Edition 5.0


# QUALITY REQUIREMENTS

EUROPEAN ENAMEL ASSOCIATION


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## EUROPEAN ENAMEL ASSOCIATION

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Deutscher Email Verband e.V. – Germany
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Centro Italiano Smalti Porcellanati – Italy
Association Pour l'étude de l'Email Vitrifié – France

Edition 5.0

www.european-enamel-association.eu

## Contents



## 0. PREFACE

The European Enamel Association (EEA) is a European federation of national associations, dealing with "porcelain and vitreous enamel" industrial articles, and coming from the following European countries:
Austria, Belgium, France, Germany, Italy, The Netherlands and United Kingdom.
The EEA represents the porcelain enamel sector in continental Europe

The main scopes of the European Enamel Association (www.european-enamel-association.eu) are:

1. The editing, managing and controlling of "harmonized quality requirements" for enamelled articles being manufactured and sold in Europe. Please find in following pages the edition 5.0 of the EEA quality requirement handbook.
2. EEA Certification of enamelling companies for compliance towards:
   *selected "EEA quality requirements" (out of chapter 7)
   *"EN-ISO product standards" for enamelled products (in case such standards are taken up in the relevant quality requirement(s) from chapter 7 of the EEA handbook)
3. Provide sufficient representation level for assistance in selected lobbying topics related to porcelain and vitreous enamelling.

Note: Marketing efforts are dominantly left over to each individual company.

The technical Content of Edition 5.0 (2020) is the last update of Edition 4.1 (2014). The front pages (1 to 7) of Edition 5.0 have been actualized for the current EEA situation. Edition 5.0 of the EEA quality requirements can be obtained free of charge as an electronic version from the EEA administration or through the national associations. Alternatively this edition can directly be downloaded from the EEA website. It is allowed to distribute this edition to other interested parties

Companies who want to be EEA certified are requested to contact either their national association or the EEA President or Secretary. The detailed EEA certification procedure is explained in chapter 1 of the EEA Manual.

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 (A))**

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

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

**Vitreous Enamellers Society** (part of IOM³)
**(VES, (UK))**

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

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

## 1.0 PROCEDURE FOR TESTING, OBTAINING AND RETAINING THE "EUROPEAN ENAMEL ASSOCIATION" CERTIFICATE / LABEL.

**Contents:**



### 1.1 General Requirements

Products which display the "European Enamel Association" quality label 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.

### 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. Within two weeks, 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 proposed to EEA by the applicant and needs to be accepted by EEA (chairman TC, chairman EC, secretary).

During this specific EEA audit, the auditor needs to verify that the specific EEA quality requirements (chapter 7) have been taken up into the quality manual (documentation) of the company. Secondly the auditor needs to verify that the company meets these requirements for the products of concern to be certified.
For ISO 9001 certified companies, the above mentioned audit process may also occur integrated in an 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, who will circulate it to the EC and TC members for approval. The EEA Technical Committee (TC) shall then make the decision to recommend that a EEA certificate / label be granted or not. The EEA Secretary will inform the company as soon as possible, but not later than two weeks after the confirmation by the TC.

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 correspondence.

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

Validity of the "European Enamel Association" certificate /label.

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.

## 1.4 Flow sheet procedure

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) Annul the failure decision

b) Confirm of the failure decision

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.

Test results

1.2.18.5
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.

Test-frequency

1.2.18.6
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 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 : see next pages

1.2.18.10 **AQL-Tables**

**Inspection level S4**

| Size of the Batch N | | Random test | Approval criterion from the quality level | | |
|---|---|---|---|---|---|
| From | Up to | n | 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 | Approval criterion from the quality level | | |
|---|---|---|---|---|---|
| From | Up to | n | 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 | Approval criterion from the quality level | | |
|---|---|---|---|---|---|
| From | Up to | n | 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 an ”EEA” label, then the company shall demonstrate that the requirements detailed in sections 1.2 are satisfied by the appropriate subcontract enamellers.

