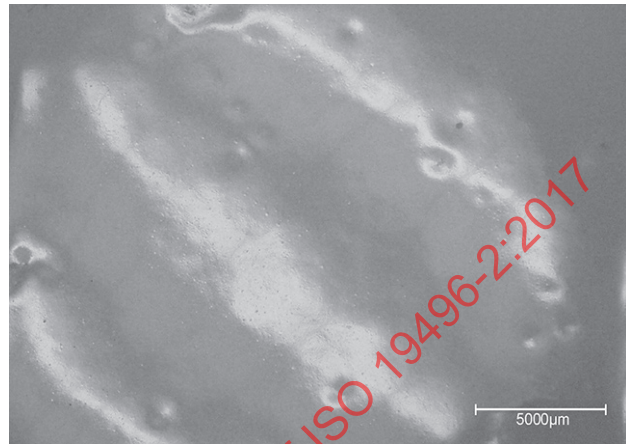
Possible causes are

— 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](#)).

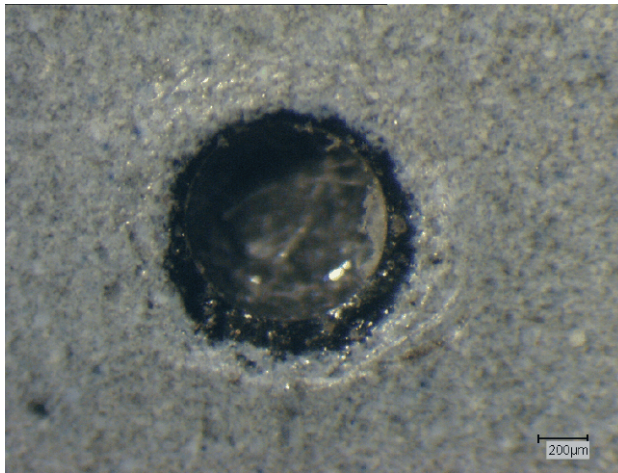
4.5.3 Origin and causes

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

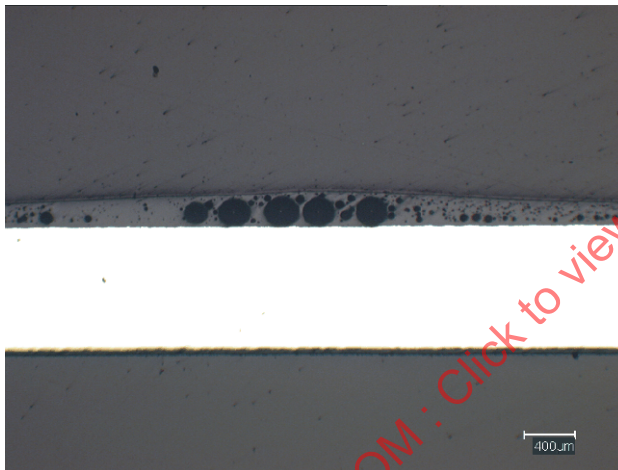
— burnt ground-coat.



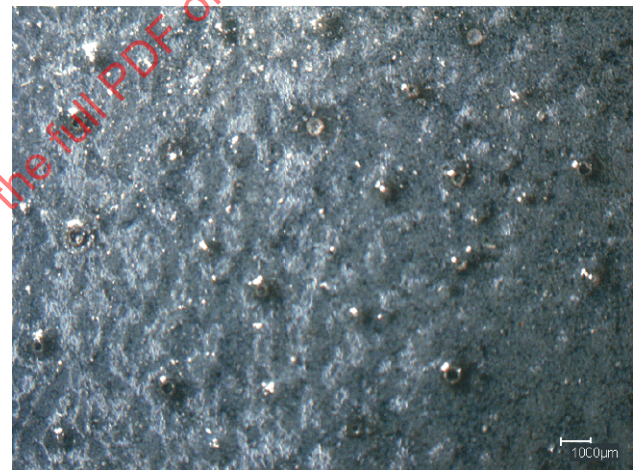
a) Open blister, top view



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

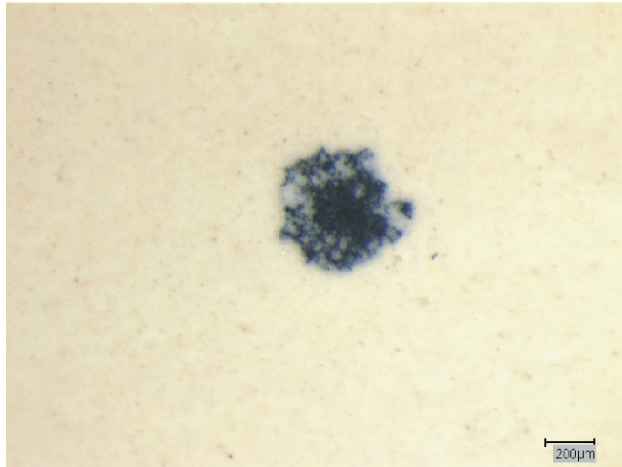
From point-shaped up to extensive colour deviation of the vitreous enamel with varying intensity; isolated or occurring in lines or groups (see [Figure 8](#)).

