

Edition 6.0



QUALITY REQUIREMENTS  
EUROPEAN ENAMEL ASSOCIATION



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# QUALITY REQUIREMENTS

## EUROPEAN ENAMEL ASSOCIATION

Edition 6.0

[www.european-enamel-association.eu](http://www.european-enamel-association.eu)

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## 0. PREFACE

The European Enamel Association (EEA) is registered as an international non-profit organization. It is a federation of European national associations representing the industries involved in the vitreous enamel (porcelain enamel) sector of activity in Europe.

The main scopes of the European Enamel Association are:

1. Provide representation and assistance to EEA members in selected lobbying topics related to enamelling activities.
2. The edition, management and inspection of “harmonized quality requirements” for enamelled articles being manufactured in Europe. Those requirements help enamellers to produce qualitative articles and can be found in this document.
3. Deliver to eligible companies a certificate of compliance (for one or more areas of application of chapter 7 of this document) to:
  - selected EEA quality requirements (for specific application areas of chapter 7).
  - EN or ISO standards for enamelled products (for specific application areas of chapter 7).
4. Contributing in enamel promotion initiatives, while marketing efforts are dominantly left over to each individual company.

This document, called EEA Quality Manual, or EEA Quality Handbook, is made by the association in order to help enamellers in manufacturing qualitative articles. Regularly updated, it provides state of the art information on how to evaluate the quality of enamelled goods.

For interested companies, it is possible to be certified by the experts of the association and the certification procedure is explained in chapter 1 of this document.

This Edition 6.0 (2025) or the latest update of the document, can be obtained free of charge as an electronic version from the EEA administration or through the website <https://www.european-enamel-association.eu>

It is allowed to distribute this edition to other interested parties.

Companies who want to be EEA certified are requested to contact the EEA Secretary.

The European National Associations united in the EEA are convinced that the above-mentioned harmonized quality requirements, EEA certification, as well as EEA lobbying efforts will contribute greatly to the significance and success of porcelain and vitreous enamelled products in today's and future markets in and outside Europe.

## European National Associations

**Deutscher Email Verband e.V. (DEV (DE))**

**Österreichischer Email Verband OEV (AT))**

**Stichting Email, The Netherlands/Belgium (SE (BE, NL))**

**Vitreous Enamel Association (VEA (UK))**

**Centro Italiano Smalti Porcellanati (CISP (IT))**

**Association Pour l'étude de l'Email Vitrifié (APEV (FR))**

**Türkiye Emaye Derneği (TED (TR))**

**Magyar Zománcipari Egyesület (MZE (HU))**

**Stowarzyszenie Polskiego Przemysłu Emalierskiego (SPPE (PL))**

## 1.0 PROCEDURE FOR THE EUROPEAN ENAMEL ASSOCIATION CERTIFICATION

### Contents:

- 1.1 General
- 1.2 Procedure for obtaining the “European Enamel Association” certificate/label by an enamelling company.
- 1.3 Procedure for obtaining the “European Enamel Association” certificate / label by a company which assembles or factors parts enamelled by subcontractors
- 1.4 Flow sheet diagram

### 1.1 General

“European Enamel Association” certified companies have the authorisation to display of their products the EEA quality label. Those products are required to comply with the quality requirements specified in subsequent sections of this document, for the area(s) of application. The rules for the use of this label and / or certificate have been established by the Executive Committee (EC) of the European Enamel Association (EEA). This committee consists of one member nominated by the European National Enamelling Associations for each country and the secretary of the EEA. The nominated member shall be a representative of the national association.



EEA quality label



## 1.2 Procedure for obtaining the “European Enamel Association” certificate / label by an enamelling company (the applicant)

See also flow sheet diagram 1.4

### 1.2.1

An applicant wishing to obtain certification for use of the “European Enamel Association” label shall submit, in writing, a certification request for the application area (number(s) out of chapter 7) to be considered, to the EEA Secretary. EEA will confirm receipt of the request in writing, and also that it is being considered.

### 1.2.2

If one or more of the applications is rejected, the applicant may appeal to the Executive Committee (EC) of the EEA. They will either:

- a) cancel the decision
- b) confirm the decision

The decision of the Executive Committee shall be final.

The applicant shall be required to pay a registration fee to EEA to start the certification procedure. The cost of this fee shall be reviewed annually by the EC of the EEA.

### 1.2.3

If the application is accepted, then a specific EEA audit needs to take place at the company's expense within six months after the receipt of the request. The external audit team or auditor needs to be appointed or authorized by EEA (chairman TC, chairman EC, secretary).

During this audit, the auditor needs to verify that the specific EEA quality requirements (chapter 7) have been taken up into the quality manual of the company (documentation). Secondly the auditor needs to verify that the company meets these requirements for the products of concern to be certified.

For EN ISO 9001 certified companies, the above-mentioned audit process may also

occur integrated in an EN ISO 9001 audit. In all cases the external auditor needs to conclude that the company meets all or not the EEA quality requirements and recommends EEA certification or not for the company products of concern.

### 1.2.4

Following this initial audit, the company will have the opportunity to introduce corrective actions if required. The final audit will take place not later than three months after the original audit.

### 1.2.5

The audit report with the recommendations of the Quality Assessor(s) shall be sent to the secretary of EEA or the chairman of the Technical Committee (TC). The EEA TC shall then make the decision to grant a EEA certificate / label or not. The company will be informed by the EEA within two weeks after receipt of the report.

### 1.2.6

If the application is rejected, the company may submit an appeal to the EC of the EEA within 30 working days.

### 1.2.7

The EC may, after hearing the appeal of parties concerned, shall give one of two findings:

- a) The committee may authorize a re-audit at the company's expense.  
The result of this re-audit is final.
- b) The committee may reject the appeal.

The decision of the Executive Committee is final.

## 1.2.8

When accreditation for use of the “European Enamel Association” label has been granted, the EEA will issue a numbered certificate with the company name and the approved areas of application; and signed by the chairman of the EC and TC. The applicant shall be required to sign up to the rules for use of the “European Enamel Association” label and shall be entitled to introduce the “European Enamel Association” label in the form of:

- a) An EEA certificate with the company name and the approved area(s) of application. Examples are given on the EEA website
- b) Certification in the form of a seal and/or label on their products and correspondences.

## 1.2.9

The applicant shall be required to pay an annual fee for the license to use the “EEA” label. The cost of this license shall be reviewed annually by the EC of the EEA.

## 1.2.10

The EEA certificate / label is valid for a period of three years. When certification expires, the EEA shall grant a new certificate, if no rejection (§1.2.11) has taken place. The “EEA” certificate / label may be used by the company on approved area(s) of application only, until a final rejection is received during an audit (§1.2.11).

## 1.2.11

Annual “EEA” certificate / label auditing procedure:

In the years between the regular audits (each 3 years) the EEA secretary will send a request to the company to submit to the Secretary of the EEA a statement of EEA compliance to all certified application areas, undersigned by both the quality manager and the managing director of the certified company. Alternatively, the company may deliver yearly an audit report performed by an EEA approved “external” auditing team or auditor.

The validity period of the certificate is three years. Before the expiration date on the certificate, a recertification audit, performed by an “external” EEA approved auditing team or auditor, needs to be organized by the certified company, followed by repeating the steps mentioned in §1.2.3 till 1.2.10 till the EEA certificate renewal and undersigning by EEA.

In the event of an audit failure, the applicant shall be given a period of two months to undertake corrective actions, after which a re-audit will take place.

## 1.2.12

If there is a failure of the re-audit, the applicant shall not be permitted to continue the use of the “EEA” label until approval is regained.

## 1.2.13

The applicant may appeal against a suspension of using the EEA certificate / label to the EC of the EEA. The EC of the EEA shall give their judgement within two months from the date of the appeal. An appeal will not suspend the rejection.

## 1.2.14

The EC of the EEA may, after hearing the parties, agree to:

- a) Cancel the decision of failure
- b) Confirm of the decision of failure

The decision of the Executive Committee is final.

## 1.2.15

Where the failure decision is confirmed, the applicant is not be permitted to use the “EEA” label. If the applicant wishes to be considered for continuing use of the “EEA” label, then the applicant shall be required to re-apply for accreditation as laid down in this chapter 1.

## 1.2.16

The costs involved for the auditing shall be set between applicant and auditor.

## 1.2.17

The company shall pay towards EEA once a registration fee; as well as an annual fee for the license to use the certificate / label. Payments shall be made within the EEA stipulated payment terms of 60 days. Failure to comply will result in the applicant being suspended until payment is received.

## 1.2.18

## Auditing Requirements

## Control of documents and apparatus

## 1.2.18.1

Relevant internal testing documents and evidence of test results shall be required. This shall include testing and results to ISO, CEN, national or EEA standards detailed in these quality requirements.

ISO 9001 certified companies shall submit their ISO 9001 accreditation documents including details of procedures, testing and production, the results obtained and standards maintained.

## 1.2.18.2

These documents shall demonstrate that correct methods of setting up apparatus, testing, and calibration are in use.

## 1.2.18.3

Documents showing the planned frequency and the date of the last calibration shall be available.

## 1.2.18.4

If a subcontractor is used for the test procedure, then the relevant documents for the tests and/or calibration shall be required. This control also effects a testing body, subcontractor, or third party.

## 1.2.18.5

## Test results

For products which are already enamelled, results of measurements and tests that have been carried out, (as part, of the quality control process) shall be available. This includes relevant documents, test results, logbooks and other records. Records, areas of responsibility for control, measuring and registration shall be available. These documents shall provide the basis for the EEA audit. Fully documented test method(s) and the result(s) obtained are required to prove conformance to this standard. Results must be expressed in the specified units.

## 1.2.18.6

## Test-frequency

The inspection of a batch shall be on the basis of a random test and assumes it to be representative of the quality of the batch. The acceptable quality level (AQL) is defined as the maximum percentage of the pieces or square meters in a batch that do not meet the quality requirement. The inspection procedure is based on EN ISO 2859, in which the size of the random test is a function of the size of the batch. The method of selection and the number of random test pieces or square meter required must comply within the batch to be inspected.

## 1.2.18.7

The number of random tests depends on the size of the batch and should meet the specified quality requirement as mentioned in the corresponding AQL table (1.2.18.10).

## 1.2.18.8

A batch is presumed to meet the requirements when the number of pieces in the random test which do not meet the related requirements, is not higher than the approval criterion for the corresponding quality level, as given in the AQL tables (1.2.18.10.)

## 1.2.18.9

Where the system for control of coating thickness does not meet the stated requirements, the tables should be used for indicating the test frequency during the EEA performed inspection.

## 1.2.18.10 AQL tables

## Inspection level S4

Size of the Batch N		Random test n	Approval criterion from the quality level		
From	Up to		AQL 2.5	AQL 4.0	AQL 6.5
-	90	5	0	0	1
91	150	8	0	1	1
151	280	13	1	1	2
281	500	20	1	2	3
501	1200	20	1	2	3
1201	3200	32	2	3	5
3201	10000	32	2	3	5
10001	35000	50	3	5	7
35001	-	80	5	7	10

## Inspection level I

Size of the Batch N		Random test n	Approval criterion from the quality level		
From	Up to		AQL 2.5	AQL 4.0	AQL 6.5
-	90	5	0	0	1
91	150	8	0	1	1
151	280	13	1	1	2
281	500	20	1	2	3
501	1200	32	2	3	5
1201	3200	50	3	5	7
3201	10000	80	5	7	10
10001	35000	125	7	10	14
35001	-	200	10	14	21

## Inspection level II

Size of the Batch N		Random test n	Approval criterion from the quality level		
From	Up to		AQL 2.5	AQL 4.0	AQL 6.5
-	90	13	1	1	2
91	150	20	1	2	3
151	280	32	2	3	5
281	500	50	3	5	7
501	1200	80	5	7	10
1201	3200	125	6	10	14
3201	10000	200	10	14	21
10001	35000	315	14	21	21
35001	-	500	21	21	21

### **1.3 Procedure for obtaining the “European Enamel Association” label by a company which assembles or factors parts or products enamelled by subcontractors**

#### **1.3.1**

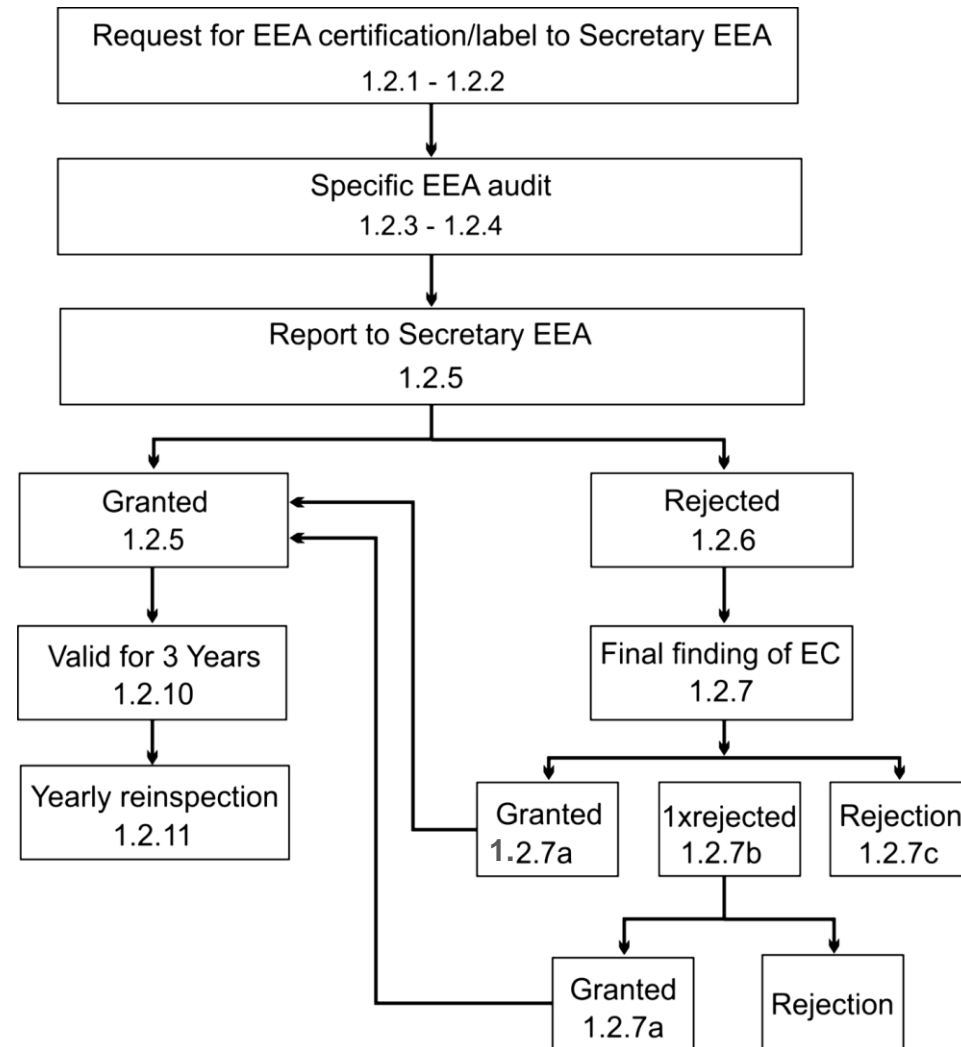
Where the applicant assembles or factors enamelled parts which have been enamelled by a subcontractor and wishes the finished product to qualify for a “EEA” label, then the company shall demonstrate that the requirements detailed in sections 1.2 are satisfied by the appropriate subcontract enamellers.

In the opposite case when the EEA certified company is an (exclusive) jobber and responsible for only the quality of the enamelling without having direct influence on the quality of the supplied base material e.g. the steel, the final enamel quality shall be agreed between the jobber and its customer.

#### **1.3.2**

This shall be accomplished by submission of relevant documents delivered by the subcontractor(s), in accordance with the instructions given in these quality requirements. The applicant may also choose to have the audit carried out at the subcontractor, if required.

#### 1.4 Flow sheet procedure



## 2.0 DEFINITIONS

This section aims to clarify the definition of terms used in the field of enamelling. The content of this paragraph complies with the content of the norm EN ISO 19469-1: Vitreous and porcelain enamels - Terminology - Part 1: Terms and definitions. For more information regarding the terms used in enamelling, it is recommended to consult the standard.

### 2.1

The general public experience confusion about the definition of “enamel”.

### 2.2 ENAMEL

Enamel should more properly be called “vitreous enamel” or “porcelain enamel” (USA and Canada). In this document, we frequently refer to “porcelain and vitreous enamel” to encompass the whole terminology.

### 2.3

Porcelain and vitreous enamel is a mainly vitreous material, which is obtained by the melting or fritting of a mixture of inorganic materials. This fritted material may be applied to a metal substrate in either the form of a suspension in water or a dry powder, in one or more layers, which will, when heated to a temperature sufficient for fusion to take place and above 480°C, be bonded chemically and physically to the metal substrate.

### 2.4

The material produced by fritting is a porcelain and vitreous enamel frit. It is the result of fusing a mixture of different inorganic raw materials, which constitute the vitrifiable base of the enamel, and then quenching (granulated frit) or laminating (flake) the molten glassy mass from temperatures between 1150°C and 1350°C

## 2.5 ENAMELLING

The process is porcelain and vitreous enamelling and consists of covering a metal surface with one or more coatings of fusion bonded vitrified, inorganic material.

### 2.6

The department carrying out the process is the vitreous or porcelain enamelling department.

### 2.7

The personnel involved in the process are often referred to as vitreous or porcelain enamellers.

### 2.8

The coated metal is porcelain and vitreous enamelled e.g. porcelain and vitreous enamelled metal.

### 2.9

An exception to these definitions is an enamel which is applied on glass and fused on the glass surface.

### 2.10

Some organic paint finishes may be incorrectly described as “enamels”. This is an unfortunate but widely operated custom which leads to confusion of the general public. These finishes should be described as “enamel paints”.

### 2.11

In some other languages there may be other forms of confusion. For example, the word “enamelling” (as translated) may be used to mean the material, the process and the finished product.

### 3.0 QUALITY REQUIREMENTS FOR EUROPEAN ENAMEL ASSOCIATION CERTIFIED PRODUCTS

#### 3.1

The porcelain and vitreous enamel should comply with the definitions given in section 2 of these requirements and needs to be at least as stringent in terms of quality than the equivalent European standard.

#### 3.2

The basis metal should be suitable for enamelling. It should be manufactured and treated so that it is not the source of defects in the enamel coating which would influence the quality and value of the final enamelled product.

#### 3.3

The dimensions and the thickness of the material should be appropriate to the specific requirements of the enamelling process to ensure satisfactory mechanical stability of the final enamelled product. The product should be designed and produced to minimize the risk of damage to the enamel coating, for example by avoiding excessively sharp radii during forming, elimination of unsuitable welding practice and care to avoid the development of stresses during firing.

#### 3.4

The porcelain and vitreous enamel coating should have sufficient corrosion resistance for the specific area(s) of application.

#### 3.5

The surface of the porcelain and vitreous enamel coating should not show obvious or substantial defects on inspection at a distance which is normal for the application, under diffuse light conditions. (See also EEA specification 8.7)

#### 3.6

Surfaces of parts of the same colour should not show unacceptable colour differences, when inspected at a normal inspection distance and under standard light conditions.

#### 3.7

The thickness of the porcelain and vitreous enamel coating should be as consistent as possible and should not show excessively increased thickness at curved surfaces or at small radii, to ensure that the useful quality of the final enamelled product is not diminished.

#### 3.8

The thickness of the porcelain and vitreous enamel coating should meet the maximum and the minimum values as defined for the specified area(s) of application.

#### 3.9

The porcelain and vitreous enamel coating should show good adherence to the basic metal.

#### 3.10

The porcelain and vitreous enamel coating should also meet the minimum requirements for other physical properties defined for the specified stated area(s) of application.

#### 3.11

The chemical resistance of the porcelain and vitreous enamel coating should be in accordance with the specified area(s) of application and should meet the quality requirements which are defined for the specified stated area(s) of application.

#### 3.12

The porcelain and vitreous enamel coating should have a minimum hardness of 5 on the Mohs (EN ISO 6769).



### 3.13

The product and the porcelain and vitreous enamel coating should meet the requirements for the specific area(s) of application as detailed in Section 7 of these Quality Requirements.

### 3.14

The following specifications are recommended for the specification of the basis substrate

material:

#### 3.14.1

Cold rolled steel as detailed in EN 10209

#### 3.14.2

Hot rolled steel as detailed in EN 10025 or EN 10111

#### 3.14.3

Cast iron as detailed in EEA-specification 8.1

## **4.0 TEST METHODS FOR PORCELAIN AND VITREOUS ENAMELLED CERTIFIED PRODUCTS**

The test methods, to which enamelled products with “European Enamel Association” label should be subjected depending on their application area, are detailed in this section.

### **4.1 Production of the test specimens**

The test specimens are produced according to EN ISO 28764.

### **4.2 Measurement of the thickness of the base substrate metal**

The thickness of the base substrate metal is measured either before the porcelain and vitreous enamel coating is applied (EN ISO 16809 ultrasonic thickness measurement) or after coating with porcelain and vitreous enamel by removal of the porcelain and vitreous enamel by grinding or chemical dissolution; or by means of an examination of the cross section, using a microscope equipped with a suitable magnification.

### **4.3 Measurement of the thickness of the porcelain and vitreous enamel coating**

Measurement of the thickness of the porcelain and vitreous enamel coating should be carried out using a coating thickness meter with a measuring accuracy of 0,01mm. For ferromagnetic substrate materials the methods specified in EN ISO 2178 should be used and for non-ferromagnetic substrate materials the methods specified in EN ISO 2360 should be used. The method using an examination of the cross section with a microscope, as specified in EN ISO 1463 may also be used.

### **4.4 Determination of the resistance to chemical corrosion by citric acid or other acids at room temperature**

The determination of the resistance to chemical corrosion by citric acid or other acids should be carried out using the methods as specified in EN ISO 28706-1/9.

### **4.5 Determination of the resistance to chemical corrosion by boiling citric acids**

The determination of the resistance to chemical corrosion by boiling citric acids, should be carried out using the methods as specified in EN ISO 28706-2/11, using apparatus as specified in EN ISO 28706-2/6.

### **4.6 Determination of the resistance to chemical corrosion by boiling water and/or water vapour**

The determination of the resistance to chemical corrosion by boiling water and/or water vapour should be carried out using the methods as specified in EN ISO 28706-2/14, using the apparatus as specified in EN ISO 28706-2/6.

### **4.7 Determination of the resistance to chemical corrosion by boiling detergent solution**

The determination of the resistance to chemical corrosion by boiling detergent solution should be carried out using the methods as specified in EN ISO 28706-3/10, using the apparatus as specified in EN ISO 28706-2/6.

The test is to be carried out during 2,5 hours. The effect is measured by the loss of mass of the test plates to be given in g/m<sup>2</sup>.

### **4.8 Specification and determination of the release of toxic elements**

The specification and determination of the release of toxic elements must comply with the requirements specified in the national laws of the country.

### **4.9 Determination of the resistance to impact**

The resistance to impact of the porcelain and vitreous enamel coating should be carried out using the pistol tester, as specified in EN ISO 4532. The resistance to impact should be carried out at a distance of at least 20 mm from the edges and the sides.

**4.10 Determination of the adherence of the porcelain and vitreous enamel to the substrate**

The testing of the adherence of the porcelain and vitreous enamel coating should be carried out using the method as specified in EN10209 Annex C.

**4.11 Determination of the resistance to thermal shock**

The determination of the resistance to thermal shock should be carried out using the methods as specified in EN ISO 2747, unless the objects concerned are not suitable for this test method. In these cases, the test method should be agreed and specified in the quality requirements.

**4.12 Determination of the porosity by the high voltage test**

The determination of the porosity by the high voltage test of the porcelain and vitreous enamel coating should be carried out using the methods as specified in EN ISO 2746 and EN ISO 28721-1/4.3. High voltage test at 20 kV – subsequently 12 kV

**4.13 Determination, detection and location of defects (non-destructive)**

The non-destructive determination and detection of defects in the porcelain and vitreous enamel coating should be carried out using either method A or B as specified in EN ISO 8289-1. The test method selected should depend on the specific application circumstances. EN ISO 8289-2 will apply for enamel slurry.

**4.14 Determination of the resistance to abrasion**

Now see 4.26

**4.15 Determination of the resistance to chemical corrosion by boiling of a solution of sodium pyrophosphate**

The definition of the resistance to chemical corrosion of a solution of sodium pyrophosphate should be carried out using EN ISO 28706-2/15 (see 4.7), using the following test solution:

100 grams sodium pyrophosphate (analytical grade)

1000 ml distilled water

The solution should be freshly prepared.

The test should be carried out for 5 hours of hard boiling during which heavy vapour bubbles must be rising from the bottom of the apparatus. The effect is measured by the loss of mass of the test plates and given in g/m<sup>2</sup>. (This test solution will need to be made up hot as the solubility at 20° C is approximately 50 g/L, and also that this test solution is twice the concentration of that used in the “Hoover” test.)

**4.16 Determination of the permeability to hydrogen**

The determination of the permeability of a cold rolled steel to hydrogen should be carried out using the methods as specified in EN 10209 Annex A1. See part 4.3 of EN ISO 28763.

**4.17 Determination of gloss**

The determination of gloss should be carried out using the methods as specified in EN ISO 2813. (This covers measurements at 20°, 60° and 85°. The USA measure specular gloss of ceramic surfaces at 45° {ASTM C246} – The angle of measurement must be specified by agreement.)

**4.18 Determination of scratch resistance**

The determination of scratch resistance should be carried out using the methods as specified in EN ISO 15695.

**4.19 Determination of colour difference**

The determination of colour difference should be carried out using the methods as specified in EN ISO/CIE 11664 and EN ISO 18314.

**4.20 Determination of edge coverage**

The determination of edge coverage should be carried out using the method as specified in EN ISO 28723.

**4.21 Determination of resistance to heat**

Determination of the resistance to heat should be carried out using the methods as specified in EN ISO 4530.

**4.22 Determination of the resistance to fish scaling**

The determination of the resistance to fishscale should be carried out using the methods as specified in EN 10209 Annex A2, by which the test sheet (150 mm x coil width) is pre-treated without nickel. The front and back sides are enamelled with a fishscale sensitive porcelain and vitreous enamel supplied by the several manufacturers of enamel/frit. Coating thickness, firing temperature, firing time and potential thermal treatment shall be specified by the frit supplier. See part 4.4 of EN ISO 28763.

**4.23 Requirements, measurements and tests for cookware, ovenware (& kettles)**

The requirements for measurements and tests for cookware are specified in EN 12983, for ovenware EN 13834 (and for kettles in EN 13750)

**4.24 Determination of the resistance of domestic utensils to mechanical dishwashing**

The determination of domestic utensils to mechanical dishwashing should be carried out in a quality agreement between the enamelling company and the customer.

**4.25 Determination of the resistance to chemical corrosion by hot sodium hydroxide solution**

The determination of the resistance to chemical corrosion by hot sodium hydroxide should be carried out using the methods as specified in EN ISO 28706-4/10 and EN ISO 28721-2/4.2.

**4.26 Determination of abrasion resistance**

The determination of the abrasion resistance should be carried out using the methods as specified in ASTM C501. For some applications EN ISO 6370-1 and -2 can be used.

**4.27 Determination of the steel surface activity (pickling speed, weight loss)**

The determination of the steel surface activity should be carried out using the methods as specified in EN 10209: Annex B.

**4.28 Determination of the quality of steel for enamelling**

Qualities of cold rolled steels for enamelling are specified in EN 10209.

EN 10025 or EN 10111 are classifying hot rolled steel qualities, but do not mention any specific performance related to enamelling.

Enamelling with hot rolled steels is not guaranteed, any quality can be used, but here are some recommendations:

DD11 or DD12 & DD13 (as defined in EN10111) can result in inconsistent mechanical properties and fatigue resistance (cyclic pressure tests) after enamelling.

References S235 JR, S275 JR, S355 MC or S240EK & S300EK (those two are not official references and proposed only by few steel providers) are preferred.

Also, qualities from EN 10149 for HSLA steels and EN 10222-1 for steel forgings for pressure applications are used.

**4.29 Determination of the quality of Aluminium for enamelling**

The quality of Aluminium for enamelling should be pure Al > 99,5 %, Al or Al-Mn (Mn < 1,7 %) Mg max 0,01 %. For other alloys a test enamelling should be done before production.

**4.30 Identification of defects for hot water tanks (non-destructive - visual only)**

The visual identification of defects should be carried out using the methods as specified in DIN 4753; BS 3831 Appendix A; IVE Atlas of Defects.

**4.31 Determination and measurement of protective current requirements for hot water tanks**

The determination and measurement of protective current requirements should be carried out using the methods as specified in DIN 4753.

**4.32 Determination and control of release of elements for hot water tanks**

The determination of the release of elements such as lead, cadmium, etc. should be carried out using the methods as specified in DIN 4753 and the UBA-Assessment Guideline for enamelled and ceramic materials in contact with drinking water. There may be differing requirements for the limits for this specification dependent on national laws. (See also Clause 4.8).

**4.33 Determination of the chemical corrosion rate in hydrochloric acid**

The determination of the chemical corrosion rate in hydrochloric acid should be carried out using the methods as specified in EN ISO 28706-2/13 and EN ISO 28721-2/4.1.

**4.34 Determination of the crack formation temperature**

The determination of the crack formation temperature should be carried out using the methods as specified in EN ISO 13807.

**4.35 Determination of the resistance to chemical corrosion by boiling sulphuric acid**

The determination of the resistance to chemical corrosion by boiling sulphuric acid should be carried out using the methods as specified in EN ISO 28706-2/12.

**4.36 Method for the packing of heat exchanger elements**

The method of packing of heat exchanger elements in baskets should be carried out using the methods as specified in EEA Specification 8.7.8

**4.37 Determination of the resistance to long-term chemical corrosion exposure to boiling water**

The determination of the resistance to long-term chemical corrosion exposure to boiling water should be carried out using the apparatus as specified in EN ISO 28706-2/6 and the test method described in EEA specification 8.6.1.

**4.38 Determination of the resistance to chemical corrosion by drinking water**

The determination of the resistance to chemical corrosion by drinking water should be carried out using the methods as specified in EN ISO 28706-2/11, EN ISO 28706-1/9 and EEA Specification 8.6.2. Testing time is 48 hours and temperature 60°C.

**4.39 Determination of the adherence of porcelain and vitreous enamel to steel of more than 3 mm thickness**

The determination of the adherence of porcelain and vitreous enamel to steel of more than 3 mm. Thickness should be carried out using the methods as specified in EEA Specification 8.6.3.

**4.40 Determination of thermal shock resistance of enamelled articles into water**

The determination of the thermal shock resistance of enamelled articles into water should be carried out using the methods as specified in EEA Specification 8.6.4.

EN ISO 28763 Annex A method may apply for some applications.

**4.41 Determination of thermal shock resistance of enamelled articles in an air-stream**

The determination of the thermal shock resistance of enamelled articles in an air stream should be carried out using the methods as specified in EEA Specification 8.6.5.

**4.42 Determination of the adhesion of porcelain and vitreous enamels on Aluminium under the action of an electrolyte (spalling test)**

The determination of the adhesion of porcelain and vitreous enamels on Aluminium should be carried out using the methods as specified in EN ISO 13805.

**4.43 Quality requirements for regenerative, packed and enamelled heat exchangers for air-gas and gas-gas heaters**

This standard defines the minimum requirements and the functional characteristics of the porcelain and vitreous enamel coating applied to profiled steel heat exchanger panels in regenerative heat exchanges, before as well as after packing in the baskets. See EN ISO 28763.

**4.44 Determination of the fluidity behaviour, fusion flow test**

Method as specified in EN ISO 4534.

**4.45 Determination of the coefficient of mean linear thermal expansion of glass**

Method as specified in EN ISO 20274 and DIN ISO 7991.

**4.46 Characteristics of the porcelain and vitreous enamel coatings applied to steel for writing surfaces**

This standard defines the requirements and the functional and aesthetic characteristics of porcelain and vitreous enamel coatings applied to plane steel for use as writing surfaces (whiteboards and chalkboards). EN ISO 28762.

**4.47 Characteristics of the porcelain and vitreous enamel coatings applied to steel panels intended for architecture**

This European standard specifies the requirements for porcelain and vitreous enamel coating applied to plane rolled steel for both exterior (exposed to weathering) and interior parts of the buildings. It includes the functional and aesthetic characteristics and resistance to graffiti of these coatings. EN ISO 28722.

**4.48 Determination of the resistance against corrosion and creeping after mechanical impact**

See EEA specification 8.6.7

**4.49 Determination against climatic impact like weathering and UV-resistance**

See EEA specification 8.6.8

## 5.0 ABBREVIATIONS

APEV	French Enamel Association	RAL	Committee for Terms of Delivery and Quality Assurance
ASTM	American Society for Testing Materials	RKW	Rationalizing Curatorship of the German Economy
ASQ	German Working Association for Statistical Quality Control	SE	Enamel Foundation for the Netherlands /Belgium
BAM	Federal Institution for Testing of Materials	sig.diff.	Significantly different
BS	British Standard	SPPE	Polish Enamel Association
BSI	British Standards Institute	TED	Turkish Enamel Association
CEN	European Committee for Standardization	TC	Technical Committee EEA
CIE	International Commission for Lighting	TrinkwV	Trinkwasserverordnung (Germany)
CISP	Italian Enamel Association	TÜV	Association for Technical Supervision (Germany)
DEV	German Enamel Association	UBA	Umweltbundesamt (Germany)
DIN	German Institute for Standardization	VEA	British Vitreous Enamel Association
DNA	German Committee for Standards (within DIN)		
EC	Executive Committee		
EEA	European Enamel Association		
EN	European Standard		
EOQC	European Organization for Quality Control		
IEI	International Enamellers Institute		
ISO	International Standards Organization		
ITE	International Tests for Enamel of the IEI		
IVE	Institute of Vitreous Enamellers		
MPA	Material Test-Institute		
MZE	Hungarian Enamel Association		
NEN	Dutch Standard		
NHR	Standardization Board for Heating and Air Conditioning		
NMP	Standardization Board for Material Testing		
NNI	Dutch Institute for Standardization		
ÖEV	Austrian Enamel Association		
PEI	Porcelain Enamel Institute		

## 6.0 BASIC CHARACTERISTICS OF PORCELAIN AND VITREOUS ENAMELLED SURFACES

**Porcelain and vitreous enamelled products exhibit a number of beneficial and unique combinations of characteristics and properties**

- It has a high corrosion resistance
- It is available for a wide range of uses, in varying applications and designs
- It is available in a large choice of colours
- It is available in glossy or matt surfaces
- It is capable of further decoration
- It combines the composite benefits of the hardness and strength of glass, with the strength and resilience of the base metal
- It is scratch and abrasion resistant
- It is frost resistant to - 60 °C (special porcelain and vitreous enamels: -273,15 °C)
- It is thermally stable to + 450 °C (special porcelain and vitreous enamels: +900 °C)
- It shows good climate and weather resistance
- It is resistant to acid and environmental attack
- It is non-combustible (class A according to DIN 4102)
- It is non fading and colour stable
- It is resistant to photo-chemical effects
- It is hygienic and resistant to bacteria
- It shows no allergic reaction
- The finished product requires little maintenance and is easy to clean
- It is manufactured from natural resources
- It employs environmentally friendly manufacturing and processing practices
- It uses non-organic solvents i.e. water
- It is fully recyclable

These characteristics of porcelain and vitreous enamelled surfaces are not included in the following section (7.0), which specifies defined quality requirements for each area of application.



## 7.0 APPLICATION AREAS

In addition to the general quality requirements, the porcelain and vitreous enamelled products with **“European Enamel Association” label/certificate** have to meet the requirements applicable to the hereunder application areas depending of their sectors of activity.

The corresponding requirements can be found on the following pages using the application area number 7. XX

- |       |  |       |  |
|-------|--|-------|--|
| 7.1.  | Cookers  | 7.14. | Architectural panels for indoor applications                                 |
| 7.2.  | Kitchen sinks  | 7.15. | Chalkboards  |
| 7.3.  | Refrigerators and freezers   | 7.16. | Projection boards  |
| 7.4.  | External steel parts of small household appliances                                 | 7.17. | Whiteboards  |
| 7.5.  | Steel holloware  | 7.18. | Regenerative, packed heat-exchangers   |
| 7.6.  | Holloware made of cast iron  | 7.19. | Heat exchanger sheet pairs and tubes for recuperative exchangers             |
| 7.7.  | Exterior enamelling of frying pans, casseroles and pots of Aluminium               | 7.20. | Industrial tanks – 1 <sup>st</sup> GROUP                                     |
| 7.8.  | Washing machines, drums and spinner baskets, wash kettles, dish-washers and dryers | 7.21. | Industrial tanks – 2 <sup>nd</sup> GROUP                                     |
| 7.9.  | Sanitary ware, bathtubs and shower basins  | 7.22. | Articles of cast iron in contact with water                                  |
| 7.10. | Bathtubs, shower basins of cast iron   | 7.23. | Armatures, form parts, pipes, valves and agitators for the chemical industry |
| 7.11. | Room/space-heating and geysers (water heaters)                                     | 7.24. | Waste-pipes of cast iron   |
| 7.12. | Hot water tanks (boilers)  | 7.25. | Agricultural silos   |
| 7.13. | Architectural panels for outdoor applications                                      | 7.26. | Agrarian articles  |
|       |  | 7.27. | Signs and advertising boards   |

## 7.1. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED COOKERS (free standing and built in)

### 7.1.1 Application area

These requirements are applicable for kitchen appliances parts of enamelled cast iron or steel, such as:

- burner caps
- pan supports
- hobs
- control panels
- cavities
- baking plates
- outside panels

### 7.1.2 Test methods

Item	Name	Applicable standards
4.2	measurement of the thickness of the base substrate metal	EN ISO 16809
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.9	determination of the impact resistance	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.17	determination of gloss	EN ISO 2813, ASTM C246
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664
4.21	determination of the resistance to heat	EN ISO 4530
4.28	determination of the quality of steel for enamelling	EN 10209 for cold rolled steel and see 4.28 recommendations for hot rolled steels, HSLA steels and steel forgings for pressure applications
4.39	determination of the adherence of enamel to steel of more than 3 mm thickness	EEA Specification 8.6.3
4.40	determination of thermal shock resistance of enamelled articles into water	EEA Specification 8.6.4

## 7.1.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.2 material thickness	burner lid and grates made of cast iron min. 3 mm troughs, baking trays and external parts min. 0,70 mm switch panels min. 0,60 mm baking ovens min. 0,50 mm		determination during design
4.3 thickness enamel	coating cast iron burner caps and pan supports max.0.60mm other applications max. 0.40 mm		S4/AQL 6.5
4.4 cold citric acid	min. class A +		when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.9 impact resistance	at 20 N no damage > 2 mm in diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.10 adherence	min. 3; for thick material min. "good" according to EEA 8.6.3	possibly done on test sheets (see 4.1)	in production 1 x a day
4.17 determination of gloss	max. allowed difference at a measuring angle of 60 is: + 4 at gloss 0 - 30 + 6 at gloss 30 - 70 + 8 at gloss 70 - 100	for burner caps, hobs, control panels and outside panels	when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.19 colour difference	even and smooth surface, evaluated equal to the appearance of an approved enamelled sample	colour difference possibly measured with a spectrometer and tolerances previously agreed by interested partners	in production 100%
4.21 resistance to heat	burner caps and pan supports: 400 °C during 3 hours		when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.28 steel quality	in accordance with norm EN 10209		determination during design
4.39 adherence	for cast iron: min. good	possibly done on test sheets (see 4.1)	in production 1 x a day
4.40 thermal shock resistance	burner caps and pan supports: 380 °C (5x) hobs: 200 °C (5x) baking platies: 260 °C (5x)	for pan supports, only applicable for the fingertips	in production 1 x a day

## 7.2. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED KITCHEN SINKS

### 7.2.1 Application area

These requirements are applicable for enamelled steel and enamelled stainless-steel sinks.

### 7.2.2 Test methods

Item	Name	Applicable standards
4.2	measurement of the thickness of the base substrate metal	EN ISO 16809
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.5	determination of the resistance to chemical corrosion by boiling citric acids	EN ISO 28706-2/11, EN ISO 28706-2/6
4.7	determination of the resistance to chemical corrosion by boiling detergent solution	EN ISO 28706-3/10, EN ISO 28706-2/6
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664
4.26	determination of abrasion resistance	ASTM C501, EN ISO 6370-1 and EN ISO 6370-2
4.28	determination of the quality of steel for enamelling	EN 10209 for cold rolled steel and see 4.28 recommendations for hot rolled steels, HSLA steels and steel forgings for pressure applications

[Items 4.1 - 4.49](#)

## 7.2.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.2 material thickness	min. 0.90 mm		determination during design
4.3 thickness enamel coating	max. 0.50 mm		S4/AQL 6.5
4.4 cold citric acid	min. class A		when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.5 boiling citric	acid max. 15 g/m <sup>2</sup> per 2 1/2 hour		when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.7 detergent solution resistance	max. 20 g/m <sup>2</sup> per 24 hours	test duration 24 hours	when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.9 impact resistance	at 20 N no damage > 2 mm diameter after 24 hours	on test sheets conform to EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.10 adherence	min. 2	on test sheets conform to EN ISO 28764	in production 1 x a day
4.19 colour difference	even and smooth surface, evaluated equal to the appearance of an approved enamelled sample	Colour difference possibly measured with a spectrometer and tolerances previously agreed by interested partners	In production 100%
4.26 abrasion resistance	max. 0.1 gram	in accordance with ASTM C501 sandpaper S33/1kg/1000 rotations	when taking into production a sig.diff. enamel recipe (excluding colour oxides) but at least 1x a year
4.28 steel quality	in accordance with norm EN 10209	is recommended: DC04EK / DC05EK / DC06EK / DC07EK	determination during design

### 7.3. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED COMPONENTS OF REFRIGERATORS AND FREEZERS

#### 7.3.1 Application area

These requirements are applicable for enamelled components in refrigerators and freezers, such as:

- the interior lining
- vegetable/fruit tray
- outside panels

#### 7.3.2 Test methods

Item	Name	Applicable standards
4.2	measurement of the thickness of the base substrate metal	EN ISO 16809
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664
4.28	determination of the quality of steel for enamelling	EN 10209 for cold rolled steel and see 4.28 recommendations for hot rolled steels, HSLA steels and steel forgings for pressure applications

[Items 4.1 - 4.49](#)

## 7.3.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.2 material thickness	min. 0.60 mm		determination during design
4.3 thickness enamel coating	max. thickness interior lining 0.30 mm outside panels and vegetable tray 0.40 mm	interior lining: thickness counts for one-layer-system  outside panels and vegetable tray: thickness counts for ground- and cover layer	S4/AQL 6.5
4.4 cold citric acid	class A		when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.9 impact resistance	at 20 N no damage > 2 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.10 adherence	min. 3	on test sheets conform to EN ISO 28764	in production 1 x a day
4.19 colour difference	even and smooth surface, evaluated equal to the appearance of an approved enamelled sample	Colour difference possibly measured with a spectrometer and tolerances previously agreed by interested partners	In production 100%
4.28 steel quality	in accordance with norm EN 10209	is recommended: DC04EK / DC01EK	determination during design

## 7.4 QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED EXTERNAL STEEL PARTS OF SMALL HOUSEHOLD APPLIANCES

### 7.4.1 Application area

These requirements are applicable for enamelled external steel parts of:

- toasters
- barbecues
- hot-plates
- baking forms

### 7.4.2 Test methods

Item	Name	Applicable standards
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.8	determination of the release of toxic elements	national laws
4.9	determination of the impact resistance	EN ISO 4532
4.10	determination of the adherence	EN 10209 Annex D
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664
4.28	determination of the quality of steel for enamelling	EN 10209 for cold rolled steel and see 4.28 recommendations for hot rolled steels, HSLA steels and steel forgings for pressure applications

[Items 4.1 - 4.49](#)



## 7.4.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.3 thickness enamel coating	max. 0.40 mm		S4/AQL 6.5
4.4 cold citric acid	class A		when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.8 release of toxic elements	conform requirements of the national laws		when taking into production a sig.diff. enamel recipe
4.9 impact resistance	at 20 N no damage > 2 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.10 adherence	min. 2		1x a day
4.19 colour difference	even and smooth surface, evaluated equal to the appearance of an approved enamelled sample	Colour difference possibly measured with a spectrometer and tolerances previously agreed by interested partners	In production 100%
4.28 steel quality	in accordance with norm EN 10209	is recommended: DC04EK	determination during design

[Items 4.1 - 4.49](#)

## 7.5. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED STEEL HOLLOWARE

### 7.5.1 Application area

These requirements are applicable for enamelled steel holloware, which is suitable for electrical as well as for gas cooking and existing out of the following categories:

- frying-pans and pots
- saucepans
- lids
- kettles (coffee and teapots)

### 7.5.2 Test methods

Item	Name	Applicable standards
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.5	determination of the resistance to chemical corrosion by boiling citric acids	EN ISO 28706-2/11, EN ISO 28706-2/6
4.6	determination of the resistance to chemical corrosion by boiling water and/or water vapour	EN ISO 28706-2/14, EN ISO 28706-2/6
4.8	specification and determination of the release of toxic elements	national laws
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.11	determination of the resistance to thermal shock	EN ISO 2747
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664
4.23	requirements, measurements and tests for cookware, ovenware and kettles	for cookware EN 12983, for ovenware EN 13834 and for kettles in EN 13750
4.24	determination of the resistance of domestic utensils to mechanical dishwashing	EN 12875-1
4.28	determination of the quality of steel for enamelling	EN 10209 for cold rolled steel and see 4.28 recommendations for hot rolled steels, HSLA steels and steel forgings for pressure applications

[Items 4.1 - 4.49](#)

## 7.5.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.3 thickness enamel coating	interior max. 0.35 mm, exterior max. 0.45 mm	excluding decor	S4/AQL 6.5
4.4 cold citric acid	min. class A		when taking into production a sig.diff. enamel recipe, but at least 2 x a year
4.5 boiling citric acid	interior max. 5 g/m <sup>2</sup> per 2 1/2 hours exterior max. 10 g/m <sup>2</sup> per 2 1/2 hours	on test sheets conform EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 2 x a year
4.6 water	boiling water interior max. 2,5 g/m <sup>2</sup> /24h (mean value)	on test sheets conform EN ISO 28764 test duration 48 hours	when taking into production a sig.diff. enamel recipe, but at least 2 x a year
water vapour	interior max.5 g/m <sup>2</sup> /24 hours (mean value)	on test sheets conform EN ISO 28764 duration test 48 hours	
4.8 release of toxic elements	conform to requirements of national laws		when taking into production a sig.diff. enamel recipe and following requirements of proper and safe surveillance plan
4.9 impact resistance	at 20 N no damages > 2 mm diameter after 24 hours	only bottom is to be tested	weekly min. 3 pans/pots
4.10 adherence	min. 3		weekly min. 3 pans/pots
4.11 thermal shock resistance	min. 280 °C	not applicable for lids	when taking into production a sig.diff. enamel recipe, but at least 1 x a month
4.19 colour difference	even and smooth surface, evaluated equal to the appearance of an approved enamelled sample	Colour difference possibly measured with a spectrometer and tolerances previously agreed by interested partners	In production 100%
4.28 steel quality	in accordance with norm EN 10209	is recommended: DC04EK /DC05EK / DC06EK / DC07EK	determination during design

## 7.5.4 Remark

On top of the quality requirements mentioned here above, also the requirements as mentioned in 4.23 need to be met.

For the testing frequency at 4.23, 4.9, 4.10 and 4.11, tests can be carried out on the same three products, taking into account a logical sequence 4.23 - 4.11 - 4.9 then 4.10.

## 7.6. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED HOLLOWARE MADE OF CAST IRON

### 7.6.1 Application area

These requirements are applicable for holloware of enamelled cast iron suitable for electric cooking as well as for gas cooking, and that consists of the following categories:

- frying-pans, casseroles, pots
- saucepans
- lids

### 7.6.2 Test methods

Item	Name	Applicable standards
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.5	determination of the resistance to chemical corrosion by boiling citric acids	EN ISO 28706-2/11, EN ISO 28706-2/6
4.6	determination of the resistance to chemical corrosion by boiling water and/or water vapour	EN ISO 28706-2/14, EN ISO 28706-2/6
4.8	specification and determination of the release of toxic elements	national laws
4.9	determination of the resistance to impact	EN ISO 4532
4.11	determination of the resistance to thermal shock	EN ISO 2747
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664
4.23	requirements, measurements and tests for cookware, ovenware and kettles	for cookware EN 12983, for ovenware EN 13834 and for kettles in EN 13750
4.24	determination of the resistance of domestic utensils to mechanical dishwashing	EN 12875-1
4.39	determination of the adherence of enamel to steel of more than 3 mm thickness	EEA Specification 8.6.3

[Items 4.1 - 4.49](#)

## 7.6.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.3 thickness enamel coating	internal 0.20-0.50 mm external max. 0.70 mm	excluding décor	in production S4/AQL 6.5
4.4 cold citric acid	internal min. class A		when taking into production a sig.diff. enamel recipe, but at least 2x a year
4.5 boiling citric acid	internal weight loss: max. 10 g/m <sup>2</sup> per 2 1/2 hours	on test sheets conform EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 2 x a year
4.6 boiling water water vapour	internal weight loss: max. 5 g/m <sup>2</sup> /24h (mean value) internal weight loss: max. 10 g/m <sup>2</sup> /24h (mean value)	on test sheets conform EN ISO 28764 test duration 48 hours	when taking into production a sig.diff. enamel recipe, but at least 2 x a year
4.7 detergent solution	in consultation but claim per 24 hours	on test sheets conform EN ISO 28764, test duration 24 hours	when taking into production a sig.diff. enamel recipe, but at least 2 x a year
4.8 release of toxic elements	conform requirements national laws		when taking into production a sig.diff. enamel recipe and following requirements of proper and safe surveillance plan
4.9 impact resistance	at 20 N no damages > 2 mm diameter after 24 hours		weekly min. 3 pans/pots
4.11 thermal shock resistance	280 °C	not applicable for lids	when taking into production a sig.diff. enamel recipe but at least 1x per month
4.19 colour difference	even and smooth surface, evaluated equal to the appearance of an approved enamelled sample	Colour difference possibly measured with a spectrometer and tolerances previously agreed by interested partners	In production 100%
4.39 adherence	min. "good"		weekly min. 3 pans/pots

## 7.6.4 Remark

On top of the quality requirements mentioned here above, also the requirements as mentioned in 4.23 need to be met.