4.6.3 Origin and causes

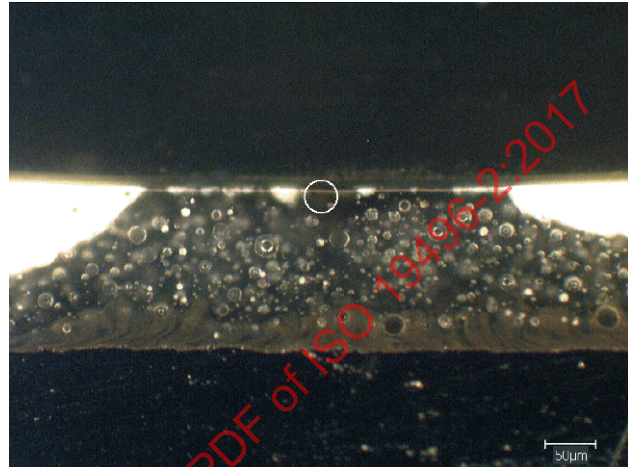
Spots and specks result from inhomogeneity in/on the fired vitreous enamel surface.

Possible causes are

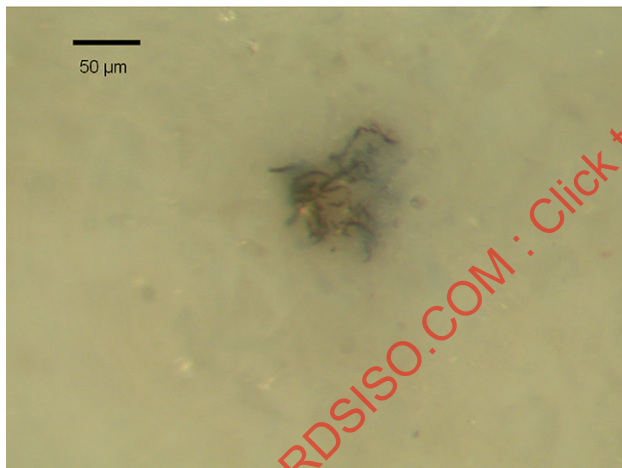
- foreign bodies which are introduced at all stages of the enamelling process, e.g. material to be milled or blasted, infestation,
- boiling of the ground layer into the cover-coat, and
- blister cluster under the surface.



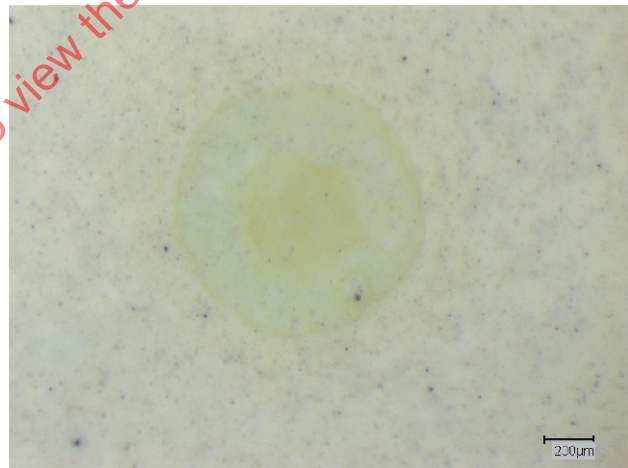
a) Spot as a result of a boiling, top view



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

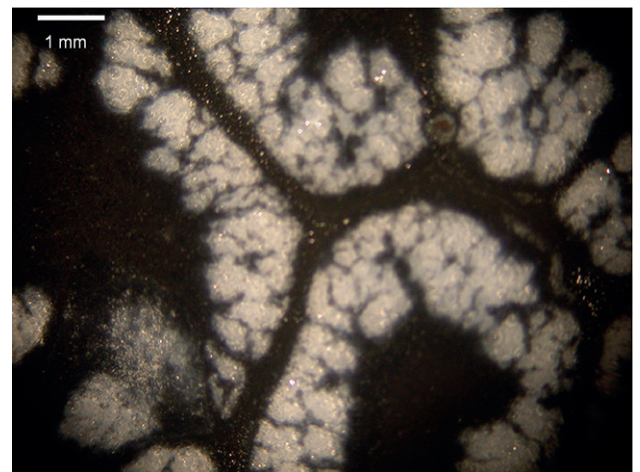
Crawling results from inadequate wetting of the substrate surface by the vitreous enamel during application, drying and firing.