For the testing frequency at 4.23, 4.9 and 4.11, tests can be carried out on the same three products, taking into account a logical sequence 4.23 - 4.11 then 4.9.

## 7.7. QUALITY REQUIREMENTS FOR EXTERIOR PORCELAIN AND VITREOUS ENAMELLING OF FRYING-PANS, CASSEROLES AND POTS OF ALUMINIUM

### 7.7.1 Application area

These requirements are applicable for exterior enamelled parts of:

- frying-pans, casseroles and pots
- saucepans.

### 7.7.2 Test methods

Item	Name	Applicable standards
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.8	specification and determination of the release of toxic elements	national laws
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664
4.23	requirements, measurements and tests for cookware and ovenware	for cookware EN 12983, for ovenware EN 13834
4.29	determination of the quality of Aluminium for enamelling	
4.42	determination of the adhesion of enamels on Aluminium under the action of an electrolyte (spalling test)	EN ISO 13805

[Items 4.1 - 4.49](#)

## 7.7.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.3 thickness enamel coating	0.05 - 0.15 mm		S4/AQL 6.5
4.8 release of toxic elements	conform requirements national laws		when taking into production a sig.diff. enamel recipe and following requirements of proper and safe surveillance plan
4.19 colour difference	even and smooth surface, evaluated equal to the appearance of an approved enamelled sample	Colour difference possibly measured with a spectrometer and tolerances previously agreed by interested partners	In production 100%
4.29 Aluminium quality	pure Al > 99.5 % Al or Al-Mn (Mn < 1.7 %), Mg max. 0.010 %		when taking into production
4.42 adhesion	EN ISO 13805		when taking into production a sig.diff. enamel recipe, but at least 1 x a year

## 7.7.4 Remark

On top of the quality requirements mentioned here above, also the requirements as mentioned in 4.23 need to be met.

## 7.8. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED WASHING MACHINES, DRUMS AND SPINNER BASKETS, WASH KETTLES, DISH-WASHERS AND DRYERS

### 7.8.1 Application area

These requirements are applicable for parts of washing boilers, drums and spinner baskets, enamelled parts such as:

- washing machines: washing drums, spinner baskets, cover-tops and outside parts
- washing kettles: bottom plates and lids
- dish-washers: rinsing-areas and outside panels
- dryers: outside panels

### 7.8.2 Test methods

Item	Name	Applicable standards
4.2	measurement of the thickness of the base substrate metal	EN ISO 16809
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.6	determination of the resistance to chemical corrosion by boiling water and/or water vapour	EN ISO 28706-2/14, EN ISO 28706-2/6
4.7	determination of the resistance to chemical corrosion by boiling detergent solution	EN ISO 28706-3/10, EN ISO 28706-2/6
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.11	determination of the resistance to thermal shock	EN ISO 2747
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664
4.28	determination of the quality of steel for enamelling	EN 10209 for cold rolled steel and see 4.28 recommendations for hot rolled steels, HSLA steels and steel forgings for pressure applications

[Items 4.1 - 4.49](#)



## 7.8.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.2 material thickness	min. material thickness: washing machines: drums 0,9 mm and centrifugal drum: 0,8 mm cover plates and outer cladding: 0,7 mm wash boiler: Ø < 460 mm 1,0 mm, Ø > 460 mm 1,25 mm dish-washers: rinsing area 0,9 mm outer cladding: 0,7 mm dryer: 0,7 mm		determination during design
4.3 thickness enamel coating	max. 0.40 mm		S4/AQL 6.5
4.4 cold citric acid	cover-tops and outside panels of washing machines, dish-washers and dryers: min. class A		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.6 boiling water and water vapour	water: weight lost max. 5 g/m <sup>2</sup> /24h (mean value)  water vapour: weight lost max. 10 g/m <sup>2</sup> /24h (mean value)	test duration 48 hours  test duration 48 hours is not applicable for outside panels, dish-washers, dryers and washing machines	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.7 detergent solution	weight loss: max. 20 g/m <sup>2</sup> per 2.5 hours;	test duration 2.5 hours	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.9 impact resistance	at 20 N no damage > 2 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.10 adherence	min. 3	on test sheets conform to EN ISO 28764	in production 1 x a day
4.11 thermal shock resistance	washing kettles: 240 °C	on test sheets conform to EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.19 colour difference	even and smooth surface, evaluated equal to the appearance of an approved enamelled sample	Colour difference possibly measured with a spectrometer and tolerances previously agreed by interested partners	In production 100%
4.28 steel quality	in accordance with norm EN 10209	is recommended: DC03ED / DC06ED / DC04EK	determination during design

## 7.9. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED STEEL SANITARY WARE, BATHTUBS AND SHOWER BASINS

### 7.9.1 Application area

These requirements are applicable for bathtubs, shower basins and enamelled steel sanitary ware, such as:

- piss-pots and slop-pails
- wash-bowls and rinsing-tubs for bathrooms
- humidifiers and cisterns

### 7.9.2 Test methods

Item	Name	Applicable standards
4.2	measurement of the thickness of the base substrate metal	EN ISO 16809
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.5	determination of the resistance to chemical corrosion by boiling citric acids	EN ISO 28706-2/11, EN ISO 28706-2/6
4.6	determination of the resistance to chemical corrosion by boiling water and/or water vapour	EN ISO 28706-2/14, EN ISO 28706-2/6
4.7	determination of the resistance to chemical corrosion by boiling detergent solution	EN ISO 28706-3/10, EN ISO 28706-2/6
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664
4.26	determination of abrasion resistance	ASTM C501, EN ISO 6370-1 and EN ISO 6370-2

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## 7.9.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.2 material thickness	min. thickness for: chamber pot and rinse bucket: 0,75 mm wash basins and sinks, humidifier and water tanks: 0,90 mm bathtubs: 2,00 mm, shower basins: 1,50 mm		determination during design
4.3 thickness enamel coating	max. thickness 0.60 mm min. thickness 0.20 mm		S4/AQL 6.5
4.4 cold citric acid	min. class A + humidifiers and cisterns min. class A; medical bathtubs class AA		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
cold sulphuric acid	min. class A +, medical bathtubs class AA		
4.5 boiling citric acid	max. 5 g/m <sup>2</sup> per 2.5 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.6 boiling water	10 g/m <sup>2</sup> /24h (mean value)	test duration 48 hours	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.7 detergent solution	wash-bowls, rinsing-tubs and bathtubs max. 8 g/m <sup>2</sup> per 2.5 hours	test duration 2,5 hours	when taking into production a sig.diff. recipe, but at least 1 x a year
4.9 impact resistance	at 20 N no damage > 2 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.10 adherence	< 2 mm min. 3, for medical bathtubs min. 2 > 2 mm min. 2	on test sheets conform to EN ISO 28764	in production 1 x a day
4.19 colour difference	even and smooth surface, evaluated equal to the appearance of an approved enamelled sample	Colour difference possibly measured with a spectrometer and tolerances previously agreed by interested partners	In production 100%
4.26 abrasion resistance	max. 0.1 gram	in accordance with ASTM C501 sandpaper S33/1kg/1000 rotations	when taking into production a sig.diff. enamel recipe (excluding colour oxides) but at least 1 x a year
4.28 steel quality	in accordance with norm EN 10209	is recommended: DC04EK / DC05EK / DC06EK	determination during design

**7.10. QUALITY REQUIREMENTS FOR CAST IRON BATHTUBS, SHOWER BASINS**

## 7.10.1 Application area

These requirements are applicable for cast iron bathtubs and shower basins for household and medical applications.

## 7.10.2 Test methods

Item	Name	Applicable standards
	cast iron quality	EN 1561
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.5	determination of the resistance to chemical corrosion by boiling citric acids	EN ISO 28706-2/11, EN ISO 28706-2/6
4.6	determination of the resistance to chemical corrosion by boiling water and/or water vapour	EN ISO 28706-2/14, EN ISO 28706-2/6
4.7	determination of the resistance to chemical corrosion by boiling detergent solution	- test apparatus according to EN ISO 28706-2 - test solution according to EN ISO 28706-3/9
4.9	determination of the resistance to impact	EN ISO 4532
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664

[Items 4.1 - 4.49](#)

## 7.10.3 Quality requirements

Test method	Requirement	Remarks	Frequency
	cast iron quality		
4.3 thickness enamel coating	minimum 0.60 mm		S4/AQL 6.5
4.4 cold citric acid	- citric acid class A + - for medical bathtubs and shower basins class AA		when taking into production a sig.diff. recipe, but at least 1 x a year
cold sulphuric acid	- sulphuric acid class A + - for medical bathtubs and shower basins class AA		
4.5 boiling citric acid resistance	weight loss: max. 5 g/m <sup>2</sup> per 2.5 hours		enamel recipe, but at least 1 x a year
4.6 boiling water	weight loss: max. 10 g/m <sup>2</sup> /24h (mean value)	test duration 48 hours	when taking into production a sig.diff.
4.7 detergent solution	weight loss: max. 8 g/m <sup>2</sup> per 2.5 hours	test duration 2,5 hours	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.9 impact resistance	at 20 N no damage > 2 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.19 colour difference	even and smooth surface, evaluated equal to the appearance of an approved enamelled sample	Colour difference possibly measured with a spectrometer and tolerances previously agreed by interested partners	In production 100%

## 7.11. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED PIECES OF APPARATUS FOR ROOM/ SPACE-HEATING AND GEYSERS (WATER-HEATERS)

**For power plant heat exchangers see 7.18 and 7.19**

### 7.11.1 Application area

These requirements are applicable for enamelled pieces, such as:

- steel panels for room heating
- steel combustion-chambers
- wall-grids which are applied in pieces of apparatus for space-heating and geysers, which can be fired with gas, coal, as well as oil (petroleum).
- chimney tubes and pipes

### 7.11.2 Test methods

Item	Name	Applicable standards
4.2	measurement of the thickness of the base substrate metal	EN ISO 16809
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.13	determination, detection and location of defects (non-destructive)	EN ISO 8289
4.21	determination of resistance to heat	EN ISO 4530
4.28	determination of the quality of steel for enamelling	EN 10209 for cold rolled steel and see 4.28 recommendations for hot rolled steels, HSLA steels and steel forgings for pressure applications
4.40	determination of thermal shock resistance of enamelled articles into water	EEA Specification 8.6.4

[Items 4.1 - 4.49](#)

## 7.11.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.2 material thickness	panels, space heating and continuous flow heaters min. 0,70 mm chimney inserts and -tubes, heaters, boilers for central heating and air heating min. 0,90 mm		determination during design
4.3 thickness enamel coating	wall-grids, cladding panels, geysers combustion areas max. 0.40 mm chimney tubes and pipes, heat-exchangers max. 0.30 mm		S4/AQL 6.5
4.4 cold citric acid	wall-grids and panels space heating: no acid resistance upper side: class A geysers: class A combustion areas: gas fired: no acid resistance oil fired: class A	on test sheets conform EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.9 impact resistance	at 20 N no damage > 2 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.10 adherence	min. 2	on test sheets conform to EN ISO 28764	in production 1 x a day
4.13 defects	Normal heat-exchangers: max. 20 defects/m <sup>2</sup> according to method A  Low temperature heat-exchangers: max. 20 defects/m <sup>2</sup> according to method A	not applicable for borders not valid in case cermet is applied  not valid for borders not valid in case cermet is applied	in production 1 x a day  in production 1 x a day
4.21 resistance to heat	when overloading of 50 °C above normal application temperature after 48 hours no bubbles, chipping off, melting or open palpable cracks	application temperature	determined in draft-stage and when changing enamel recipe
4.28 steel quality	in accordance with norm EN 10209	is recommended: DC04EK	determination during design
4.40 thermal shock resistance	panels space-heating, geyser 250 °C (test 5 x), combustion areas gas fired 250 °C (5 x), oil fired 400 °C (5x), heat-exchangers 350 °C (5 x), wall-grids: not applicable	the thermal shock resistance of the pieces is to be determined by heating to the temperature as recorded in the table and afterwards cooled down in water of 20 ± 2 °C	when taking into production a sig.diff. enamel recipe, but at least 1 x a year

#### 7.11.4 Remarks

For steel-plated combustion spaces and heat-exchangers, counts that in case the enamel layer shows so-called drain lines, then the enamel layer should be max. 1 mm thick at those areas.

For normal central heating heat-exchangers which are used only for floor-heating at low temperature, the requirements for low temperature heat-exchangers apply.



## 7.12. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED HOT WATER TANKS (BOILERS)

### 7.12.1 Application area

These requirements are applicable for enamelled steel hot water stock tanks (boilers) in which water is heated that is also meant for consumption, with an operating principle according to CEE publication 11, part II, section E (2nd edition, November 1996), and that may be equipped or not with a magnesium anode.

GENERAL: THE PRODUCTS MEANT FROM THIS GROUP NEED TO MEET THE REQUIREMENTS AS DESCRIBED IN THE DIN 4753

### 7.12.2 Test methods

Item	Name	Applicable standards
	steel quality	EN 10025, EN 10204, EN 10209, DIN 50049, DIN 4753
	general requirements – construction	DIN 4753
	general requirements – enamelling	DIN 4753
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.8	specification and determination of the release of toxic elements	UBA-guideline + national laws + DIN 4753-3
4.9	determination of the impact resistance	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.30	identification of defects for hot water tanks (non-destructive - visual only)	DIN 4753-3; BS 3831 Appendix A; IVE Atlas of Defects
4.31	determination and measurement of protective current requirements for hot water	DIN 4753-3
4.32	determination and control of release elements for hot water tanks	UBA-guideline + national laws (see also clause 4.8) + DIN 4753-3
4.37	determination of the resistance to long-term chemical corrosion exposure to boiling water	EN ISO 28706-2/6, DIN 4753
4.40	determination of thermal shock resistance of enamelled articles into water	EEA Specification 8.6.4

[Items 4.1 - 4.49](#)

## 7.12.3 Quality requirements

Test method	Requirement	Remarks	Frequency
	steel quality, construction and enamelling	see DIN 4753	when taking into production
4.3 thickness enamel coating	min. 0.15 mm		1 %
4.4 cold citric acid	min. class A	solution 10 % HCl test duration 1 hour	when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.9 impact resistance	at 10 N no damage > 1.5 mm diameter after 24 hours	on test sheets conform to EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.10 adherence	DIN 4753	on test sheets, following EN ISO 28764, fire conditions should be specified.	in production 1 x a year
4.28. steel quality	in accordance with norm EN 10025 in accordance with the new EN-design "hot rolled enamelling steels for one-sided enamelling" in accordance with EN 10111 For certain non-critical parts, also qualities DC02EK / DC04EK in accordance with EN 10209 are used	is recommended: S235J / S275J is recommended: S235EK1, S275EK1 is recommended: DD11	recommendation during design
4.30 defects	DIN 4753-3		100 %
4.31 protective current requirements	DIN 4753-3	Test done on tank capacities <1000L	in production 1 x a day
4.32 physiological control	UBA guidelines for enamels in contact with drinking water	Test done according to EN 12873-1	<b>See § risk based testing program of the 4MS document on the certification and approval of products in contact with drinking water</b>
4.37 long exposure boiling water	max. 12 g/m <sup>2</sup>	testing time: 2 periods of 3 weeks, on test sheets conform to EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.40 thermal shock resistance	3 tests: 200 °C, repeat 5 x	on test sheets conform to EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 1 x a year

### 7.13. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED ARCHITECTURAL PANELS FOR OUTDOOR APPLICATIONS

#### 7.13.1 Application area

These requirements are applicable for enamelled architectural panels for outdoor applications of which the base material consists of steel.

GENERAL: THE PRODUCTS MEANT FROM THIS GROUP NEED TO MEET THE REQUIREMENTS AS DESCRIBED IN EN ISO 28722:

“Vitreous and porcelain enamels – Characteristics of the enamel coatings applied to steel panels intended for architecture”.

#### 7.13.2 Test methods

Item	Name	Applicable standards
4.2	measurement of the thickness of the base substrate metal	EN ISO 16809
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.5	determination of the resistance to chemical corrosion by boiling citric acids	EN ISO 28706-2/11, EN ISO 28706-2/6
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.12	determination of the porosity by the high voltage test	EN ISO 2746
4.13	determination, detection and location of defects (non-destructive)	EN ISO 8289
4.18	determination of scratch resistance	EN ISO 15695
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664
4.26	determination of abrasion resistance	ASTM C501, EN ISO 6370-1 and EN ISO 6370-2
4.28	determination of the quality of steel for enamelling	EN 10209 for cold rolled steel and see 4.28 recommendations for hot rolled steels, HSLA steels and steel forgings for pressure applications

[Items 4.1 - 4.49](#)

## 7.13.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.2 material thickness	min. 0.75 mm, not valid for laminated panels		determination during design
4.3 thickness enamel coating	max. 0.40 mm	not applicable if covered with several colour layers in order to achieve special decorative effects	S4/AQL 6.5 (when coil production, 1 x per 100 m <sup>2</sup> )
4.4 cold citric acid	min. class A		when taking into production a sig.diff. enamel recipe, but at least 1 x per year
4.5 boiling citric acid	max. weight loss: 18.5 g/m <sup>2</sup> per 2.5 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.9 impact resistance	at 20 N no damage > 2.0 mm diameter after 24h		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.10 adherence	min. 2	on test sheets, conform to EN ISO 28764	in production 1 x a day
4.12 porosity	max. 10 defects per m <sup>2</sup>		in production min. 1 %
or:			
4.13 determination of defects	max. 10 defects per m <sup>2</sup> or max. 5 defects per m <sup>2</sup>	in accordance with EN ISO 8289 method B in accordance with EN ISO 8289 method A	in production min. 1 % in production min. 1 %
4.18 scratch resistance	min. 7 N min. 4 N for metallic finishes and silk-screened finishes		when taking into production a sig.diff. enamel recipe (excluding colour oxides), but at least 1 x a year
4.19 colour difference	even and smooth surface, evaluated equal to the appearance of an approved enamelled sample	Colour difference possibly measured with a spectrometer and tolerances previously agreed by interested partners	In production 100%
4.26 abrasion resistance	max. 0.1 gram	in accordance with ASTM C501 sandpaper S33/1kg/1000 rotations EN ISO 6370-1 and EN ISO 6370-2	when taking into production a sig.diff. enamel recipe (excluding colour oxides) but at least 1 x a year
4.28 steel quality	in accordance with norm EN 10209	is recommended: DC01EK / DC04EK / DC04ED	determination during design

#### 7.13.4 Remarks

The thickness of the sheet material and/or the panel construction must ensure that distortion cannot be imposed through manual force.

Articles must be equipped with sufficient protection against corrosion at the back side.

Finished flat architectural panels may not deviate more than 0.75 % in flatness with respect to the longest side and diagonal of the article, and must meet the requirements of the manufacturer with regard to sheet thickness, sheet quality, construction and technical design of the article. The inspection frequency for this additional requirement during production is at least 1 x per month. Panels are measured in the position in which they will be installed.

Possible firing marks at the back side of the non-glued panels must be retouched in order to prevent corrosion. The inspection frequency for this additional requirement during production is at least 1 x a day.

The enamelled surface shall be visually examined either in natural light or in artificial daylight D 65 (see EN ISO 105-J03). The surface shall be examined from a minimum distance of 1.5 m, or at the distance at which the fixed panel would normally be viewed, whichever is the greater. The enamelled surface exposed to the atmosphere shall be free from defects liable to change the general appearance of the panel.

Resistance to graffiti: After eight days of ageing, inks, varnishes, lacquers or paints, shall be easily removable with suitable solvents without any visible gloss or colour change in the enamel surface.

## 7.14. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED ARCHITECTURAL PANELS FOR INDOOR APPLICATIONS

### 7.14.1 Application area

These requirements are applicable for enamelled architectural panels for indoor applications of which the base material consists of steel.

GENERAL: THE PRODUCTS MEANT FROM THIS GROUP NEED TO MEET THE REQUIREMENTS AS DESCRIBED IN EN ISO 28722:

“Vitreous and porcelain enamels – Characteristics of the enamel coatings applied to steel panels intended for architecture”

### 7.14.2 Test methods

Item	Name	Applicable standards
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.18	determination of scratch resistance	EN ISO 15695
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664
4.26	determination of abrasion resistance	ASTM C501, EN ISO 6370-1 and EN ISO 6370-2
4.28	determination of the quality of steel for enamelling	EN 10209 for cold rolled steel and see 4.28 recommendations for hot rolled steels, HSLA steels and steel forgings for pressure applications

[Items 4.1 - 4.49](#)

## 7.14.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.3 thickness enamel coating	max. 0.40 mm	not applicable if covered with several colour layers in order to achieve special decorative effects	S4/AQL 6.5  (when coil production, 1 x per 100 m <sup>2</sup> )
4.4 cold citric acid	class A		when taking into production a sig.diff. enamel recipe, but at least 1 x per year
4.9 impact resistance	at 20 N no damage > 2 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.10 adherence	min. 3	on test sheets, conform to EN ISO 28764	in production 1 x a day
4.18 scratch resistance	7 N min. 4 N for metallic finishes and silk-screened finishes		when taking into production a sig.diff. enamel recipe (excluding colour oxides), but at least 1 x a year
4.19 colour difference	even and smooth surface, evaluated equal to the appearance of an approved enamelled sample	Colour difference possibly measured with a spectrometer and tolerances previously agreed by interested partners	In production 100%
4.26 abrasion resistance	max. 0.1 gram	conform to ASTM C 501 sandpaper S33/1kg/1000 rotations EN ISO 6370-1 and 6370-2	when taking into production a sig.diff. enamel recipe (excluding colour oxides), but at least 1 x a year
4.28 steel quality	in accordance with norm EN 10209	is recommended: DC01EK / DC04EK / DC04ED	determination during design

#### 7.14.4 Remarks

The thickness of the sheet material and/or the (laminated or non-laminated) panel construction must ensure that distortion cannot be imposed through manual force.

Finished flat architectural panels may not deviate more than 0.75 % in flatness with respect to the longest side and diagonal of the article, and must meet the requirements of the manufacturer with regard to sheet thickness, sheet quality, construction and technical design of the article. The inspection frequency for this additional requirement during production is at least 1 x per month. Panels are measured in the position in which they will be installed.

The enamelled surface shall be visually examined either in natural light or in artificial daylight D 65 (see EN ISO 105-J03). The surface shall be examined from a distance at which the fixed panel would normally be viewed. The enamelled surface shall be free from defects liable to change the general appearance of the panel.

Resistance to graffiti: After eight days of ageing, inks, varnishes, lacquers or paints, shall be easily removable with suitable solvents without any visible gloss or colour change in the enamel surface.



## 7.15. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED CHALKBOARDS

### 7.15.1 Application area

These requirements are applicable for enamelled chalkboards of which the basic material consists of steel or laminated steel.

GENERAL: THE PRODUCTS MEANT FROM THIS GROUP NEED TO MEET THE REQUIREMENTS AS DESCRIBED IN EN ISO 28762:

“Vitreous and porcelain enamels – Enamel coatings applied to steel for writing surface – Specification”

### 7.15.2 Test methods

Item	Name	Applicable standards
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.17	determination of gloss	EN ISO 2813, ASTM C246
4.26	determination of abrasion resistance	ASTM C501, EN ISO 6370-1 and EN ISO 6370-2
4.28	determination of the quality of steel for enamelling	EN 10209 for cold rolled steel and see 4.28 recommendations for hot rolled steels, HSLA steels and steel forgings for pressure applications

[Items 4.1 - 4.49](#)

## 7.15.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.3 thickness enamel coating	max. 0.20 mm		S4/AQL 6.5 (in coil production 1 x per 100 m <sup>2</sup> )
4.9 impact resistance	at 20 N no damages > 2.0 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x per year
4.10 adherence	min. 3	on test sheets conform to EN ISO 28764	in production 1 x a day
4.17 gloss degree	2-20	measuring angle 60°	S4/AQL 6.5 (in coil production 1 x per 100 m <sup>2</sup> )
4.26 abrasion resistance	max. 0.1 gram	conform to ASTM C 501 sandpaper S33/1kg/1000 rotations EN ISO 6370-1 and 6370-2	when taking into production a sig.diff. enamel recipe (excluding colour oxides), but at least 1 x per year
4.28 steel quality	in accordance with norm EN 10209	is recommended: DC01EK / DC04EK / DC04ED	determination during design

## 7.15.4 Remark

The surface of the chalkboards must be suitable and easy to write on. Removal of writing should go smoothly with a dry felt eraser or a latex sponge.

## 7.16. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED PROJECTION BOARDS

### 7.16.1 Application area

These requirements are applicable for enamelled projection boards of which the basic material consists of steel or laminated steel.

### 7.16.2 Test methods

Item	Name	Applicable standards
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.17	determination of gloss	EN ISO 2813, ASTM C246
4.26	determination of abrasion resistance	ASTM C501, EN ISO 6370-1 and 6370-2
4.28	determination of the quality of steel for enamelling	EN 10209 for cold rolled steel and see 4.28 recommendations for hot rolled steels, HSLA steels and steel forgings for pressure applications

[Items 4.1 - 4.49](#)

## 7.16.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4. 3 thickness enamel coating	max. 0.20 mm		S4/AQL 6.5 (in coil production 1 x per 100 m <sup>2</sup> )
4.9 impact resistance	at 20 N no damages > 2 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x per year
4.10 adherence	min. 3	on test sheets conform to EN ISO 28764	in production 1 x a day
4.17 gloss	5 - 90	measuring angle 60°	S4/AQL 6.5 (in coil production 1 x per 100 m <sup>2</sup> )
4.26 abrasion resistance	max. 0.1 gram	conform to ASTM C 501 sandpaper S33/1kg/1000rotations EN ISO 6370-1and 6370-2	when taking into production a sig.diff. enamel recipe (excluding colour oxides), but at least 1 x per year
4.28 steel quality	in accordance with norm EN 10209	is recommended: DC01EK / DC04EK / DC04ED	determination during design

## 7.16.4 Remark

The white surface must be suitable for projection applications.

## 7.17. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED WHITEBOARDS

### 7.17.1 Application area

These requirements are applicable for enamelled whiteboards of which the basic material consists of steel or laminated steel.

GENERAL: THE PRODUCTS MEANT FROM THIS GROUP NEED TO MEET THE REQUIREMENTS AS DESCRIBED IN EN ISO 28762:

“Vitreous and porcelain enamels – Enamel coatings applied to steel for writing surface – Specification”

### 7.17.2 Test methods

Item	Name	Applicable standards
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.17	determination of gloss	EN ISO 2813, ASTM C246
4.18	determination of scratch resistance	EN ISO 15695
4.19	determination of colour difference	EN ISO/CIE 11664, EN ISO 18314
4.26	determination of abrasion resistance	ASTM C501, EN ISO 6370-1 and 6370-2
4.28	determination of the quality of steel for enamelling	EN 10209 for cold rolled steel and see 4.28 recommendations for hot rolled steels, HSLA steels and steel forgings for pressure applications

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## 7.17.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.3 thickness enamel coating	max. 0.25 mm		S4/AQL 6.5 (in coil production 1 x per 100 m <sup>2</sup> )
4.4 cold citric acid	class A		when taking into production a sig.diff. enamel recipe, but at least 1 x per year
4.9 impact resistance	at 20 N no damages > 2.0 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x per year
4.10 adherence	min. 3	on test sheets, conform to EN ISO 28764	in production 1 x a day
4.17 gloss	min. 35	measuring angle 60°	S4/AQL 6.5 (in coil production 1 x per 100 m <sup>2</sup> )
4.18 scratch resistance	min. 7 N min. 4 N for metallic finishes and silk-screened finishes		when taking into production a sig.diff. enamel recipe, but at least 1 x per month
4.19 colour difference after cleaning	$\Delta E^* < 0,5$	after a thorough wet cleaning, the surface contamination or colour fading under influence of the marker pigment should not exceed $\Delta E^* = 0,5$ .	when taking into production a sig.diff. enamel recipe, but at least 1 x per year
4.26 abrasion resistance	max. 0.1 gram	conform to ASTM C501 sandpaper S33/1kg/1000 rotations EN ISO 6370-1 and 6370-2	when taking into production a sig.diff. enamel recipe (excluding colour oxides), but at least 1 x per year
4.28 steel quality	in accordance with norm EN 10209	is recommended: DC01EK / DC04EK / DC04ED	determination during design

#### 7.17.4 Remarks

- A. The surface must be easy to write on with dry-erasable, water-soluble or permanent felt markers.

Writing with dry erasable felt markers should be easy to wipe off with a felt eraser or a cotton cloth.

Water-erasable writings should be easy to wipe off with water.

Permanent felt-marker writing should be easy to remove with alcohol or any other solvent.

- B. The whiteboard must have a surface hardness of min. 5 according to the scale of Mohs.

This requirement must at least be checked when taking into production a significantly different enamel recipe.

## 7.18. QUALITY REQUIREMENTS FOR REGENERATIVE, PACKED AND PORCELAIN AND VITREOUS ENAMELLED HEAT-EXCHANGERS FOR AIR-GAS AND GAS-GAS HEATERS

### 7.18.1 Application area

These requirements are applicable for the steel, the enamel and the enamelled profiled heat-exchanger plates, before and after packing in baskets (See part 6.6 of EN ISO 28763).

### 7.18.2 Test methods

<b>A.</b>	<b>Steel base</b>	
<b>Item</b>	<b>Name</b>	<b>Applicable standards</b>
3.9.5.1	steel analysis	EN 10209 / part 4.2 EN ISO 28763
4.16 / 4.43	determination of the permeability to hydrogen	EN 10209 Annex A1, See part 4.3 of EN ISO 28763
or 4.22 / 4.43	determination of the resistance to fish scaling	EN 10209 Annex A2, See part 4.4 of EN ISO 28763
4.27	determination of the steel surface activity (pickling speed, weight loss)	EN 10209 Annex B

<b>B.</b>	<b>Enamel frits</b>	
<b>Item</b>	<b>Name</b>	<b>Applicable standards</b>
4.6	determination of the resistance to chemical corrosion by boiling water and/or water vapour	EN ISO 28706-2/14, EN ISO 28706-2/6
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.35	determination of the resistance to chemical corrosion by boiling sulphuric acid	EN ISO 28706-2/12
4.40	determination of thermal shock resistance of enamelled articles into water	EEA Specification 8.6.4
4.44	determination of the fluidity behaviour, fusion flow test	EN ISO 4534
4.45	determination of the coefficient of mean linear thermal expansion of glass	EN ISO 20274, ISO 7991

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<b>C.</b>	<b>Enamelling</b>	
<b>Item</b>	<b>Name</b>	<b>Applicable standards</b>
3.5	visual assessment	EN ISO 10141, EEA 8.7 / part 3 & 6.4 EN ISO 28763
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.13	determination, detection and location of defects (non-destructive)	EN ISO 8289-1 and EN ISO 8289-2
4.20	determination of edge coverage	EN ISO 28723
4.35	determination of the resistance to chemical corrosion by boiling sulphuric acid	EN ISO 28706-2/12
4.40	determination of thermal shock resistance of enamelled articles into water	EEA Specification 8.6.4

<b>D.</b>	<b>Packaging</b>	
<b>Item</b>	<b>Name</b>	<b>Applicable standards</b>
3.5	visual assessment	EN ISO 10141, EEA 8.7 / part 3 & 7.2 EN ISO 28763
4.20	determination of edge coverage	EN ISO 28723
4.36	method for the packing of heat exchanger elements	EEA Specification 8.7.8

## 7.18.3 Quality requirements

<b>A. Steel base</b>			
Certificate (3.1 according to EN 10204) to be provided by steel manufacturer, stating:			
Test method	Requirement	Remarks	Frequency
steel analysis	according to norm	suitable for double-sided enamelling	per melt
4.16 /4.43 hydrogen permeability	> = 120	does not apply for steel types DC06EK / DC06ED and DC07EK	per coil
or 4.22/4.43 fish scale test	no fish scales allowed		per coil
4.27 pickling speed	if required in consultation with the steel manufacturer and the enameller		per coil

<b>B. Enamel frits</b>			
The enameller has to use checked enamel frits for this object The guarantee should be given by the frit manufacturer in a certificate The requirements and the test recipes are determined in consultation between enameller and frit manufacturer The results are given in a certificate according to EN 10204 3.1			
Test method	Requirement	Remarks	Frequency
4.6 resistance against boiling water and/or vapour	if required by the enameller air-gas: 20 g/m <sup>2</sup> /48h; gas-gas: 6 g/m <sup>2</sup> /48h		per 10,000 kg
4.35 resistance against boiling sulphuric acid	air-gas: 10 g/m <sup>2</sup> /48h; gas-gas: 2 g/m <sup>2</sup> /48h		per 5,000 kg
4.40 resistance against thermal shock	if required in consultation with the frit manufacturer and the enameller; 5 x 350 degrees C, according EN ISO 28763 annex A		per 10,000 kg
4.44 fusion flow	if required in consultation with the frit manufacturer and the enameller		per 10,000 kg
4.45 coefficient of expansion	if required in consultation with the frit manufacturer and the enameller		per 10,000 kg

C. Enamelling			
Test method	Requirement	Remarks	Frequency
4.3 thickness enamel coating	<p>the mean of the 54 measurements (36 measurements at point number 1 and point number 2 of the corrugated panel plus the 18 measurements at point number 3 of the undulated panel) shall be <math>150\ \mu\text{m} \pm 30\ \mu\text{m}</math>, unless a different mean is agreed between customer and supplier at the time of ordering. Along the area bordering the edge of the panel the total thickness may measure up to <math>600\ \mu\text{m}</math> (i.e. 2 sides of <math>300\ \mu\text{m}</math>) plus thickness of the substrate.</p> <p>If a different mean has been agreed between customer and supplier then total enamel thickness along the area bordering the edge of the panel may vary, but should be kept to a minimum to avoid chipping, spalling etc.</p> <p>With the exception of edges and suspension holes, the application thickness beside the measuring point (such as both sides of the notches of the corrugation) shall nowhere fall below <math>80\ \mu\text{m}</math></p>	<p>for measuring method: see § 4</p> <p>EN ISO 1463</p>	<p>1 % in production</p> <p>measurements other than those on the indicated position points shall be determined using a microscope</p>
4.10/4.43 adherence	min. 2 A	on test sheets conform to EN ISO 28764 and EN ISO 28763	in production 2 x per day

<b>C. Enamelling (cont.)</b>			
<b>Test method</b>	<b>Requirement</b>	<b>Remarks</b>	<b>Frequency</b>
3.5 visual assessment	fundamental defects may not occur	fundamental defects are: blisters, burn-off, chipping, copper heads, cracking, crazing fish scales, spalling and tearing as described in EN ISO 28763 part 6.4.	100 %
4.13 open defects in accordance with method B	maximum number of open defects: air-gas heaters: 50/m <sup>2</sup> gas-gas heaters: 15/m <sup>2</sup>	defects in form of cracks are not permitted	in a random check op 10 pairs of panels out of a production of 1000 pairs of panels; alternatively, the number of defects on pairs of heat exchanger panels may be determined by checking 1% of production on a 2 hours cycle.
4.20 edge covering	<u>for air-gas heaters</u> requirements in consultation with the enameller and the end user  <u>for gas-gas heaters</u> if required by the customer the edge covering of the pair of panels shall be determined in accordance with EN 14863. The mean has to be agreed between customer and supplier at the time of ordering		
flatness requirement	after the enamelling if required in consultation between enameller and packager		
4.35 boiling sulphuric acid	Maximum mass loss: air-gas heaters: 10.0 g/m <sup>2</sup> gas-gas heaters: 2.0 g/m <sup>2</sup>	test specimens shall be prepared in accordance with EN ISO 28764 and shall be pre-treated and enamelled under the same circumstances as the production of the heat exchanger plates. They shall have an enamel layer thickness of 150µm ± 20µm.	1 x per 5 tons frits
4.40 thermal shock resistance	5 x 350 °C	on test sheets conform to EN ISO 28764, the resistance is tested on sheets of 100 x 100 mm with an enamel coating thickness of 150µm +/- 20µm. The sheets are cooled down in water at 20 °C	1 x per order

<b>D. Package</b>			
<b>Test method</b>	<b>Requirements</b>	<b>Remarks</b>	<b>Frequency</b>
3.5 visual assessment	<p>for air-gas heaters: requirements in consultation with the enameller and the end user</p> <p>for gas-gas heaters: a visual examination should be carried out for defects such as chipping, cracking or spalling (see Clause 3).</p> <p>Special attention shall be given on the contact points between the corrugated and undulated plates (the 2nd, the middle and the last but one pair of panels in the basket)</p>	the visual examination shall be performed after pressurizing the basket complete with elements but without the pack being welded	one basket per rotor ring shall be tested
4.20 edge covering	<p>for air-gas heaters requirements in consultation with the enameller and the end user</p> <p>for gas-gas heaters the edge covering shall be determined on three pairs (corrugated + undulated) of panels per basket (the second, the middle and the last but one pair of panels in the basket) and there shall be an overall edge covering of <math>\geq 95\%</math></p>		once per ring
4.36 package pressure	5000 - 8000 ( $\pm 1000$ ) kg/m <sup>2</sup>	profile related	100 %

## 7.18.4 Remarks (see also EEA 8.6.6)

On behalf of the test method 4.3 the following regulations must be respected:

Adjustment of the measuring equipment shall be carried out on profile concerned.

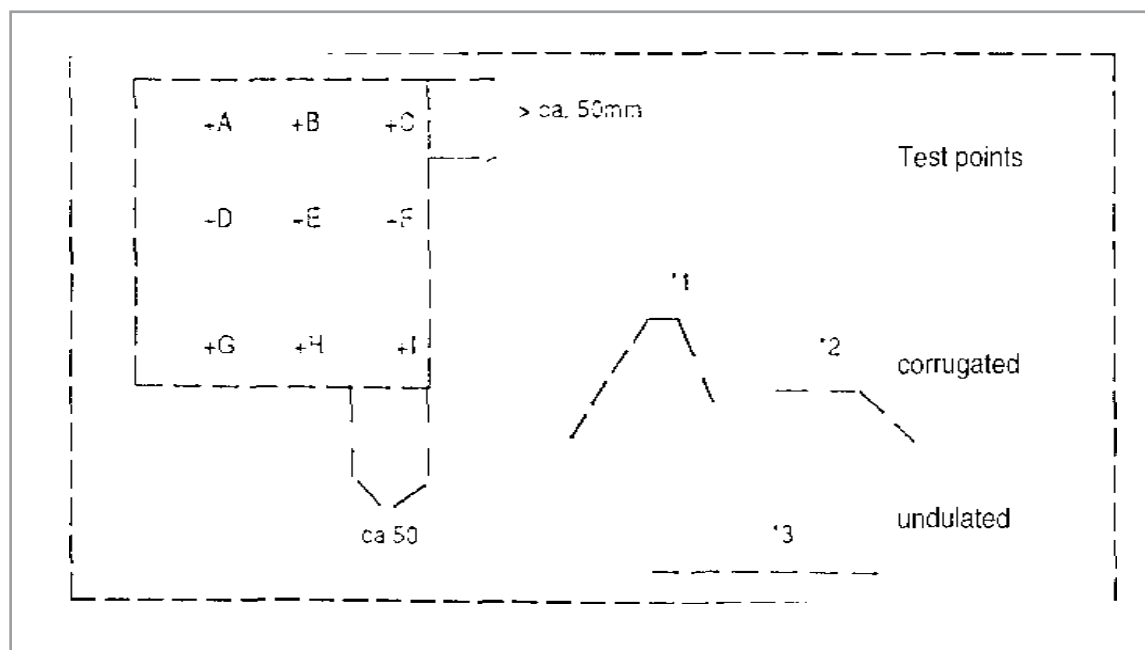
Contrary to chapter 4.3 the measurement shall be carried out from point A to I (see figure).

The test points are situated at least 50 mm from the edge.

The measuring points on the corrugated panel are marked with the numbers 1 and 2, on the undulated panel with 3.

This will result in 54 measurements from each pair of panels tested, 36 from each corrugated panel and 18 from each undulated panel.

Examples are shown in the figure:



## 7.19. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED HEAT EXCHANGER SHEET PAIRS AND TUBES FOR RECUPERATIVE EXCHANGERS

### 7.19.1 Application area

These requirements are applicable for the steel and the enamel coating of the heat exchanger sheet pairs and tubes in recuperative exchangers.

### 7.19.2 Test methods

<b>A.</b>	<b>Steel base</b>	
<b>Item</b>	<b>Name</b>	<b>Applicable standards</b>
3.9.5.1	Steel analysis	EN 10209
4.16 / .43	determination of the permeability to hydrogen	EN 10209 Annex A1, See part 4.3 of EN ISO 28763
or 4.22 / 4.43	determination of the resistance to fish scaling	EN 10209 Annex A2; See part 4.4 of EN ISO 28763
4.27	determination of the steel surface activity (pickling speed, weight loss)	EN 10209 Annex B

<b>B.</b>	<b>Enamelling</b>	
<b>Item</b>	<b>Name</b>	<b>Applicable standards</b>
3.5	visual assessment	EEA 8.7, NEN 2711
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.13	determination, detection and location of defects (non-destructive)	EN ISO 8289
4.34	determination of the crack formation temperature	EN ISO 13807
4.40	determination of thermal shock resistance of enamelled articles into water	EEA Specification 8.6.4

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## 7.19.3 Quality requirements

**A. Steel base**

Certificate (3.1. according to EN 10204) to be provided by steel manufacturer, stating:

Test method	Requirement	Remarks	Frequency
steel analysis	according to norm	suitable for double-sided enamelling	per melt / shipment
4.16 / 4.43 hydrogen permeability	> = 120	does not apply for steel types DC06EK / DC06ED and DC07EK	per coil
or 4.22 / 4.43 fish scaling test	no fish scales allowed		per coil
4.27 pickling speed	in consultation with the steel supplier and the enameller		per melt / shipment



**B. Enamelling**

Test method	Requirement	Remarks	Frequency
3.5 visual assessment	external: fundamental defects may not occur internal: in consultation	fundamental defects are flake off, chip off, copper heads, fish scales, pull off, burning through as described in NEN 2711	100 %
4.3 thickness enamel coating	120 - 400µm		2 % in production
4.9 impact resistance	at 20 N no damages > 2.0 mm diameter after 24 hours	on test sheets, conform to EN ISO 28764	when taking into production new recipe, but at least 1 x a year
4.10 adherence	min. 2	on test sheets, conform to EN ISO 28764	in production 1 x a day
4.13 defects	external < 25 / m <sup>2</sup> per individual sheet according to method B; average < 10 / m <sup>2</sup> with respect to sheets forming part of a heat exchanger bloc. Internal method and quality requirement to be discussed in consultation with principal and enameller, depending on application	defects in the form of cracks are not permitted	2 %
flatness requirement	after the enamelling if required in consultation between enameller and customer		if required in consultation between enameller and customer
4.35 boiling sulphuric acid	max. 3.0 g/m <sup>2</sup>	Test specimens shall be prepared in accordance with EN ISO 28764 and shall be pre-treated and enamelled under the same circumstances as the production of the heat exchanger parts. They shall have an enamel layer of 150µm ± 20µm.	1 x per 10 tons enamel
4.40 thermal shock resistance	5 x 350 °C	on test sheets conform to EN ISO 2723  the resistance is tested on sheets of 100 mm x 100 mm with an enamel coating thickness of 150µm ± 20µm. The sheets are cooled down in water at 20°C	when taking into production new enamel recipe, but at least 1 x a year

## 7.20. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED INDUSTRIAL TANKS – 1<sup>st</sup> GROUP

### 7.20.1 Application area

These requirements are applicable for enamelled panels for bolted steel tanks for the storage or treatment of water or municipal or industrial effluents and sludges (not chemical vessels). This section (7.20) refers exclusively to the tanks dedicated to the below listed applications:

- Industrial effluent process/treatment including aggressive chemical industrial effluent /high temperature applications
- Industrial tanks with aeration processes
- Roofs exposed to gaseous zone in biogas digester for agricultural waste (not the cylinders, see section 7.21)
- Cylinders and roofs of thermophilic/pasteurisation digesters
- Roofs exposed to gaseous zone in municipal mesophilic digesters (not the cylinders, see section 7.21)
- Liquid leachate
- Roofs exposed to gaseous zone in municipal sludge treatment (not the cylinders, see section 7.21)
- Borehole / brackish / sea water

See also for other application areas the section 7.21 QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED INDUSTRIAL TANKS – 2<sup>nd</sup> GROUP

### 7.20.2 Test methods

Item	Name	Applicable standards
3.5	visual assessment	EEA 8.7
3.9.3	determination of the hardness referring to Mohs	EN ISO 6769
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by acids at room temperature	EN ISO 28706-1/9, EN ISO 28706-1/10, EN ISO 28706-1/11
4.5	determination of the resistance to chemical corrosion by boiling citric acids	EN ISO 28706-2/11
4.6	determination of the resistance to chemical corrosion by boiling water and/or water vapour	EN ISO 28706-2/14
4.7	determination of the resistance to chemical corrosion by standard detergent solution	EN ISO 28706-3/10

## Test methods (cont.)

Item	Name	Applicable standards
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.12	determination of the porosity by the high voltage test	EN ISO 2746
4.25	determination of the resistance to chemical corrosion by hot sodium hydroxide solution	EN ISO 28706-4/9
4.26	determination of abrasion resistance	EN ISO 6370-1 and EN ISO 6370-2
4.28	determination of the quality of steel for enamelling	conforming EN 10111, EN 10025-1, EN 10149-1 and ASTM A 1011 see also 4.28 recommendations for hot rolled steels and HSLA steels
4.33	determination of the chemical corrosion rate in hydrochloric acid	EN ISO 28706-2/13
4.39	determination of the adherence of enamel to steel of more than 3 mm thickness	EEA Specification 8.6.3
4.40	determination of thermal shock resistance of enamelled articles into water	EN ISO 28763 Annex A

## 7.20.3 Quality requirements

Test method	Requirement	Remarks	Frequency
3.5 visual assessment	Inside surface: discontinuity free (see 4.12) Outside surface: max. 3 defects/m <sup>2</sup> with a max. defect size of 1mm in diameter (*)		in production 100 %
3.9.3 hardness	hardness Mohs $\geq 5$	on test sheets	when taking into production a sig.diff. enamel recipe, but at least 1 x a month
4.3 thickness enamel coating	Outside surface: $330 \pm 170\mu\text{m}$ Inside surface: $360 \pm 100\mu\text{m}$ except for roofs of thermophilic/pasteurisation digesters, industrial tanks with aeration processes and aggressive chemical industrial effluent / high temperature applications: Inside surface: $400 \pm 100\mu\text{m}$		In accordance with EN ISO 2859-1
4.4 cold citric acid cold sulphuric acid	class AA class A+ min., except for roofs of thermophilic/pasteurisation digesters, industrial tanks with aeration processes and aggressive chemical industrial effluent / high temperature applications: class AA required	EN ISO 28706-1/9 EN ISO 28706-1/10	in production 1 x per month in production 1 x per month
cold hydrochloric acid	class A min., except for roofs of thermophilic/pasteurisation digesters, industrial tanks with aeration processes and aggressive chemical industrial effluent / high temperature applications: class AA required	EN ISO 28706-1/11 10% solution 15min.	in production 1 x per month
4.5 boiling citric acid	weight loss: max. 1,5 g/m <sup>2</sup> after 2.5 hours except for roofs of thermophilic/pasteurisation digesters and industrial tanks with aeration processes: max. 0,75 g/m <sup>2</sup> except for aggressive chemical industrial effluent / high temperature applications: max. 0,5 g/m <sup>2</sup>	EN ISO 28706-2/11 on test sheets conform to EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.6 boiling water	<u>liquid phase</u> max. weight loss: 2,5 g/m <sup>2</sup> after 48 hrs. except for aggressive chemical industrial effluent / high temperature applications: max. 1,0 g/m <sup>2</sup> <u>vapour phase</u> max. weight loss: 7,5 g/m <sup>2</sup> after 48 hrs. except for roofs of thermophilic/pasteurisation digesters and industrial tanks with aeration processes: max. 5,0 g/m <sup>2</sup> except for aggressive chemical industrial effluent / high temperature applications: max. 2,5 g/m <sup>2</sup>	EN ISO 28706-2/14 on test sheets conform to EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 1 x a year

(\*) When agreed between parties, it is permissible to rectify defects on outside surfaces using an approved material and process, at the condition rectified defects have a design life similar to that of the original coating.