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](#)).

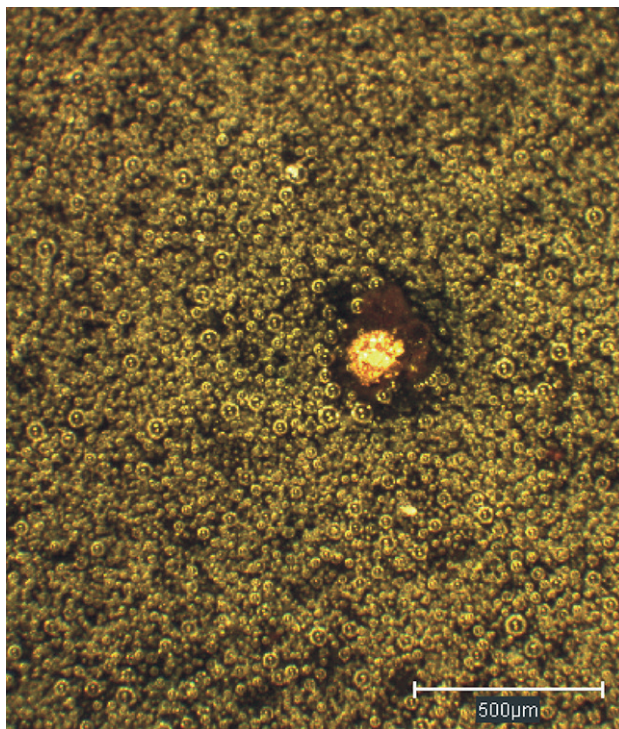
4.8.3 Origin and causes

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

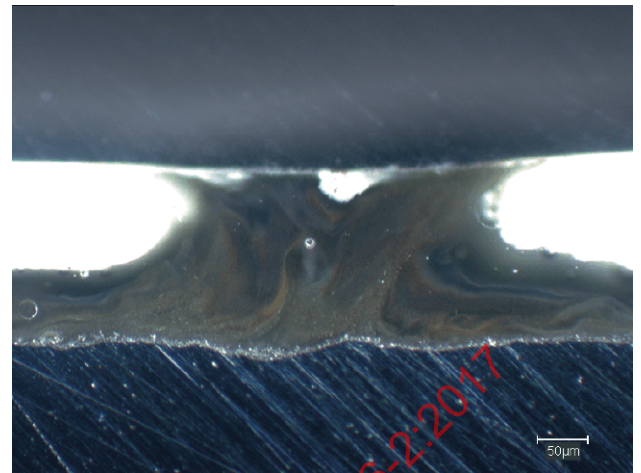
Possible causes are

- 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.

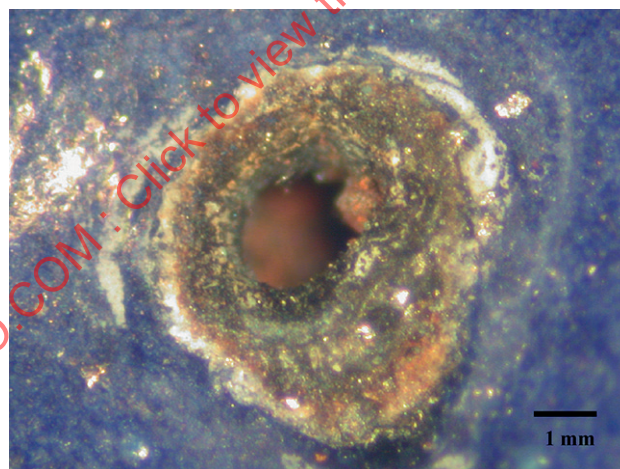
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a) Copperheads, top view



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

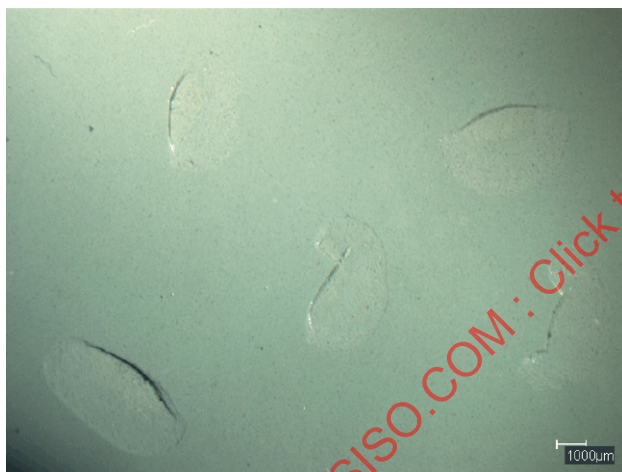
Fish scales are a result of too high a hydrogen pressure out of the steel on the boundary layer steel/vitreous enamel.

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](#)).