## Quality requirements (cont.)

Test method	Requirement	Remarks	Frequency
4.7 detergent solutions	max. weight loss: 5,0 g/m <sup>2</sup> after 24 hrs. except for roofs of thermophilic/pasteurisation digesters and industrial tanks with aeration processes: max. 2,5 g/m <sup>2</sup> except for aggressive chemical industrial effluent / high temperature applications: max. 2,0 g/m <sup>2</sup>	EN ISO 28706-3/10 on test sheets conform to EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.9 impact resistance	at 40 N no damage > 2 mm ø after 24 hours except for aggressive chemical industrial effluent / high temperature applications: tested at 50 N force no damage > 2 mm ø	EN ISO 4532	in production 1 x a month
4.10 adherence	min. class 2 except for aggressive chemical industrial effluent / high temperature applications: min. class 1	EN 10209 Annex C, on test sheets conform to EN ISO 28764	in production 1 x a month
or 4.39 for thickness >3mm	min. "good"	EEA Specification 8.6.3, on test sheets conform to EN ISO 28764	in production 1 x a month
4.12 porosity	For inside surface only: discontinuity free With test voltage 1.100V Except for roofs of thermophilic/pasteurisation digesters and Industrial tanks with aeration processes: 1.500V Except for aggressive chemical industrial effluent and high temperature applications: 2.000V	EN ISO 2746 Test A	in production 100 % (every panel)
4.25 sodium hydroxide 80° C	max. weight loss of 6 g/m <sup>2</sup> after 24 hours except for aggressive chemical industrial effluent / high temperature applications: max. weight loss of 5 g/m <sup>2</sup>	EN ISO 28706-4/9	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.26 abrasion resistance	<0,9 relative amount of wear	conform to EN ISO 6370-1 and EN ISO 6370-2	when taking into production a sig.diff. enamel recipe (excluding colour oxides), but at least 1 x per year determination during design
4.28 steel quality	conforming EN 10111, EN 10025-1, EN 10149-1 and ASTM A 1011 and others (including grades DD 11, S235, S420, S460, S500, S550 and S700), with appropriate pre-treatments	quality to be agreed between the enameller and the steel manufacturer	
4.33 corrosion rate in hydrochloric acid vapor	weight loss after 7 days in vapour phase is ≤8g/m <sup>2</sup> Except for aggressive chemical industrial effluent /high temperature applications, Industrial tanks with aeration processes and roofs of thermophilic/pasteurisation digesters where max. weight loss is 7g/m <sup>2</sup>	EN ISO 28706-2/13	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.40 thermal shock resistance	no damage	EN ISO 28763 Annex A on test sheets conform to EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 1 x a year

#### 7.20.4 Remarks

Colour and colour tolerances of the outside surface shall be agreed between interested parties. Inspection frequency to be determined according EN ISO 2859-1. Inspection method to be approved prior to production.

Consult with supplier for suitability for specific applications. All applications subject to concentration and temperature considerations of the stored liquid.

## 7.21. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED INDUSTRIAL TANKS – 2<sup>nd</sup> GROUP

### 7.21.1 Application area

These requirements are applicable for enamelled panels for bolted steel tanks for the storage or treatment of water or municipal or industrial effluents and sludges (not chemical vessels). This section (7.21) refers exclusively to the tanks dedicated to the below listed applications:

- Cylinders in biogas digester for agricultural waste (excluding the roofs exposed to gaseous zone, see section 7.20)
- Cylinders in municipal mesophilic digesters (excluding the roofs exposed to gaseous zone, see section 7.20)
- Cylinders in municipal sludge treatment (excluding the roofs exposed to gaseous zone, see section 7.20)
- Municipal sludge / sludge cake storage
- Filter tanks
- Storm / fire water
- Potable waters DWI listed, Reg. 31 and NSF/ANSI/CAN 61

See also for other application areas the section 7.20 QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED INDUSTRIAL TANKS – 1<sup>st</sup> GROUP

### 7.21.2 Test methods

Item	Name	Applicable standards
3.5	visual assessment	EEA 8.7
3.9.3	determination of the hardness referring to Mohs	EN ISO 6769
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by acids at room temperature	EN ISO 28706-1/9
4.5	determination of the resistance to chemical corrosion by boiling citric acids	EN ISO 28706-2/11
4.6	determination of the resistance to chemical corrosion by boiling water and/or water vapour	EN ISO 28706-2/14

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## Test methods (cont.)

Item	Name	Applicable standards
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.12	determination of the porosity by the high voltage test	EN ISO 2746
4.13	determination, detection and location of defects (non-destructive)	EN ISO 8289-1 Method A
4.25	determination of the resistance to chemical corrosion by hot sodium hydroxide solution	EN ISO 28706-4/9
4.28	determination of the quality of steel for enamelling	conforming EN 10111, EN 10025-1, EN 10149-1 and ASTM A 1011 see also 4.28 recommendations for hot rolled steels and HSLA steels
4.39	determination of the adherence of enamel to steel of more than 3 mm thickness	EEA Specification 8.6.3



## 7.21.3 Quality requirements

Test method	Requirement	Remarks	Frequency
3.5 visual assessment	Inside surface: discontinuity free (see 4.12) Outside surface: max. 3 defects/m <sup>2</sup> with a max. defect size of 1mm in diameter (*)		in production 100 %
3.9.3 hardness	hardness Mohs $\geq 5$	on test sheets	when taking into production a sig.diff. enamel recipe, but at least 1 x a month
4.3 thickness enamel coating	Outside surface: $330 \pm 170\mu\text{m}$ Inside surface: $300 \pm 100\mu\text{m}$  except for cylinders in biogas digester for agricultural waste: Inside surface: $260 \pm 100\mu\text{m}$		In accordance with EN ISO 2859-1
4.4 cold citric acid	class A+, except for cylinders in biogas digester for agricultural waste: class A min.	EN ISO 28706-1/9	in production 1 x per month
4.5 boiling citric acid	weight loss: max. 3,0 g/m <sup>2</sup> after 2.5 hours  except for cylinders in biogas digester for agricultural waste: max. 5,0 g/m <sup>2</sup>	EN ISO 28706-2/11 on test sheets conform to EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.6 boiling water	<u>liquid phase</u> max. weight loss: 5,0 g/m <sup>2</sup> after 48 hrs.  no requirement for vapour phase	EN ISO 28706-2/14 on test sheets conform to EN ISO 28764	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.9 impact resistance	at 20 N no damage > 2 mm $\varnothing$ after 24 hours	EN ISO 4532	in production 1 x a month
4.10 adherence	min. class 2	EN 10209 Annex C, on test sheets conform to EN ISO 28764	in production 1 x a month
or 4.39 for thickness >3mm	min. "good"	EEA Specification 8.6.3, on test sheets conform to EN ISO 28764	in production 1 x a month
4.12 porosity	for inside surface only: discontinuity free With test voltage 700V	EN ISO 2746 Test A	in production 100 % (every panel)
4.13 defects detection	except for cylinders in biogas digester for agricultural waste: no defect detected using EN ISO 8289-1 method A	EN ISO 8289-1 Method A	Frequency determined with EN ISO 2859-1
4.25 sodium hydroxide 80° C	max. weight loss of 7 g/m <sup>2</sup> after 24 hours	EN ISO 28706-4/9	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.28 steel quality	conforming EN 10111, EN 10025-1, EN 10149-1 and ASTM A 1011 and others (including grades DD 11, S235, S420, S460, S500, S550 and S700), with appropriate pre-treatments	quality to be agreed between the enameller and the steel manufacturer	determination during design

(\*) When agreed between parties, it is permissible to rectify defects on outside surfaces using an approved material and process, at the condition rectified defects have a design life similar to that of the original coating.

#### 7.21.4 Remarks

Colour and colour tolerances of the outside surface shall be agreed between interested parties. Inspection frequency to be determined according EN ISO 2859-1. Inspection method to be approved prior to production.

Consult with supplier for suitability for specific applications. All applications subject to concentration and temperature considerations of the stored liquid.

## 7.22. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED VALVES AND FITTINGS OF CAST IRON IN CONTACT WITH WATER

### 7.22.1 Application area

These requirements are applicable for parts of cast iron in contact with raw water and drinking water.

### 7.22.2 Test methods

Item	Name	Applicable standards
3.9.5.3	cast iron quality	DIN EN 1561, DIN EN 1563
3.9.3	determination of the hardness referring to Mohs	EN ISO 6769
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.6	determination of the resistance to chemical corrosion by boiling water and/or water vapour	EN ISO 28706-2/14, EN ISO 28706-2/6
4.9	determination of the resistance to impact	EN ISO 4532
4.13	determination, detection and location of defects (non-destructive)	EN ISO 8289
4.18	determination of scratch resistance	EN ISO 15695
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664
4.26	determination of abrasion resistance	EN ISO 6370-1 and 6370-2
4.40	determination of thermal shock resistance of enamelled articles into water	EEA Specification 8.6.4
4.48	determination of the resistance against corrosion and creeping after mechanical impact	EEA specification 8.6.7
4.49	determination against climatic impact like weathering and UV-resistance	EEA specification 8.6.8

[Items 4.1 - 4.49](#)

## 7.22.3 Quality requirements

Test method	Requirement	Remarks	Frequency
3.9 hardness	hardness Mohs scale $\geq 4$	respecting cutability	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.3 thickness enamel coating	200 – 600 $\mu$ m (flat area) $\geq 150\mu$ m (edge covering)	the coat thickness depends on the intended use	S4/AQL 6.5
4.4 cold citric acid	class AA suitable for soil class III	soil class III	each lot when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.6 boiling water	no visible change of surface structure, loss of gloss is acceptable	48 hours water 100°C, steam $\geq 100^\circ\text{C}$	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.9 impact resistance	at 10 N no damages > 1,5 mm diameter after 24 hours	DIN 3475	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.13 surface properties	single defect $\leq 1$ mm diameter, less than 7 pores within 35 mm circle	visual check without magnification	S4/AQL 6.5
4.18 scratch resistance	no creeping, no loss of adherence	3 days in distilled water $\geq 80^\circ\text{C}$	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.19 colour difference	even and smooth surface	small colour differences at edges are legal	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.26 abrasion resistance	no creeping, no loss of adherence	test with 100 N, 60 mm relatively 3 days in distilled water $\geq 80^\circ\text{C}$	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.40 thermal shock	no visible defect	temperature difference = 200°C	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.48 mechanical impact resistance	no creeping, no loss of adherence	3 days in distilled water $\geq 80^\circ\text{C}$	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.49 weathering & UV resistance	no separation, no loss of corrosion resistance, no chalky change of colour	cycle time 12 hours, 10-50°C, 30-75% rel. humidity, afterwards 168 hours UV-radiation 300 W, 0,5 m then 3 days in distilled water $\geq 80^\circ\text{C}$	when taking into production a sig.diff. enamel recipe, but at least 1 x a year

**7.23. QUALITY REQUIREMENTS FOR ARMATURES, FORM PARTS, PIPES, VALVES AND AGITATORS FOR THE CHEMICAL INDUSTRY**

## 7.23.1 Application area

These requirements are applicable for:

- parts of steel
- parts of cast iron
- parts of stainless steel

## 7.23.2 Test methods

Item	Name	Applicable standards
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.25	determination of the resistance to chemical corrosion by hot sodium hydroxide solution	EN ISO 28706-4/9
4.33	determination of the chemical corrosion rate in hydrochloric acid vapour	EN ISO 28706-2/13
4.34	determination of the crack formation temperature	EN ISO 13807

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## 7.23.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.3 thickness enamel coating	0.8 - 2.5 mm (cast iron) 1.0 - 2.2 mm (steel)	the coating thickness depends of the enamels used and the intended use	in consultation between enameller and customer
4.25 corrosion rate in sodium hydroxide solution	$\leq 0.40$ mm/a		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.33 corrosion rate in hydrochloric acid	$\leq 0.08$ mm/a		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.34 crack formation temperature	$\geq 190$ °C		when taking into production a sig.diff. enamel recipe, but at least 1 x a year

## 7.24. QUALITY REQUIREMENTS FOR WASTE-WATER-PIPES OF CAST IRON

### 7.24.1 Application area

These requirements are applicable for cast iron waste-pipes.

### 7.24.2 Test methods

Item	Name	Applicable standards
3.9.5.3	cast iron quality	EN 1561
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.5	determination of the resistance to chemical corrosion by boiling citric acids	EN ISO 28706-2/11, EN ISO 28706-2/6
4.6	determination of the resistance to chemical corrosion by boiling water and/or water vapour	EN ISO 28706-2/14, EN ISO 28706-2/6
4.9	determination of the resistance to impact	EN ISO 4532

[Items 4.1 - 4.49](#)

## 7.24.3 Quality requirements

Test method	Requirement	Remarks	Frequency
3.9.5.3	cast iron quality	EEA-specification 8.1	when taking into production
4.3 thickness enamel coating	< 1.5 mm		1%
4.4 cold citric acid cold sulphuric acid	class AA class AA		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.5 boiling hydrochloric acid resistance	weight loss: max. 10 g/m <sup>2</sup> /24h (mean value)	test duration 48 hours	when taking into production a sig.diff. enamel recipe, but at least 1x a year
4.6 boiling water	weight loss: max. 10 g/m <sup>2</sup> /24h (mean value)	test duration 48 hours	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.9 impact resistance	at 20 N no damages > 2 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x a year



## 7.25. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED SILOS FOR AGRICULTURAL SOLIDS

### 7.25.1 Application area

This norm is applicable for enamelled silos for agricultural solids, made from steel.

This norm is not applicable for enamelled industrial tanks. For these tanks apply application areas 7.20 or 7.21.

### 7.25.2 Test methods

Item	Name	Comparable standards
3.5	visual assessment	EEA 8.7
3.9.3	determination of the hardness referring to Mohs	EN ISO 6769
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by acids at room temperature	EN ISO 28706-1/9
4.5	determination of the resistance to chemical corrosion by boiling citric acids	EN ISO 28706-2/11
4.6	determination of the resistance to chemical corrosion by boiling water and/or water vapour	EN ISO 28706-2/14
4.8	specification and determination of the release of toxic elements	national laws
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.13	determination, detection and location of defects (non-destructive)	EN ISO 8289-1 Method A
4.25	determination of the resistance to chemical corrosion by hot sodium hydroxide solution	EN ISO 28706-4/9
4.28	determination of the quality of steel for enamelling	conforming EN 10111, EN 10025-1, EN 10149-1 and ASTM A 1011 see also 4.28 recommendations for hot rolled steels and HSLA steels
4.39	determination of the adherence of enamel to steel of more than 3 mm thickness	EEA Specification 8.6.3

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## 7.25.3 Quality requirements

Test method	Requirement	Remarks	Frequency
3.5 visual assessment	internal 0 defects, external max. 5 defects/m <sup>2</sup>		in production 100 %
3.9.3 hardness	hardness Mohs $\geq 5$	on test sheets	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.3 thickness enamel coating	inner and outer $0.34 \pm 0.16$ mm		S4/AQL 2.5
4.4 cold citric acid	min. class A	EN ISO 28706-1	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.5 boiling citric acid	internal 7 g/m <sup>2</sup> per 2.5 hours	EN ISO 28706-2	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.6 boiling water	internal 7 g/m <sup>2</sup> per 48 hours liquid phase	test duration 48 hours, EN ISO 28706-2	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.8 release of toxic elements	conform to the national laws		when taking into production a sig.diff. enamel recipe
4.9 impact resistance	inner and outer: at 20 N no damage > 2.0 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.10 adherence	min. 2 (metal less than 3 mm)	on test sheets conform to EN ISO 28764	in production 1 x a month
4.13 defects	inner max. 5 defects per m <sup>2</sup> according to EN ISO 8289 and no defects > 1 mm diameter, reparations (touch up) are allowed		S4/AQL 2.5
4.25 sodium hydroxide 80 °C	max. 8 g/m <sup>2</sup> per 24 hours	test duration 24 hours EN ISO 28706-4	when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.28 steel quality	double-sided enamelling steel quality or suitable construction steel for applied processing		
4.39 adherence	min. "good" (metal more than 3 mm)	on test sheets conform to EN ISO 28764	in production 1 x a month

## 7.26. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED AGRARIAN ARTICLES

### 7.26.1 Application area

These requirements are applicable for enamelled cattle water-troughs in cast iron.

### 7.26.2 Test methods

Item	Name	Applicable standards
4.2	measurement of the thickness of the base substrate metal	EN ISO 16809
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.8	specification and determination of the release of toxic elements	national laws
4.9	determination of the resistance to impact	EN ISO 4532
4.39	determination of the adherence of enamel to steel of more than 3 mm thickness	EEA Specification 8.6.3

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## 7.26.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.2 material thickness	min. 3.0 mm		when taking into production
4.3 thickness enamel coating	max. 0.80 mm		S4/AQL 6.5
4.4 cold citric acid	class A		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.8 release of toxic elements	conform requirements of the national laws		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.9 impact resistance	at 10 N no damage > 2 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.39 adherence	min. "good"	on test sheets conform to EN ISO 28764	in production 1 x a day

## 7.27. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED SIGNS AND ADVERTISING BOARDS

### 7.27.1 Application area

These requirements are applicable for enamelled signs and advertising boards of which the base material consists of steel.

### 7.27.2 Test methods

Item	Name	Applicable standards
4.2	measurement of the thickness of the base substrate metal	EN ISO 16809
4.3	measurement of the thickness of the enamel coating	EN ISO 2178, EN ISO 2360, EN ISO 1463
4.4	determination of the resistance to chemical corrosion by citric acid or other acids at room temperature	EN ISO 28706-1/9
4.5	determination of the resistance to chemical corrosion by boiling citric acids	EN ISO 28706-2/11, EN ISO 28706-2/6
4.9	determination of the resistance to impact	EN ISO 4532
4.10	determination of the adherence of the enamel to the substrate	EN 10209 Annex C
4.12	determination of the porosity by the high voltage test	EN ISO 2746, EN 14430
4.13	determination, detection and location of defects (non-destructive)	EN ISO 8289-1, EN ISO 8289-2
4.18	determination of scratch resistance	EN ISO 15695
4.19	determination of colour difference	EN ISO 18314, EN ISO/CIE 11664
4.26	determination of abrasion resistance	ASTM C501
4.28	determination of the quality of steel for enamelling	EN 10209 for cold rolled steel and see 4.28 recommendations for hot rolled steels, HSLA steels and steel forgings for pressure applications

[Items 4.1 - 4.49](#)

## 7.27.3 Quality requirements

Test method	Requirement	Remarks	Frequency
4.2 material thickness	min 0.75 mm	is not valid for laminated panels	determination during design
4.3 thickness enamel coating	max. 0.50 mm	not applicable if covered with several colour layers in order to achieve special decorative effects	S4/AQL 6.5 (when coil production, 1 x per 100 m <sup>2</sup> )
4.4 cold citric acid	class A		when taking into production a sig.diff. enamel recipe, but at least 1 x per year
4.5 boiling citric acid	max. weight loss: 18.5 g/m <sup>2</sup> per 2,5 hours	only for outdoor application	when taking into production a sig.diff. enamel recipe, but at least 1 x per year
4.9 impact resistance	at 20 N no damage > 2.0 mm diameter after 24 hours		when taking into production a sig.diff. enamel recipe, but at least 1 x a year
4.10 adherence	min. 2	on test sheets conform to EN ISO 28764	in production 1 x a day
4.12 porosity or: 4.13 determination of defects	max. 10 defects per m <sup>2</sup> max. 10 defects per m <sup>2</sup> or max. 5 defects per m <sup>2</sup>	only for outdoor application in accordance with EN ISO 8289 method B in accordance with EN ISO 8289 method A	in production min. 1 % in production min. 1 % in production min. 1 %
4.18 scratch resistance	min. 4 N		when taking into production a sig.diff. enamel recipe (excluding colour oxides), but at least 1 x a year
4.19 colour difference	even and smooth surface, evaluated equal to the appearance of an approved enamelled sample	Colour difference possibly measured with a spectrometer and tolerances previously agreed by interested partners	In production 100%
4.26 abrasion resistance	max. 0.1 gram sandpaper S33/1kg/1000 rotations	in accordance with ASTM C501	when taking into production a sig.diff. enamel recipe (excluding colour oxides), but at least 1 x a year
4.28 Steel quality	in accordance with norm EN 10209	is recommended: DC01EK / DC04EK / DC04ED	determination during design

#### 7.27.4 Remarks

The thickness of the sheet material and the construction must ensure that distortion cannot be imposed through manual force.

This can be achieved by installing stiffeners such as flanged rims or otherwise, as determined in the design.

Articles must be equipped with sufficient protection against corrosion at the back side.

Signs may not deviate more than 1 % in flatness with respect to the longest side and diagonal of the article, and must meet the requirements of the manufacturer with regard to sheet thickness, sheet quality, construction and technical design of the article. The inspection frequency for this additional requirement during production is 1 % of the material, but at least 1 x per month. Signs are measured in the position in which they will be installed.

Possible firing marks at the back side of the non-glued panels must be retouched in order to prevent corrosion. The inspection frequency for this additional requirement during production is at least 1 x a day.

The enamelled surface shall be visually examined either in natural light or in artificial daylight D 65 (see EN ISO 105-J03). The surface shall be examined from a minimum distance of 1.5 m, or at the distance at which the fixed panel would normally be viewed, whichever is the greater.

In certain conditions and in agreement with the manufacturer signs and advertising boards for interior use may be produced with lower resistance against citric acid.

Graffiti has to be removed with a sponge or cloth and an appropriate solvent. After eight days of drying at ambient temperature, ink and varnish colours should also be washable without visible traces (does not apply for precious metal coatings).

The quality requirements and testing regulations also apply for silk-screened-art enamelled articles. However, they are not valid for artistically free designed enamelled articles (for the latter, special arrangements can be made).

## 8.0 EEA-SPECIFICATIONS

### 8.1 Cast iron, suitable for enamelling

8.1.1 Cast iron with lamellar graphite complying to DIN EN 1561 (grey cast iron)

Chemical analysis:

The following limiting values of the main elements should be kept:

a)	Carbon, total	C	3.20 - 3.40
b)	Carbon, combined	C	max. 0.20
c)	Silicon	Si	2.50 - 3.25
d)	Manganese	Mn	max. 0.45
e)	Phosphorus	P	0.25 - 1.00
f)	Sulphur	S	max. 0.12

Trace elements:

g)	Chromium	Cr	max. 0.05
h)	Copper	Cu	max. 0.10
i)	Molybdenum	Mo	max. 0.05
j)	Nickel	Ni	max. 0.10
k)	Titanium	Ti	max. 0.05
l)	Vanadium	V	max. 0.05
m)	Tin	Sn	max. 0.10
n)	Sum Cr + V + Ti		max. 0.12

The silicon content plays an important role. Low silicon contents, below 2.5 %, are slowing down the ferritization process so that it is not finalized after the enamelling process has been completed. An elevated outgassing, due to the conversion of perlite, causes pores and pin holes during the final stage of firing.

Because of the perlite stabilizing effect, manganese contents more than 0.45 % should be avoided. They lead to an embrittlement and to a formation of strong stresses in the composite material cast iron / enamel.

Particularly critical for the enamelling are the trace elements Chromium, Molybdenum, Nickel, Titanium and Vanadium if the above-mentioned maximal concentrations are exceeded. Consequently, the perlite is that much stabilized, that only an incomplete composition to ferrite takes place during enamelling. It leads to a fluctuating expansion behaviour of the casting, depending upon its wall thickness.

The Sulphur content is in particular to consider by applying the wet enamelling process for cast iron. Sulphur contents up to max. 0.12 % in general do not cause defects.

Higher Sulphur contents can lead to severe difficulties in the enamelling because of the diffusion of Sulphur towards the cast iron surface. During the hot process the velocity of oxidation is that much increased, that the thereby formed quantities of iron oxide cannot be absorbed by the enamel.

The formation of stresses within the composite system cast iron / enamel is mainly, under consideration of different designs, a matter of the structure of the cast iron. After the casting process the structure must be Perlitic, not Cementitic.

For the enamelling process the surface of the cast iron has to be clean and free of burned- in sand. Its medium roughness should not exceed 300 microns.

Saturation value: Sc = min. 1.04 max. 1.08



For cleaning the cast iron prior to enamelling only angular shot blasting material on the basis of cast-steel or chilled cast iron has been proved. Both grades are having the essential hardness and edge stability (Vickers-Hardness HV above 650). Fractionated corundum also is very well suitable.

#### 8.1.2. Cast iron with spherical graphite complying to DIN EN 1563 (spherical graphite iron)

##### Chemical analysis

The following limiting values of the main elements should be kept:

Cast iron with spherical graphite structure after thermal treatment

			<b>Ferritic</b>	<b>Ferritic/Perlitic</b>
a)	Carbon, total	C	3.00 - 4.00	3.00 - 4.00
b)	Carbon, combined	C	max. 0.10	max. 0.50
c)	Silicon	Si	2.80 - 4.00	2.40 - 3.00
d)	Manganese	Mn	max. 0.20	max. 0.40
e)	Phosphorus	P	max. 0.05	max. 0.05
f)	Sulphur	S	max. 0.005	max. 0.005
g)	Magnesium	Mg	max. 0.05	max. 0.05
h)	Aluminium	Al	max. 0.005	max. 0.005

##### Trace elements

i)	Chromium	Cr	max. 0.05
j)	Copper	Cu	max. 0.10
k)	Molybdenum	Mo	max. 0.05
l)	Nickel	Ni	max. 0.05
m)	Titanium	Ti	max. 0.05
n)	Vanadium	V	max. 0.05
o)	Tin	Sn	max. 0,05
p)	Sum Cr + V + Ti		max. 0,12

Saturation value      Sc = min. 1.04    max. 1.08

In cast iron with spherical graphite the element Magnesium has the function to convert the lamellar crystallizing carbon (graphite) into the spherical state of crystallization during casting and the following thermal treatment.

Due to the ferritic structure and the spherical form of graphite, steel-like elasticity properties are attained.

Besides the nucleus formation and separation of spherical graphite, magnesium binds Sulphur as Magnesium Sulphide. This Magnesium Sulphide is preferably absorbed by the slag of which it reduces its surface tension considerably, so that magnesium slags cannot be wetted by glasses.

Castings are contaminated and not suitable for enamelling if an inadequate slag separation takes place during the casting process. Notice has to be taken of a good slag separation. Particularly good enamelling results are attainable if a spherical graphite iron can be produced with a magnesium content less than 0.05 %.

Just as negative as on lamellar cast iron are the trace elements Chromium, Molybdenum, Nickel, Titanium and Vanadium if the max. concentrations, as mentioned, are exceeded. Consequently, the perlite is that much stabilized, that only an incomplete decomposition to ferrite takes place during enamelling. This is not only leading to a fluctuating expansion behaviour depending on the wall thickness of the casting; there are also zones having a structural transformation during enamelling by which a degassing occurs.

As for the enamelling of lamellar cast iron, the surface of the casting has to be clean and free of burned-in sand.

The medium roughness should not exceed 300 microns.

For cleaning the cast iron prior to enamelling only angular shot blasting material on the basis of cast-steel or chilled cast iron has been proved. Both grades are having the essential hardness and edge-stability (Vickers - Hardness HV above 650). Fractionated corundum is also very well suitable.

## 8.2 Examination of metal pre-treatment

### 8.2.1. Control of the sheet steel pre-treatment

#### 8.2.1.1 Testing of degreasing baths

##### Explanation

Customary emulsifying degreasing is based on the emulsification of oily or greasy residues in blends of hydrocarbons under the addition of surfactants or wetting agents. These are mostly long catenary organic compounds possessing a lipophilic (on-grease accumulating) and a hydrophilic (on-water accumulating) part of a molecule. There are anionic or cationic active or non-ionogenic surfactants. Due to skilful combinations optimal degreasing results for each, oil, grease and emulsions are achieved by the manufacturers of degreasing agents.

The multiplicity of combinations in degreasing agents does not permit to name a simple and in general valid analysis for enamelling works. For controlling the degreasing baths manufacturers of degreasing agents issue obligatory processing guidelines.

Because of the complicated control of degreasing baths, it is recommendable to register on a daily basis the  $m^2$  - surface throughput and its degree of fouling. A good general view about the efficiency of degreasing baths results from the quantity of degreasing agents used, the surface throughput and the degree of fouling.

##### Quick-test of degreasing baths

In order to check the effectiveness quickly, the following small-scale test should be carried through several times per day.

A degreased component out of production is to be immersed for about 30 sec. into the pickling bath (e.g. hot, 9 % sulphuric acid) and consequently rinsed with cold water. The water film on the surface must remain closed and should not pull apart.

### 8.2.1.2 Determination of acid concentration, sulphuric acid pickling

##### Analysis instructions:

Take a 10 ml cooled (20 °C) sample of the pickling bath solution into a 100 ml measuring flask and top up to the mark with distilled water. 10 ml of this solution (= 1 ml original) are to be pipetted in an Erlenmeyer flask. After an addition of about 100 ml distilled water, about 5 g Ammonium sulphate and 5 drops Bromocresol green, titrate with 0.1n NaOH until the colour changes from orange to blue.

**ml consumption 0.1 n NaOH x 4.9 g H<sub>2</sub>SO<sub>4</sub> / l pickling solution**

##### Required reagents:

Ammonium sulphate

Bromocresol green

0.1 g Bromocresol green dissolved in 100 ml ethanol

0.1 n caustic soda solution

## 8.2.1.3 Determination of bivalent iron, sulphuric acid pickling

Purpose and scope

Too high a content of iron (II)-sulphate can lead to a crystallizing pickling bath while cooling down. The concentration of iron in pickling baths has to be checked regularly.

Analysis instructions

5 ml of a cooled (20 °C) sample of the pickling bath solution is to be mixed with about 100 ml distilled water and 10 ml Reinhardt-Zimmermann-solution in an Erlenmeyer flask and titrated under strong agitation with 0.1 n KMnO<sub>4</sub> solution. The titration is brought to an end when after the last addition of potassium permanganate, the solution still shows after one minute a light pink.

**ml consumption 0.1 n KMnO<sub>4</sub> x 1.1 = g Fe<sup>2+</sup> / l pickling solution**

Required reagents:

Reinhardt-Zimmermann-solution:

67 g MnSO<sub>4</sub> x 4 H<sub>2</sub>O, 138 ml H<sub>3</sub>PO<sub>4</sub> (density 1.70) and  
130 ml H<sub>2</sub>SO<sub>4</sub> (density 1.82) are to be filled up with 1000 ml distilled water.  
0,1n potassium permanganate solution

## 8.2.1.4 Determination of nickel sulphate, nickel-exchange bath

Purpose and scope

In order to guarantee an even nickel deposition, the concentration of nickel sulphate is to be kept constant.

Analysis instructions:

25 ml of a cooled (20 °C) sample of the nickel bath is to be diluted with about 100 ml distilled water in an Erlenmeyer flask. After about 20 ml ammonium chloride solution has been added, it has to be mixed with a triethanolamine solution. This solution has to be slightly acidic so that the masking of iron by triethanolamine can be realized. If necessary, some drops of hydrochloric or sulphuric acid can be used for adjustment. The slight acidic solution is to be set ammoniacal with about 25 ml ammonia and after the addition of Murexid, titrate with:

'0.1 m Complexon-III-solution until the colour changes from brownish pink to deep violet.

**ml consumption 0.1 m Complexon-III-solution x 1.1 = g NiSO<sub>4</sub> x 7H<sub>2</sub>O / l nickel bath solution**

Required reagents:

Ammonium chloride: 54 g NH<sub>4</sub>Cl per Liter

Ammonia 25 %, p.a

Triethanolamine – solution: TriEthanol diluted in water in a proportion 1 : 1

Murexid: Murexid is mixed with NaCl in a proportion 1 : 200

0.1 m Complexon-III-solution:

Complexon-III-solution is the disodium salt of the ethylenediamine tetra acetic acid (mol. weight 372.1) and is known under the trade name Titriplex® (Merck) and Idranal® (Riedel de Haen).

## 8.2.1.5 Determination of bivalent iron in the nickel-exchange bath

Purpose and scope

In order to guarantee an even nickel deposition and to avoid a crystallization by cooling, the iron (II) sulphate must be checked.

Analysis instructions:

25 ml of a cooled (20 °C) sample of the nickel bath solution is to be diluted with about 100 ml distilled water in an Erlenmeyer flask and after addition of about 20 ml 20 %-sulphuric acid and 5 drops diphenylaminosulfonic acid to be titrated with 0.02 n  $K_2Cr_2O_7$  - solution. Near the end point the green colour of the solution deepens. The titration is brought to an end when the colour of the solution changes from green to blue-violet.

**ml consumption  $0.02 \text{ n } K_2Cr_2O_7 \times 0.04 = \text{g Fe}^{2+} / \text{l nickel bath solution}$**

Required reagents:

Diphenylaminosulfonic acid:

0.2 g Diphenylaminosulfonic acid to be dissolved in 100 ml n  $H_2SO_4$

0.02 n  $K_2Cr_2O_7$ -solution

## 8.2.1.6 Determination of the nickel deposit on sheet steel

Purpose and scope

It is often desirable to make knowledge of the nickel quantity deposited onto the steel.

Analysis instruction

A sample of a defined size (approx. 5 X 5 cm) is to be cut out of a component that is to be examined. The deposited nickel on its surface has to be taken off by a cold 10% nitric acid, then rinse the sample thoroughly with distilled water. Warm up the nitric acid solution and blend it with about 10 g of tartaric acid in order to mask possible dissolved iron. Set up the solution with ammonia whereby iron hydroxide must not precipitate; in case of this, increase the amount of tartaric acid.

Precipitate the nickel with 10 ml of a 2% alcoholic dimethylglyoxime solution and pass the red precipitate through a "white-ribbon" filter, rinse thoroughly with distilled water and dissolve it in about 5 ml of a 10% nitric acid.

Dilute the clear solution with water, set it up with ammonia to slight ammoniacal, add Murexid and titrate with 0.01m Complexion-III solution till the colour changes from brownish-pink to deep violet.

**ml consumption  $0.01\text{m Complexion-III-solution} \times 5.87 = \text{g Ni/m}^2 \text{ steel surface}$**   
cm<sup>2</sup> sample surface

List of reagents:

10% nitric acid Tartaric

acid Dimethylglyoxime solution: 2 g dimethylglyoxime are dissolved in alcohol

Murexid: is to blend with NaCl in a proportion 1 : 200

## 0.01m Complexion-III-solution:

Complexion-III is the disodium salt of ethylene diamine tetraacetic acid (mol.wt. 372.1 and available as Titriplex® (Merck) and Idranal® (Riedel de Haen)).

**8.3 Examination of enamels and additives for enamelling**

## 8.3.1 Surface tension of enamels

## Explanation

Surface tension or interfacial tension is, the surface of a liquid effecting, inwards directed force. Because of these molecular forces liquids attempt to reduce their surface. Quite small amounts of liquids endeavour to form a spherical shape. The higher the surface tension the sooner the ideal spherical shape is attained (Mercury has a high, water a low surface tension in relation to it). There are substances by which the surface tension of liquids can be altered.

In the field of enamels and enamelling the surface tension is an object, when the material changes over from the solid to the liquid state and vice versa. This takes place while melting as well as while firing the enamel. Porcelain and vitreous enamels with a high surface tension are aligned during firing towards the metal substrate; those with a low surface tension towards the surface against air. In fact, the frit manufacturer greatly attends to this and chooses an oxide composition of the enamel accordingly. Quincke (1868), Winkelmann and Schott (1884) and others had found relations between surface tension and the oxide composition of glasses. Dietzel picked up the tasks and obtained similar correlations to the oxide composition of enamels. In 1942, he published a list of surface tension factors comprehending a lot of enamel raw materials. The factors have been established for mN/m percentage by weight. They permit a quite exact predetermination of the surface tension of enamels. Later on, the list has been enlarged several times. In the rank described below a small excerpt out of the table of these factors is given to calculate the surface tension of enamels. The factors relate to 1 percent by weight at times.

-10	- 5.9	0.1	0.8	1.5	3.0	3.4	4.1	4.5	6.2	6.6
MoO <sub>3</sub>	Cr <sub>3</sub> O <sub>3</sub>	K <sub>2</sub> O	B <sub>2</sub> O <sub>3</sub>	Na <sub>2</sub> O	TiO <sub>2</sub>	SiO <sub>2</sub>	ZrO <sub>2</sub>	CoO/ NiO	Al <sub>2</sub> O <sub>3</sub>	MgO

As a comparison, the surface tension of:

Aluminium enamels	= 170 to 250 mN/m
Cover coats	= 220 to 250 mN/m
Ground coats	= 240 to 300 mN/m

#### Measurement of surface tension of enamels

To measure the surface tension of enamels, one makes use of the drop method. Like all measuring methods referring to this, the drop method also postulates an absolute observance of many working and instrument parameters.

The discussion upon measuring procedures and conditions is not the aim of this specification sheet.

## 8.4 Enamel powder for the electrostatic application on sheet steel

The parameters of a powder affecting its workability in the enamel shop are residue of powder, fluidity, electrical resistance as well as adherence of the powder on the sheet steel after electrostatic application. They are to be registered in the laboratory and to be reproduced within quantitatively acceptable limits.

The following standard data have proved to be characteristic for an electrostatic powder:

- Residue of powder RP > 40µm in %
- Fluidity of powder FP in g/s
- Short time powder adherence STPA in %
- Surface resistance of powder SRP in Ω cm  
(the resistivity is mostly determined in Ω cm)

From instrumental and external influences cleared measuring data is condition of a basic research in the field of electrostatic powder application as well as quality control in the plant and information concerning the powder behaviour in the enamel shop.

### 8.4.1 Testing of powder fineness

The particle size distribution and especially the share of grains > 60µm in powder enamels affects the application properties in the enamelling shop. It can be determined by the known PEMCO test sieve (screen aperture 0.06 mm = 60µm = 10000 mesh/cm<sup>2</sup>).

The residue of the powder in percentage by weight is a measure for the frequency of the particles > 60µm.

The figures can be reproduced up to an exactness of ± 0.5%. With laser or XRF-methods – also used for the production control of powder enamels – a complete granulometric analysis including statistical information (d50, standard deviation) can be obtained.



#### 8.4.2 Testing of powder fluidity

The fluidity of a powder means the ability to get whirled up in a gas stream. This property is essential for how the powder can be transported through the tubes and pipes of a powder installation. Also, the output of the spray guns is depending on it. The fluidity can be measured by the SAMES fluidity meter type AS100 or comparable.

In order to get reproducible results, the following parameters are essential:

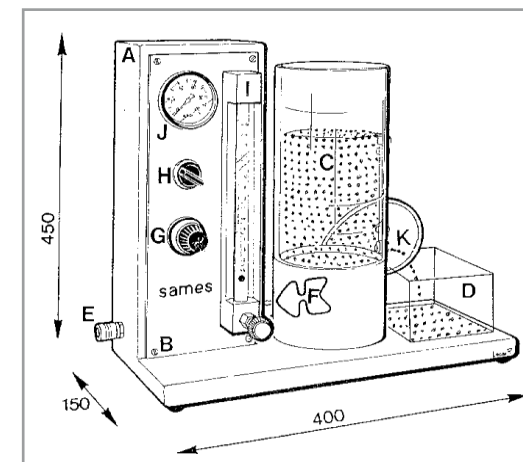
- a. the regularity of the powder
- b. the temperature and humidity of the air stream
- c. the velocity of the air stream
- d. the geometry of the fluidizing bottom and the powder outlet

##### Test procedure:

250 g of powder is filled into the cylinder C with perforated bottom (see fig.). The powder is to be fluidized with a well-defined air stream (rel. humidity < 5 % C, temp. 25 °C, airflow ca. 200 N1/h) and additionally stirred with a spatula for one minute. After the fluidized powder has reached a maximum volume in the cylinder, the outlet K is opened and the powder trickling out in a container D during 30 seconds is then weighed. The average value in gram can be used as a direct indication for fluidity of the powder which will be expressed as gram/30 s. Quite generally a minimum fluidity of 70 g/30 s will be required, the individual values being dependent on the specific conditions in the powder booth.

#### Fluidity meter (sketch)

- A – air flow regulation unit
- B – control panel
- C – fluidizing cylinder with perforated bottom
- D – weighing container
- E – inlet pressurized air
- F – fine regulator air flow
- G – coarse regulator air flow
- H – switch button
- I – graduated air flow meter
- J – pressure indication
- K – powder outlet



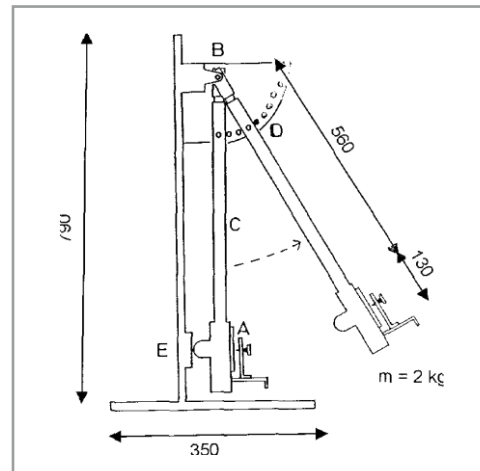
### 8.4.3 Testing of powder adhesion

For the determination of the powder adhesion a special impact apparatus has been developed (see fig.). A 200 x 200 mm stainless steel sheet, covered with about 20 g enamel powder on one side, is fixed on the pendulum arm C by a screw. After removing the positioning bolt D the pendulum arm bounces on the rack E. By this impact a part of the powder drops. The steel sheet is then removed from its fixture and the remaining powder is reweighed. The quotient of the powder on the steel sheet in g before and after the impact, multiplied by 100 gives the value of adhesion in %.

Because the powder adhesion drops with the time between powder coating and impact, an interval of 15 min. has been defined for standard applications. Under these conditions the powder adhesion should have a minimum value of 60 %.

#### Impact Apparatus (sketch)

- A – fixed test plate
- B – adjusting bench for pendulum arm
- C – pendulum arm
- D – positioning bolt
- E – rack



### 8.4.4. Testing of the electrical resistance of the powder

The electrical resistance of enamel powder can be determined by a simple principle. The powder (80 g) is placed between two electrodes formed as tank and stamp (see fig.). By applying an electrical voltage, a current begins to flow; its intensity is a measure for the resistance of the enclosed powder.

The reliability of the test result depends essentially on the amount of powder, the surface and geometry of the electrodes and the pressure of the stamp onto the powder. Standardized measuring conditions can be achieved in a standard cell (see fig.) with integrated resistance device. The graduation allows readings up to  $10^{16} \Omega$ . Between the electrodes in the tank and the stamp, two paths for the current are available:

- a. the path of high resistance ( $> 10^{16} \Omega$ ) throughout the enamel particles
- b. the path of minor resistance along the surface of the particles.

As the current always chooses the way of the lowest resistance, it flows principally along the surface. This means, that the determined  $\Omega$ -value is identical to the **surface resistance** of the powder. Multiplication of this value with the quotient of the electrode area (stamp) in  $\text{cm}^2$  and the thickness of the powder layer gives the **specific surface resistance** in the dimension  $\Omega \cdot \text{cm}$ . These values have been reported mostly. As the specific resistance is a constant property of a solid material - according to the volume resistance - this parameter should not be used for the characterization of powders of low density and surface conductivity. Therefore, the surface resistance in  $\Omega \cdot \text{cm}$  is best suited for the expression of the electrical resistance of powders. Despite the fact, that the figures are only relative, the measuring results achieved under standard conditions allow for an effective comparison of different electrostatic powders.

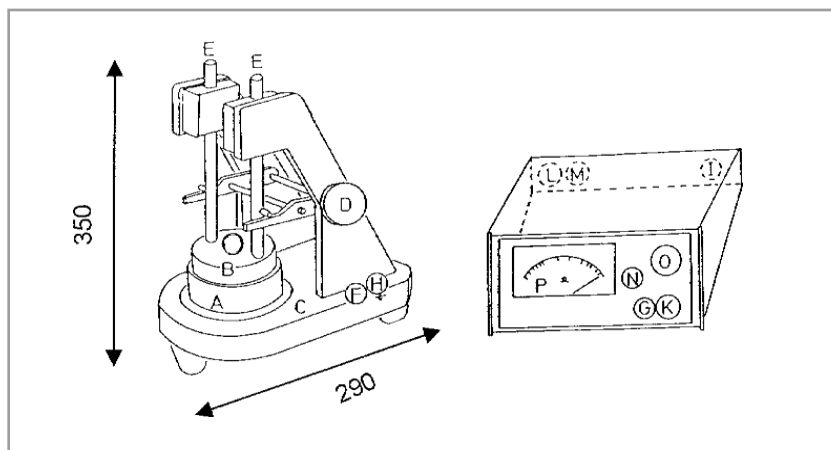
#### Correlation between surface resistance and powder adhesion

A good powder adhesion requires that the enamel particles spread onto the sheet

steel keep their electrical charge for some time. The Coulomb interaction between the negatively charged particle (powder) layer and the positively charged steel plate will only continue as long as the charge difference remains. After the entire loading of the particles has flown off, the particles fall down. Consequently, enamel particles must have dielectric properties and have therefore a high current flow resistance. Untreated enamel powder does not adhere because of the relatively high conductivity of the surface bound OH- groups and adsorbed water. By coating the powder with reactive Silanol components the harmful influence of the OH-groups and traces of water can be eliminated and the surface conductivity can be reduced considerably. As a result, coated powders show an increased surface resistance of about 7 orders of magnitude!

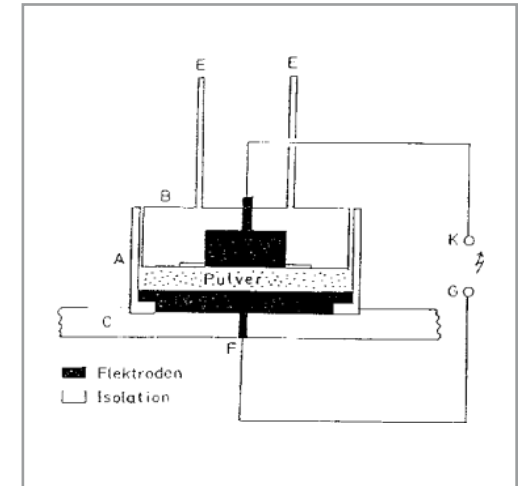
The surface resistance is a measure of the efficiency of the particle coating. Moreover, it indicates whether the coated powder withstands any attack by humidity out of the air after ageing. Powders with a high surface resistance ( $>10^{14} \Omega$ ) result in good figures for the powder adhesion.

#### Standard Cell Commercial Measuring Unit



- A – measuring cell of PTFE
- B – electrode stamp
- C – bottom plate
- D – vertical adjustment
- E – steering rods
- F – clamp
- G – ground
- H – diode socket
- I – printer connection
- K – electrode connection
- L – power supply
- M – switch button
- N – voltage control
- O – resistance range
- P – resistance display

#### Measuring Principle



## 8.5 Examination of enamelling clays

### Purpose and scope

The rheological effects of enamelling clays in enamel suspensions can be classified by a methylene blue titration. The following should be controlled:

1. Adsorption of methylene blue
2. pH-value in aqueous suspension
3. Colour co-ordinates
4. Cleanliness

### Analysis instruction

#### 1. Determination of the methylene blue adsorption

Dry the clay at 105 °C. Weigh precisely a sample of 2.2 g blue clay or 2.5 g white clay and boil it for 5 minutes in 25 ml of distilled water. Add 3 ml 6n H<sub>2</sub>SO<sub>4</sub> and mix intensively for at least 30 seconds. After being cooled, add 25 ml methylene blue solution (I) and stir for 5 minutes (magnetic stirrer). Place one drop of this suspension onto a filter paper. When the ending edge is achromatic, titrate the suspension with methylene blue solution (II) till the ending fluid edge gleams blueish; that is to say until the clay does not absorb any more methylene blue. In order to guarantee a complete adsorption, the supply of methylene blue during titration has to be slow. Stir about 2 minutes between supply and checkup. Consumption = a ml.

$$\frac{(25 \times 3.2) + (a \times 1.6)}{\text{g weight of sample}} = \text{mg methylene blue per 1 g clay}$$

As a measure of a classification of enamelling clays, the following figures are valid:

- Blue clay 40-46 mg/g
- White clay 33-38 mg/g

#### 2. pH-value of the clay-water-suspension

Stir 50 g clay into 100 ml distilled water. Store it for 30 minutes and measure the pH-value of the unfiltered sludge. pH-values between 4.3 and 5.5 are valid.

#### 3. Determination of colour co-ordinates

The colour of the fired clay is to be checked in a white enamelling as described.

A white enamelling with a standard clay is to be compared to such a white enamelling with a test clay. For milling, a Rosetti-mill is used with the following formula:

Standard frit	100.00
Clay	3.50
Sodium aluminate	0.15
Potassium carbonate	0.10
Water	47.00

The specific gravity of the slip should be at least 1.7 g/ml.

Apply the enamel slip onto normal sheet steel plates over ground coat and fire them according to the type of the standard frit (e.g. 820 °C; 3 minutes).

In order to determine the colour co-ordinates, use a spectrometer or similar colour measuring apparatus.

#### 4. Control of cleanliness

100 g clay are to be suspended in water, intensively stirred and screened through a 3600-mesh sieve (=100µm mesh aperture). The residue is to be mingled into 100 g white enamel slip. A test enamelling on ground coated sample plates must result in a faultless white enamelling.

Required reagents:

## Methylene blue solution (I)

Dissolve 3.2 mg methylene blue in 500 ml distilled water of about 70 °C. Put this solution in a 1000 ml measuring flask and fill up at 20 °C with distilled water.

## Methylene blue solution (II)

Dissolve 1.6 g methylene blue in 500 ml distilled water of about 70 °C. Put this solution in a 1000 ml measuring flask and fill up at 20 °C with distilled water.

## 6n sulphuric acid

Mix 167 ml concentrated H<sub>2</sub>SO<sub>4</sub> (Density 1.84) with 700 ml distilled water and fill up to 1000 ml with distilled water.

## 8.5.1 Testing of setting agents and other accessory materials

Purpose and scope

Testing of setting agents and other accessory materials can mostly be done in the laboratory of the enamelling shop. The various analytical processes presuppose training and experience.

Normally, setting agents are genuine or chemically pure chemicals supplied by the chemical industry with their final quality control.

It is substantial for the processing plant to store the setting agents according to their storage specifications. Some of them, e.g. sodium aluminate, are hygroscopic. That is to say, they adsorb water, so that the agent cannot be used for enamelling if not stored properly.

In case of doubt about the correct storage of accessory materials, suppliers or manufacturers should be contacted for the corresponding specifications.

### 8.5.2 Requirements set on water to be used in the enamelling shop

#### Generally

In general water is not considered to be an enamel raw material, although it is used with about 30% in the enamel slip. The other consumer of water in the enamelling shop is the pre-treatment line. Requirements upon the quality of water as requested by these two users are quite different.

#### Water for the pre-treatment

The particular pre-treatment steps are finishing with a rinse. Task of the rinse is to wash-off emulsified and saponified greases, oils and salts. No chemical reaction must take place between the products arising from the various working processes and the rinsing water. Water to be used must be extensively free of alkaline earths. The percentage of alkaline earths in the water is expressed in degree of water hardness which can be inquired from the water supplier. In order to achieve the highest possible production assurance, the use of at least cation-desalinated water is recommended.

#### Water for the preparation of the enamel slip

On earth, water is the most widespread solvent. The purer a water, the more eager it is to assimilate ions. With the preparation of enamel slips this dissolving behaviour is undesired because it is looked upon equivalent to the leaching process of enamels. A too high alkali content in the water of the slip normally influences the setting characteristics of the clay in a negative way. The properties of the slip become uncontrollable because of the longer lasting dissolving process. The use of harder waters for milling is proven. Thereby, additions of clay and setting agents can be reduced. In order to have always the same level of calcium in the milling water, one adjusts by adding calcium silicate hydrate to about 350 GH, which is the degree of saturation.

Units of water hardness of different countries and their conversion factors  
(mval/kg = 28 mg CaO or 50 mg CaCO<sub>3</sub> per 1000 ml water):

#### Germany:

$1^{\circ}\text{GH} = \text{German degree of hardness} = 10 \text{ mg CaO per 100 ml water}$

$1^{\circ}\text{GH} = 1.78^{\circ}\text{FH} = 1.25^{\circ}\text{BH} = 17.8 \text{ ppm} = 0.357 \text{ mval/kg}$

#### France:

$1^{\circ}\text{FH} = \text{French degree of hardness} = 10 \text{ mg CaCO}_3 \text{ per 1000 ml water}$

$1^{\circ}\text{FH} = 0.56^{\circ}\text{GH} = 0.7^{\circ}\text{BH} = 10 \text{ ppm} = 0.2 \text{ mval/kg}$

#### Great Britain:

$1^{\circ}\text{BH} = \text{British degree of hardness} = 1 \text{ grain CaCO}_3 \text{ per gallon} = 14.3 \text{ mg CaCO}_3 \text{ per 1000 ml water}$

$1^{\circ}\text{BH} = 0.8^{\circ}\text{GH} = 1.43^{\circ}\text{FH} = 14.3 \text{ ppm} = 0.286 \text{ mval/kg}$

#### USA:

$\text{ppm} = 1 \text{ part per million} = 1 \text{ mg CaCO}_3 \text{ per 1000 ml water}$

$1 \text{ ppm} = 0.056^{\circ}\text{GH} = 0.1^{\circ}\text{FH} = 0.07^{\circ}\text{BH} = 0.02 \text{ mval/kg}$

#### Regulations for the analysis of water

##### Determination of the pH-value

The pH-value indicates the acidic or alkaline character of the water. It is measured on an electrometric basis with potentiometers. For the calibration of the testing instruments, test solutions are available.

##### Determination of the conductivity

The conductivity is measured on an electrometric basis with potentiometers.

Determination of the total hardness

Take 100 ml of the water to be tested and mix it with few drops ammonia and one indicator buffer tablet. Titrate with Complexon-A from red violet via grey till the colour changes into green.

**ml consumption of Complexon X 5.6 = ° German hardness**

Determination of the calcium and magnesium hardness

Mix 100 ml of the water to be tested with 4 ml potash lye and 5 - 10 drops of 0.4% Calcon carboxylic acid. In presence of Ca-ions the solution is wine red. Titrate this with Complexon-C-solution till the colour changes into net blue.

**ml consumption of Complexon X 2.4 = ° German calcium hardness**

The magnesium hardness is calculated:

**magnesium hardness = total hardness - calcium hardness**

Required reagents

Complexon A

Indicator buffer tablets for the determination of hardness

Ammonia solution p.a. (about 25%)

Complexon C

Potash lye

50 g solid potassium hydroxide to be dissolved in

50 ml distilled water

!!! wear protective glasses !!!

Calcon carboxylic acid solution

0.4 g Calcon carboxylic acid to be dissolved in 100 ml methanol

Test report

To be mentioned are:

Kind and origin of samples

Place and date of test

Water temperature

pH-value and conductivity of water

Total-, Calcium- and Magnesium hardness

### 8.5.3 Conditions of grinding

#### 8.5.3.1 Test of the fineness of grinding

##### Purpose and scope

Wet milling of enamels requires to focus on the fineness of grinding and to strive for an always stable grain structure. For testing the fineness of grinding, simple devices, which are easy to attend, are available. For usual enamellings, adequate results are obtainable. But one must be aware of too high expectations from these hand tests. Simple test equipment cannot be precise and has not been geared for that purpose.

The PEMCO enamel test sieve proved itself in practice. It comprises the following items: Sieving funnel of transparent plastic with test sieves made of phosphor bronze in a plastic screw base (different colours depending on the screen aperture):

- Measuring tube with scale and stopper
- Funnel tube
- Measuring beaker of plastic (formerly brass)

The screen aperture of test sieves is depending on the purpose of the slip. For dipping or spraying, black sieves of 100µm mesh aperture = 3600 mesh per cm<sup>2</sup>, for electrostatic applications, blue sieves of 75µm mesh aperture = 6400 mesh per cm<sup>2</sup> are in use. Aluminium enamels are even finer ground. Test white sieves of 40µm mesh aperture = 16900 mesh per cm<sup>2</sup> are essential. The sieves are standardized in accordance with EN ISO 3310-1

##### Operating instructions

To check the fineness of grinding, fill the measuring beaker (12.5 ml) to the brim with the slip under test. Rinse the sample through the funnel tube onto the test sieve and wash the slip through the test sieve. Best is to swing the sieving funnel in a container of water.<sup>1)</sup>

<sup>1)</sup> The widespread method to press the slip through the test sieve by means of a strong jet of water is wrong. By this, the test sieve netting expands, so that the coarser particles are forced through. An experienced checker will be able to measure almost any desired fineness of grinding.

When the fine grains are washed out, the coarse particles, being bigger than the mesh aperture of the test sieve, remain on the test sieve. The sieving procedure is over as soon as clear water runs out of the sieving funnel. Then, close the measuring tube with the stopper, fill it with water and put the sieving funnel on it. Allow a strong jet of water to pass from the outside through the sieve. Remove any existing air bubbles by gentle knocking and dislodge the sieve residue by agitation after which it drops into the measuring tube, where the amount can be read on the graduation of the scale.

The percentage of the coarse particles in the slip is calculated by a multiplication of the read off units by factor 1.7. It would be absurd to calculate the percentage down to the decimal point, because the sensitivity of this test is not that precise. It is just a typical handy check, suitable in the best manner for the shop.

PEMCO and Vibrantz developed test methods for the determination of the fineness of grinding, but with distinguished graduation figures. The existing relations between these two methods can be tabulated:

##### Graduation on the devices of PEMCO and Vibrantz

0.5	3.5
1	5.5
2	7.3
3	8.7
4	10.0

The test method PEMCO requires a sample of 12.5 ml, whereas the test with the conical Vibrantz test sieve needs 250 ml.

By using this test method, one catches the coarse grains only; consequently only a few percent of the total grain structure. In order to diminish this lack, it is advisable to use a test sieve which permits a test sieve residue of at least 3 scale graduations. Preferably use test sieves of 6400 to 10000 mesh instead of 3600 mesh test sieve. One can also use a laser particle size analyser to get a full grain size distribution.



### 8.5.3.2 Examination of test sieve residue

#### Purpose and scope

In order to reduce the share of defects in enamelling, it is recommendable to investigate the collected sieve residue, that is left over from the test of fineness of grinding, thoroughly. Such residue delivers references to mill damage and other dragged-in contamination.

After the test of fineness of grinding, the sieve residue is in the measuring tube. Pour a part of the supernatant water, shake and mix the sieve residue with the rest of the water and pour it onto a filter paper or white cloth. Should the sieve residue consist not only of enamel particles but also of other materials, then further measures are recommended to find out which foreign matter it is and from where it originates. White, very hard particles are mostly porcelain or steatite caused by broken milling balls or mill lining. Smudgy or sticky, greyish looking pellets which can be crushed, are clay minerals. In this case, after the mill was loaded, clay formed a big clot in the mill, not being wetted by the mill water. Also, particles of rust are no rarity. Their origin can be of various kinds. In any case, one should search for the sources of contamination, because black, grey or white specks in the enamelling often arise from contaminated slips. In most of these cases these contaminations can be recognized in the sieve residue.

To make sure, that the sieve residue is not causing defects in the enamelling, take a bigger quantity of slip, screen it and stir about 5 - 10 g of this residue into 100 ml of slip in use. Test plates enamelled with this mixture will indicate the defects which can derive from the sieve residue.

### 8.5.4 The flow characteristics of enamel slip (slurry)

#### Elucidation

Enamel slips do belong to the muds and are in the widest meaning not a Newtonian liquid. For the most part, muds are colloidal systems i.e. one phase is very fine distributed but embedded in another phase. The media can be in a solid, liquid or gaseous state. Colloids are not in a thermodynamic equilibrium. One of their most important properties is, that their internal surface is much larger than their external one. Systems with solid state particles embedded in liquids are called suspensions. Independence of the size of the solid-state particles, one has to differentiate between coarse dispersive, colloid dispersive and molecular dispersive systems. The transitions are floating and are numerically not defined. If in a colloidal system, the gaps between the solid-state particles are repleted with liquid and are then getting smaller than their average diameter, the system solidifies; the liquid suspension becomes a gel. The viscosity of muds mainly depends on the velocity gradient, the flow duration and pressure. In aqueous solutions temperature only plays a subordinated role and is sufficiently described as room temperature, quite different to oil emulsions. In this case, the functional relationship of the oil temperature strongly influences the rheological properties.

Enamel slips are intrinsic viscous liquids with a flow limit and superimposed thixotropy. They consist of a mixture of ground frits, water and additions like clay, quartz, colouring oxides, setting agents and substances which subsequently influence the dry enamel layer.

Various demands are imposed upon the flow behaviour of the enamel slip. It is supposed to be relatively viscous; it is not allowed to settle and must have an easy workability for application. It must be uniformly distributed on the article. The applied wet layer should not move when transported. The dried biscuit must be free of cracks and has to have enough biscuit strength to withstand the transfer onto the firing chain without any damage.

These requirements exclude any subjective opinion of the slip. Its physical characteristics like density, flow behaviour etc. must be secured by defined data and permissible limits.

The science of flowing is called rheology. The term “flowing” is not to be explained in just one sentence. One knows about fast, viscous, uniformly and jerky flowing. Water e.g., flows uniformly and fast, paste is viscous and emulsions like body lotions are viscous but can be liquefied by shaking. In order to describe the flow of a substance, some more rheological terms are in use (see also DIN 13342).

#### 8.5.4.1 Terms of rheology

##### Viscosity

Viscosity is a measure of the internal friction of a substance, i.e. the force to conquer the interior of a body to affect its appearance.

From a scientific point of view, viscosity is the proportion of shearing strength to the slope of velocity. This interdependence graphically represented in the corresponding coordinate system for perfect liquids shows a straight line intersecting the origin of the coordinates. Liquids without this behaviour, e.g. enamel slips, are non-Newtonian.

##### Yield point

The start of flow is called yield point. Flow only starts after some defined force has been applied or stops after force removal.

##### Thixotropy

Thixotropy is the transition of a substance from a gel to a liquid and vice versa.

##### Shearing strength

Shearing strength is the requisite force to shift two plates against each other having a liquid in between them.

##### Slope of velocity

The shearing strength allows a liquid to flow in the gap between two plates. Consequently, different decreases of velocity will arise in dependence of each kind of a liquid.

#### 8.5.4.2 Determination of the density of slips

##### Purpose and scope

The density or specific gravity is the weight of one Liter of slip in kilogram. The slip density results from densities of the single components. Frit, quartz and clay have in average a density of 2.6 g/cm<sup>3</sup>. There are also enamels available with a higher or lower density. The frit supplier has this information. Water has a density of 1.0 g/ml. Colouring oxides have very different densities. They can be as high as 4 g/cm<sup>3</sup> and more. The small quantities of setting agents can be neglected by the calculation of the density of slips.

To predetermine the slip density, divide the sum of the weights of the single components by the sum of their volume.

The fineness of grinding of the slip has no influence upon its density.

##### Method of operation

One Liter or a part of the slip can be weight out. Normally, the PEMCO density meter with a volume of 100 ml is used.

#### 8.5.4.3 Determination of the flow behaviour of enamel slips by simple methods

##### Purpose and scope

The meaning of this specification sheet is to determine the slip properties by simple methods. The equipment required is reasonably priced and easy to handle, though always the sum of several flow parameters is registered.

With the described equipment, the following is obtained:

1. Dipping test sheet or cylinder Yield point and Thixotropy
2. Enamel slip gauge Viscosity and Thixotropy
3. Slump test Viscosity and Thixotropy
4. Outflow cup Flow in pipes

##### 1. Dipping test and dipping cylinder

The flow of a slip can be simulated with plane or shaped sheet sections. By weighing and conversion into one square meter of surface, the amount of slip left on the to be enamelled part is obtained. This amount permits an estimation of the subsequent application thickness of enamel. This test method is among other things affected by varied manual draw-out velocities.

##### Method of operation:

A degreased test sheet of defined dimensions is dipped into the slip and withdrawn obliquely. After the excess slip has drained off, the amount left on the sheet is determined by weighing. Since the area of the sheet is readily measured, it is easy to calculate the specific amount applied.

There is no need for any calculation if the same sheet is used frequently. Then the applied weight is a direct measure. For external use, the application weight has to be expressed in g/m<sup>2</sup>, because the size of the test sheet is unknown to the interlocutor. In order to fit a

larger surface within small space, the test sheet is bent to give a cylinder. The results by this are more accurate.

The application weight and the observations made of the flow, can be, in a limited way, the criteria of the application behaviour of the slip.

## 2. Enamel slip gauge

The PEMCO enamel slip gauge has been developed in order to characterize the consistency of the slip quickly, without weighing. The device allows comparisons of slips of the same type and consists of a blade of stainless steel, sized 27 x 4 cm with ten holes with steadily increasing diameters from 5 to 14 mm.

### Method of operation:

Use the gauge to stir the slip under test, then lift out the blade vertically with uniform velocity. By draining the slip off the blade, the holes open up, incipient with the lowest, the biggest. The number of open holes can be of information about the application behaviour.

The test method is among other things affected by varied manual draw-out velocities.

## 3. Slump test

The slump test belongs to the more costly but also more exacting test methods. The spread of a fixed volume of slip on a panel scored with concentric rings is measured. The test provides information about viscosity and thixotropy. Both properties are covered by one sum in which the spreading of watery slips is predominantly affected by its viscosity. An existing thixotropy affects the test results of viscous enamel slips.

### Method of operation:

A metal cylinder is placed in time, no real statement can be made about the application behaviour of enamel slips. It has been tried again and again to change the design of outflow cups, enabling them for mud processing, but non representative or reproducible results have been achieved.

Helpful information can be achieved with regard to the judgement of fluidity of muds in closed pipes (pump feeding).

## 4. Outflow cup

Viscosity cups, also called DIN or Ford cups, are suitable for lower viscosities and not for highly viscous substances. The most accurate results are achieved with fluids within the range complying with Newton's law. Nevertheless, when applicable, the cups may provide interesting comparisons between slurries on how they flow through pipes, pump and spraying hoses.

#### 8.5.4.4 Determination of the flow-characteristic of enamel slips by means of rotary viscosity meters

##### Purpose and scope

The principle of rotary viscosity meters in combination with coaxial cylinder-measuring systems allows the absolute measurement of single flow-characteristics. In the ring slot, between the plates formed to cylinders, there is the to be measured liquid. By a defined motion of the cylinders against each other and a measurement of the appearing forces, the measuring problem can be solved in a mathematical way.

One distinguishes from two forms in the execution of the measuring system:

1. The Searle-system: The inner cylinder (body of revolution) rotates with a constant or variable rate of revolutions, while the outer cylinder (measuring beaker) is in a fixed state. The liquid in the ring slot flows and generates a torque, that is directly depending on the liquid's viscosity.
2. The Couette-system: The outer cylinder rotates and makes the liquid in the ring slot flow. The resistance of the liquid against the shearing action transfers a directly on the viscosity of the liquid depending torque onto the inner cylinder.

Details of standard measuring-systems are described in DIN 53018.

The relation between the torsional shearing stress and the velocity gradient are nowadays automatically seized in a flow diagram. Out of this, the flow-characteristics of a liquid or a mud can be seen. Because of the fact, that most of the laboratories are equipped with desk calculators, single measurements can be printed and can be compared to one another.

#### 8.5.4.5 Determination of the flow-characteristic of enamel slips by means of viscosity testers

##### Purpose and scope

Viscosity testers are rotary viscosity meters, with which one is able to measure the torsional shearing stress with the help of given velocity gradients. According to construction and measuring-system, the measurements are directly comparable to continuous working devices. Due to the fact, that viscosity testers are only able to do point determinations, no flow diagram is available. As a measuring system, the Searle-system is used predominantly. The adjustable velocity gradient steps should be in-between 75 to 600 s<sup>-1</sup>.

Viscosity testers provide very good measurements for the internal control of enamel slips.

## 8.6 Testing of porcelain and vitreous enamel coatings

### 8.6.1 Determination of resistance to boiling water by long-term exposure

#### Purpose and scope

The vitreous enamel coating of devices and receptacles, that have to face repetition of stress by means of boiling or hot water, is tested for its resistance by a long-term exposure. Because of the high expenditure of time that is necessary for the test - especially for hot water tanks - a suitable testing method must be followed.

#### Method of testing

The tests will be made according to EN ISO 28706-2 and the DIN 4753. The testing time is set for 6 weeks. The tested plate is installed at the bottom of the apparatus while the top plate (vapour phase) is a glass-plate (borosilicate glass 3.3 according to DIN ISO 3585). The test solution is demineralised water with a conductivity of max. 1 µS/cm and renewed according to the following scheme:

1. to 5. day	daily water-replacement	(1 <sup>st</sup> week)
6. and 7. day	no water-replacement	
8. to 12. day	daily water-replacement	(2 <sup>nd</sup> week)
13. and 14. day	no water-replacement	
15. to 19. day	daily water-replacement	(3 <sup>rd</sup> week)
20. and 21. day	no water-replacement	
22. day	The test plates are removed out of the device and are cleaned and weighed. After the weighing, the test plates are put in the device again. The second testing round starts just like the first day	(4 <sup>th</sup> week)
23. to 26. day	daily water-replacement	(4 <sup>th</sup> week tbc)
27. and 28. day	no water-replacement	

29. to 33. day	daily water-replacement	(5 <sup>th</sup> week)
34. and 35. day	no water-replacement	
36. to 40. day	daily water-replacement	(6 <sup>th</sup> week)
41. and 42. day	day no water-replacement	
43. day	The test plates are, cleaned, dried and weighed.	

#### Testing-device

Apparatus according to EN ISO 28706-2/6

#### Testing-time

If no further arrangements have been made, a testing-time of 2 x 3 weeks is valid; the second testing round is rated.

#### Testing-temperature

If no further arrangements have been made, the test is realised at boiling temperature using a condenser and graduated collector such as described in EN ISO 28706-2/6 and following procedure EN ISO 28706-2/8 for its usage.

#### Test plates

The test plates should be made out of the same steel as the to be tested receptacle. Because of the weighing accuracy, the plates should not be thicker than 2 mm. The enamelling should be of a thickness of at least 0.25 mm and its surface should be free of weak or defective spots.

The test plates can be produced either in the laboratory or in the enamel shop. In the last case, the test plates should be hooked on a stainless-steel hook and should be fired in the interior of a receptacle of the production. Using this method, the sample enamelling gains the same thermal treatment experience as the receptacle-enamelling. Three test plates have to be tested. The average weight loss should not be higher than 12 g/m<sup>2</sup>.

Testing report

In the testing report, the following has to be mentioned:

kind and origin of the test plates  
place and date of testing  
single weight losses and average

## 8.6.2 Determination of the resistance to drinking water

Purpose and scope

Fittings, moulded bodies, pipes and receptacles can get in contact with drinking, natural and treated water. The stress can be highly variable, according to water hardness and index of pH. The relevant temperatures are beneath the usual room temperature. In this specification sheet a method is described, that tests the resistance of enamels to the attack of such water. To test the influence of the bicarbonate-hardness, the tests take place at a temperature of beneath 100 °C.

Method of testing

The prepared test plates are to be put into the corresponding casings and put into the device according to EN ISO 28706-4, the enamelling towards the inside. The device is heated up to the wanted temperature and filled with the water, that has been heated up to the testing-temperature. The filling-capacity is about 320 ml. After the agreed testing-time has passed, the device is to be emptied, the samples have to be taken out, according to EN ISO 28706-4, and cleaned. Afterwards, the enamelling has to face the 'pencil-test', according to EN ISO 28706-1.

Testing-time

If no further arrangements have been made, a testing-time of 48 hours is valid.

Testing-temperature

If no further arrangements have been made, a testing-temperature of 60 °C is valid.

Test plates

Two test plates or cuts out of devices have to be tested.

Testing report

In the testing report, the following has to be mentioned:

kind and origin of the test plates

place and date of testing

resistance class, according to EN ISO 28706-4 (classes AA-unclassified)

testing-time and -temperature

### 8.6.3 Testing of adherence of porcelain and vitreous enamel to steel of more than 3 mm thickness

Purpose and scope

The test method described in this specification sheet is to classify the adherence of enamel to steel on enamelled articles made of steel heavier than 3 mm of thickness.

Test method

The enamelling of the test piece is to destroy by impact. The destruction can be executed by a dynamic ball-indentation or a blow of a hammer. Because of the chipping and splintering enamel safety glasses are absolutely to be worn during this test.

Test device

No binding regulation

Judgement of the test-spot

Following the destruction by only one single impact, relics of enamel on the steel surface must be clearly visible. The steel surface may not appear silvery bright. Because of the undefined mechanical shock method, a classification into ranks of adherence is not possible. One virtually has to decide between “good” or “insufficient”.

Test report

To be mentioned in the test report:

kind and origin of the test piece

place and date of testing

location of the test-spot on the test piece

judgement of adherence / bond



#### 8.6.4 Determination of thermal shock resistance of porcelain and vitreous enamelled articles in water

##### Purpose and scope

A lot of enamelled articles are subject to thermal shocks during usage. This specification sheet describes the quenching stability which is not to be mixed up with the resistance to thermal shocks of cooking utensils or other holloware. The latter applies to EN ISO 2747.

##### Test method

Small enamelled articles, cut-outs of utensils or test plates are to be used for this test. These are to be heated up to the claimed temperature (on air) and immediately after that to be quenched (entirely immersed) in water of about 15 °C. This process is to be repeated according to the quality requirements. Damage of the enamelling, visible by the naked eye, is not permitted. There are at least three, preferably five samples to be tested.

##### Test device

No binding regulation

##### Test temperature

The quenching temperature is a matter of arrangement in each case.

##### Test report

In the test report to be mentioned:

- kind and origin of sample
- place and date of testing
- quenching temperature and number of quenching

#### 8.6.5 Determination of thermal shock resistance of porcelain and vitreous enamelled articles in an air-stream

##### Purpose and scope

This specification sheet describes a test procedure to determine the thermal shock resistance of especially heat exchanger panels. (For the thermal shock resistance of cookware and similar holloware EN ISO 2747 is valid).

##### Test method

Enamelled plates out of production, sized DIN A4, are to be used for testing. They are to be heated up to the required temperature (on air). Following the heating-up phase the test plates are to be kept at this temperature for 10 minutes and then cooled down to ambient temperature by an air stream. This testing cycle has to be repeated 5 times. No visual damage of the enamelling is permitted.

##### Test device

No binding regulation

##### Test temperature

For heat exchanger panels a testing temperature of 350 °C is valid.

##### Test report

To be mentioned in the test report:

- kind and origin of test plates
- place and date of testing
- testing temperature and number of test cycles

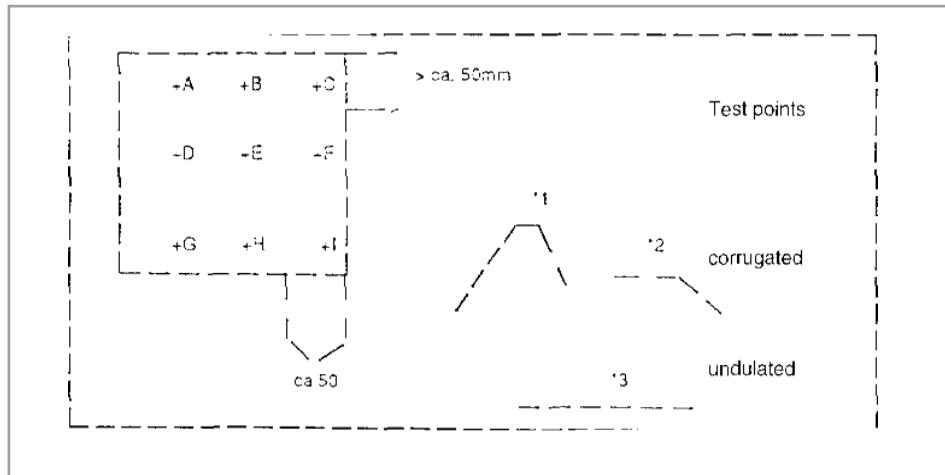
8.6.6. Admissible differences of application thickness on corrugated and undulated pairs of sheet steel panels for heat exchanger

#### Purpose and scope

Enamelled heat exchanger panels are exposed to mechanical and chemical demand. In both cases, the application thickness of the protecting enamel layer is of decisive importance. Due to the nature of these parts, an absolutely even application is not possible. Hence, this specification sheet tries to plot the requirements for admissible tolerances.

#### Test method

Use a thickness measuring instrument of an accuracy of 0.01 mm. Measurements are to be carried out from point A to I on the front and reverse side of the panel, according to the sketch represented at the bottom. The test points are situated about 50 mm off the edge. The measuring points on the corrugated panel are marked with No. 1 and 2, on the undulated panel with No. 3. Per pair of panels (one corrugated and one undulated) 54 measurements (36+18) result from this test.



#### Consideration

The mean out of the 36 measurements on points No. 1 and 2 of the corrugated panel must be  $< 250\mu\text{m}$ . A peak thickness on these points of  $< 300\mu\text{m}$  is permissible, but only one measurement, out of the 36, can be 20% above the maximum value. The average thickness on the 18 measuring points No. 3 of the undulated panel must be  $< 200\mu\text{m}$ . The maximum thickness is  $< 250\mu\text{m}$ , merely one measurement can be as high as  $300\mu\text{m}$ . With the exception of edges and suspension holes, the application thickness should nowhere fall below  $80\mu\text{m}$ .

On the edge area the entire thickness of the panel may measure  $750\mu\text{m} + \text{thickness of the sheet}$ .

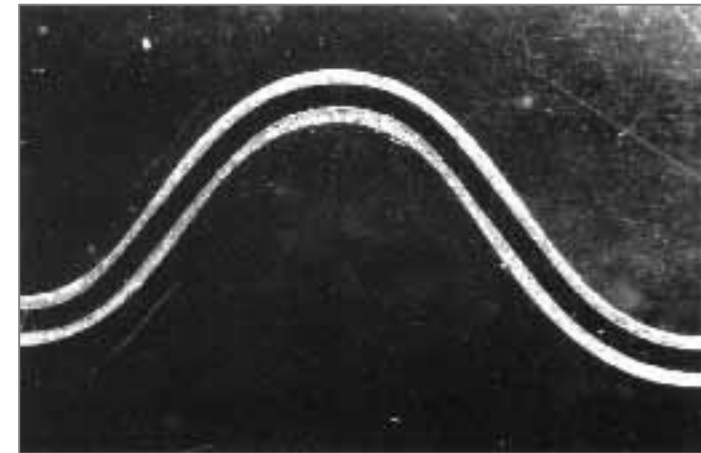


Illustration: Optical layer distribution on undulated sheet steel (enlargement 6 : 1)

#### 8.6.7 Determination of the resistance against corrosion and creeping after mechanical impact

The mechanical impact is carried out with a sharp-edged falling mass.

Height of fall:	300 mm
Weight of mass:	0.2 kg
Material of mass:	like steel 1.2210
Hardness of mass:	> 60 HRC
Geometry of mass:	Conus 60 °, radius r = 2 mm

Afterwards the test plate with the impact spot is taken in a water resistance test as described in EN ISO 28706-3, with a deviating solution of distilled water, using a temperature of 80°C during 72 hours (3 days).

#### 8.6.8 Determination against climatic impact like weathering and UV-resistance

The weathering test is carried out on sample plates conform to EN ISO 11341. First use a cycle of temperature and humidity of 12 hr, 10-50 °C, 30-75% relative humidity. Then use the water corrosion test related to EN ISO 2744 using 80 °C and 3 days. Finally, the plates must be inspected for corrosion, partial detaching of the surface or any change of the surface structure.

## 8.7 Valuation of enamelling defects

### 8.7.1 General hints

#### Definition

Defects in the enamelling are locally limited interruptions of the compactness or structure of the glasslike coating. The local penetration of one layer by another is likewise to be seen as a defect on multilayer enamellings, as in this case it is also a structural interruption. Structural interruptions are not always visible by naked eye. Physical or chemical analyses may be used for the detection of defects.

By judging the defects, one should consider, whether thereby a diminution of function of the article or merely an optical detraction arises. The optical Valuation is independent of the functional application.

Typical enamelling defects are:

Burn off	(EEA 8.7.2)
Cracks	(EEA 8.7.3)
Pores and Inclusions	(EEA 8.7.4)
Chipping, Spalling	(EEA 8.7.5)
Contamination, fallen-on	(EEA 8.7.6)
(all production areas)	
Black Specks in the enamelling	(EEA 8.7.7)

The common characteristic of enamellings is the melting together of siliceous (glass-like) and metallic components in a temperature range of 500 - 950 °C. By this, reactions with the formation of gasses occur (mainly H<sub>2</sub>, CO and CO<sub>2</sub>). Detrimental secondary effects can be suppressed but never entirely eliminated. Within an industrial process, contaminations, also from different production lines are never entirely avoidable - their effects intensify by the reaction with the molten enamel at elevated temperature. A certain part of defects is therefore on enamellings unavoidable.

The defect frequency will be reduced down to a minimum by a neat operation in good controlled plants, and utilisation of defined and checked base materials.

For the optical surface quality, real and to the functional purpose of the workpiece adjusted control standards are in particular an important criterion. Relating to this, a too severe standard reduces in general the entire product quality. The susceptibility to mechanical damage (chipping, cracks) increases with the rise of enamel thickness. With each rework operation, the application thickness increases inevitably. To secure the corrosion resistance on difficult accessible areas of articles with a high corrosion demand, special testing methods can be helpful (e.g. measurement of the protective current requirement on enamelled hot water tanks).

If by agreement with a client of certain articles, a certain number of defects (pores) is not to be infringed, porosity tests complying to the defined standards EN ISO 2746 (high voltage) respectively to EN ISO 8289, NEN 2709 (sponge test with low voltage) have to be carried out. Note: High voltage can cause open defects (pores) from big blisters.

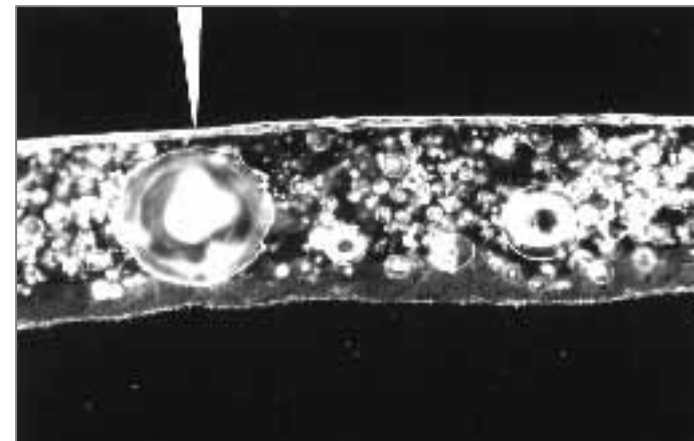


Illustration: Big blister in an enamel layer. Its thin glass-skin can be disturbed by the high voltage test. (enlargement 200 : 1)

### 8.7.2 Valuation of burn-off on enamellings

#### Definition and cause

Burn-offs or burnings are locally limited defects, caused by a too thin applied enamel coating. Due to an excessive oxidation of the metal substrate by firing, the enamel coat could not form a regular stratified structure or it has been destroyed by a super saturation of metal oxides.

Typical burnings occur on cutting edges or in the reach of welding seams. The thickness of the destroyed enamel layer is not measurable with customary types of measuring instruments complying to EN ISO 2178. The determination has to be carried out on cross sections with the help of a light-microscope.

The illustrations (Enlargement 50 : 1 resp. 500 : 1) display the result of a poor cutting edge with a direct-on white enamelling.



Direct-on white enamelling  
on a squeezed-off edge (50 : 1)



Direct-on white enamelling  
on a squeezed-off edge (500 : 1)

As a result of the firing process, high amounts of iron oxide withdraw the opacifying  $\text{TiO}_2$  from the enamel layer, due to the formation of iron Titanate (needle like crystals). The covering power in the defect area is reduced - as a black line is formed (optical impairment). In the reach of burnings, corrosive stressed articles do not have a complete protection against corrosion. Therefore, burnings are to be bound by perfect processed cutting edges and welding seams.

#### Consideration and description

The judgement of the linear extension of burnings is performed by naked eye and, as agreed upon, to be measured out. The dimension of the destroyed surface is to be expressed in  $\text{cm}^2$ .

On difficult accessible containers, equipped with protecting anodes, a measurement of the protective current requirement can be an indication for the extent of burnings.

#### Test report

To be mentioned in the test report:

- kind and origin of the test piece
- place and date of the testing
- description of defects, number and extent
- location of defects on the enamelled article

### 8.7.3 Valuation of cracks in enamellings

#### Definition and cause

Following the definition of DIN 50903: Cracks are mostly laminar interruptions in enamel- lings. They often run vertical to the surface, but occur also under different angles. Their causes are mainly mechanical - or thermal tensions in the compound system.

Under thermal shocks, tensile stresses are built up due to different expansion behaviours of the metal substrate and the enamel to which an enamelling is less resistant as to compressive stresses. Unreasonable deformations or impact stresses on finished enamellings set off cracks.

#### Consideration and description

The judgement of damage by cracks is performed by naked eye.

One differentiates between:

- a. open, piercing cracks
- b. open, non-piercing cracks
- c. masked cracks

Open, piercing cracks are interruptions in the enamel layer down to the metal substrate. They can be made visible clearly by physical (e.g. electrostatic) or chemical methods. Open, non-piercing cracks cease in the enamel layer. They cannot be made visible by such method, as there is no prerequisite reaction with the metal substrate. Wet or dry pigments are rubbed into the enamel surface, in order to recognize such crack formation. These pigments concentrate on the edges of cracks, by which they clearly indicate the crack propagation.

Masked (inner) cracks glimmer in the enamel layer like mother-of-pearl, dependent on the lighting equipment and lighting angle.

The formation of cracks, as a result of a too long and unreasonable influence of high temperature, (e.g. more than 530 °C) often displays a metallic luster as a result of the diffusion of metal oxide.

To be mentioned in the test report:

- kind and origin of the test piece
- place and date of the testing
- description of defects, number and extent

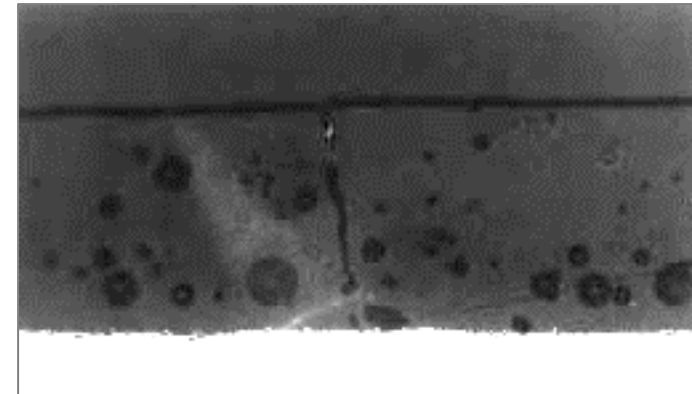
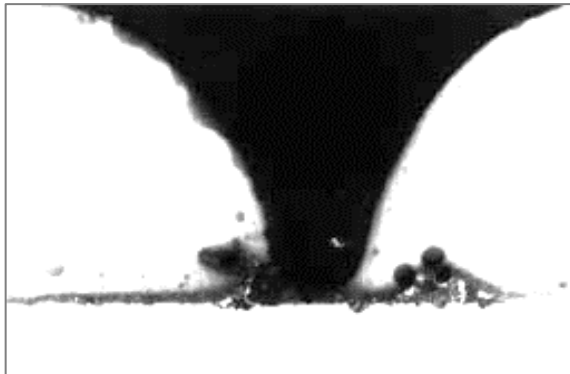


Illustration: Formation of cracks in an enamel layer (enlargement 200 : 1)

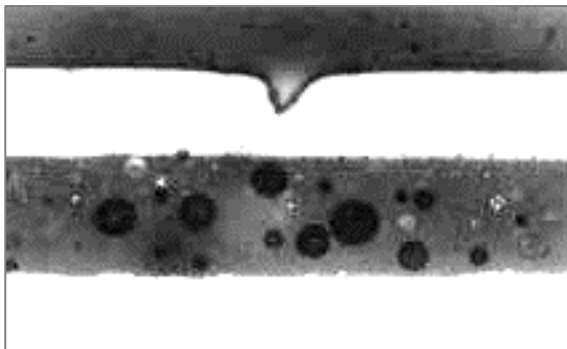
#### 8.7.4 Valuation of pores in enamellings

##### Definition and cause

Following the definition of DIN 50903: Pores are locally limited interruptions in the enamel- ling. Pores are caused by gas reactions during the firing process. Their largest extent is mostly found vertically to the enamel surface. Pores are often - especially in light coloured direct-on enamellings - connected with black specks. In these cases, gas reactions during firing convey the adhesive layer, being rich in iron oxides, towards the surface.



Direct-on enamelling / pore with black speck (enlargement 200 : 1)



Conventional enamelling with a pore not pulling through (enlargement 200 : 1)

##### Consideration and Description

The judgement of damage by pores is performed by naked eye. One differentiates:

- a. open, pulling through pores
- b. open not pulling through pores

Open, pulling through pores are interruptions in the enamelling down to the metal substrate. They can be made visible by physical (e.g. electrostatic) or chemical methods.

Open, not pulling through pores cease in the enamel layer. They cannot be made visible by such method, as there is no prerequisite reaction with the metal substrate.

##### Test report

In the test report to be mentioned:

- kind and origin of the test piece
- place and date of testing
- description of defect, number and size

### 8.7.5 Valuation of chipping / spalling on enamellings

#### Definition and cause

Chipping or spalling on enamellings are mechanical destructions caused by cold deformation, impact or inner stresses being self-caused within the composite material. Chipping or spalling on cutting edges is mostly leading back to an imperfect cutting operation or to a too heavy application of enamel. On principle the cause of chipping is, as far as possible, to be cleared on the spot.

#### Consideration and description

The judgement of damage is performed by naked eye. The description has, among other things, also to assess the reverse side of the damaged part.

#### Test report

To be mentioned in the test report:

- kind and origin of test piece
- place and date of testing
- description of defect, number and extent
- complete state of the article

### 8.7.6 Valuation of defects as can be caused by deposits of impurities from different production lines

#### Definition and cause

In almost every manufacturing process of the enamelling shop (Raw manufacturing - Metal pretreatment - Milling - Application - Drying - Firing) there are characteristic deposits of impurities. Inclusions in the enamelling arise in dependence of the contaminating process: Defects from a defective mill-lining (Fig. 1 and 2) or superficially molten-on deposit: Scale, deposited in the furnace (Fig. 3)

If sulphuric acid is used in a pickling plant sulphates can be transported (e.g. by hangers or via air streams) to the firing area. Deposited spots leave characteristic dimples behind because of a decrease of the surface tension. (Fig. 4 and 5)

Fig. 1

Defective mill-iron shaving

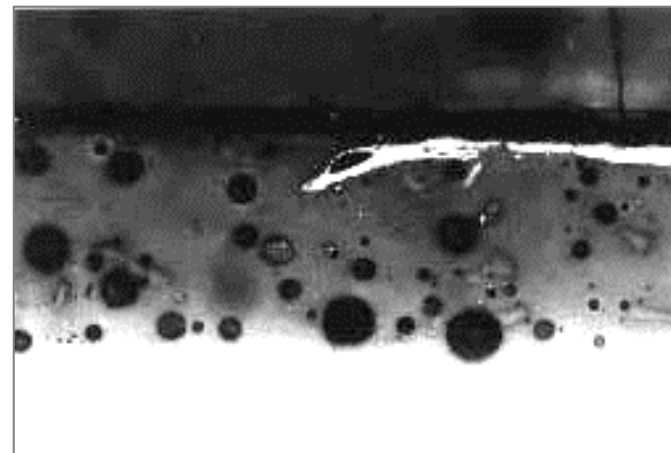




Fig. 2  
Defective  
mill-lining material

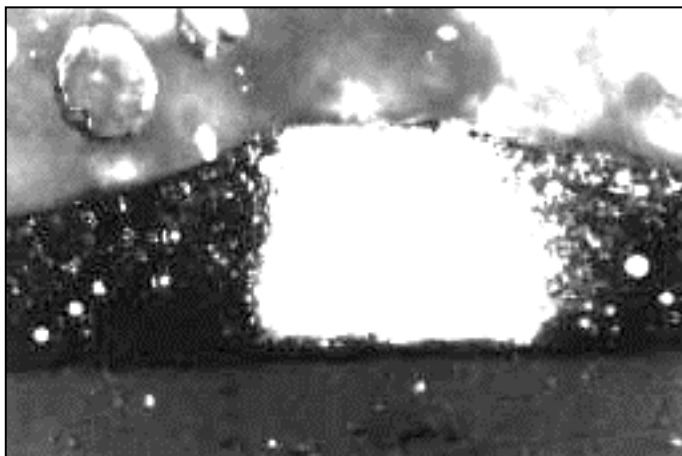


Fig. 3  
Scale deposit

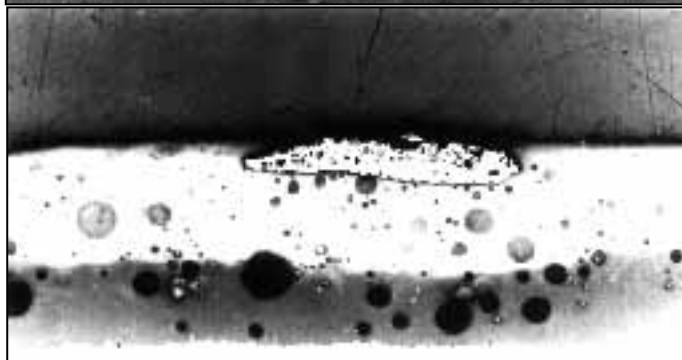
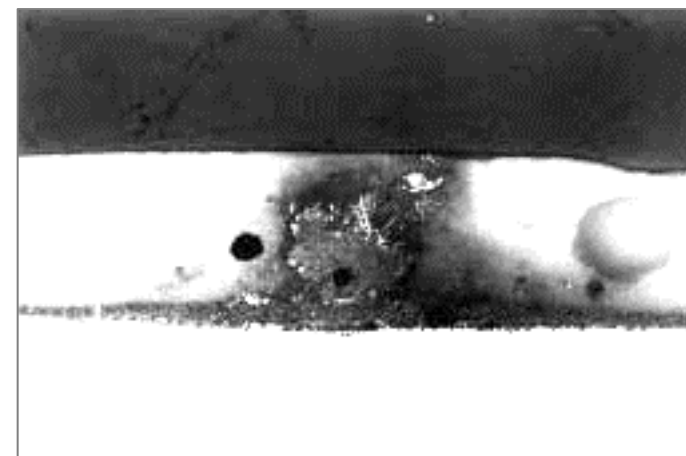


Fig. 4  
Sulphate Dimple



Fig. 5  
Sulphate dimple  
(cross section)



#### Consideration and description

At first the judgement of defects is to be performed by naked eye. Often these defects are (e.g. by scale deposit in the furnace) only imperfections because the enamel layer beneath the defect is undamaged. Deposits on the pretreated part or deposited during application can damage the entire layer, whereby the corrosion resistance could be in question.

#### Test report

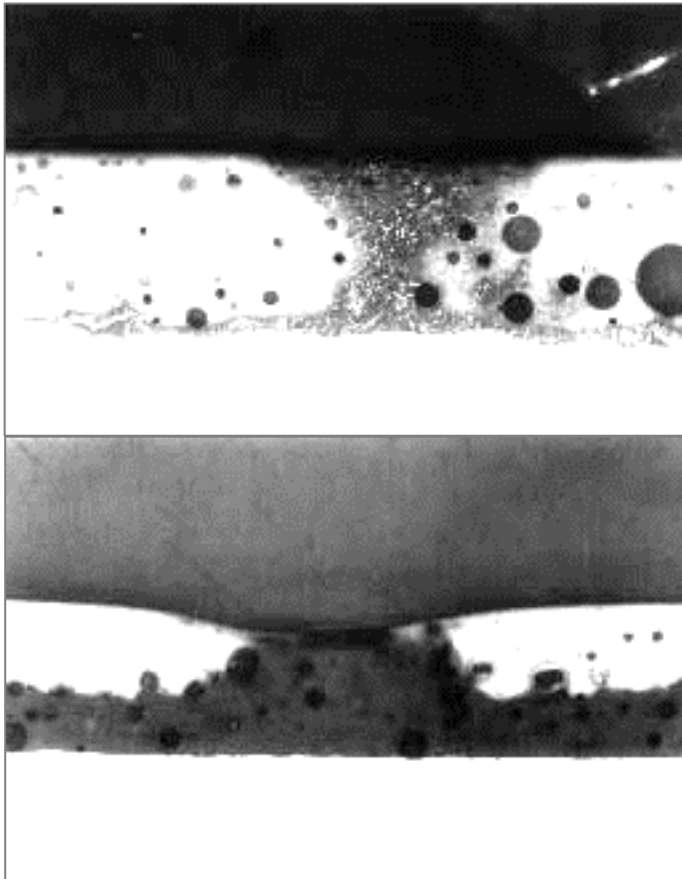
In the test report to be mentioned:

- kind and origin of the test piece
- place and date of testing
- description of defects, number and extent
- complete state of the test piece.

### 8.7.7 Valuation of black specks in the enamelling

#### Definition and cause

On light coloured direct-on enamellings (white or coloured) black specks can appear. In these cases, reacting gases convey, during firing, the adhesive layer respectively a trans- parent layer (being rich in  $\text{FeTiO}_3$ ) towards the surface. By conventional enamellings the ground coat layer then reaches the surface of the cover coat.



### 8.7.8 Packing enamelled plates in baskets for regenerative heat exchangers

The way of packing in the baskets should be that the “notches” of the corrugated and undulated plates always must be crossed.

The tuning of the pressing force for packing shall be done on the required pressing force as written down in the specifications for the heat exchangers.

The calculation of the pressure on the filled basket is:  $P = F / A$

$P$  = pressure in  $\text{kg/m}^2$

$F$  = pressing force in kg

$A$  = pressed area in  $\text{m}^2$

The calculation of  $A$  = (the one side surface area in  $\text{m}^2$  of the lower plate in the basket + the surface of the upper one) / 2.

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## 10.0 HOW TO ORDER

The Quality Requirements Manual of the EEA can be downloaded free of charge from the website of the EEA:

<http://www.european-enamel-association.eu>

Please verify website for updates

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