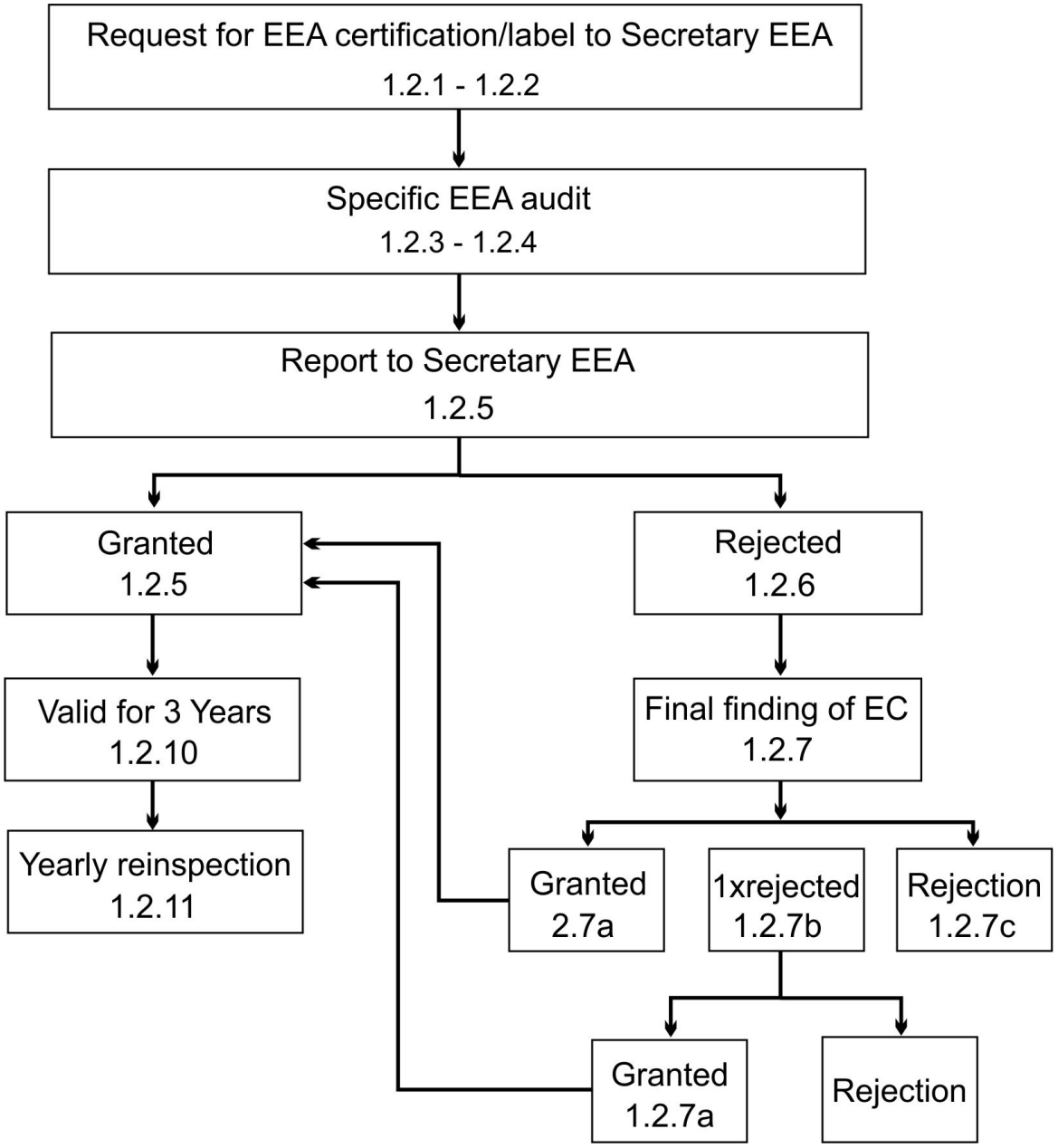
In the opposite case when the EEA certified company is an (exclusive) jobber and responsible for only the quality of the enamelling without having direct influence on the quality of the supplied base material e.g. the steel, the final enamel quality shall be agreed between the jobber and it’s customer.

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

Back to point 1.2.11



## 2.0 DEFINITIONS

**Terminology:**
Porcelain and Vitreous Enamel, the Porcelain and Vitreous Enamelling Process and Porcelain and Vitreous Enamelled Products.

2.1
The general public experience confusion about the definition of ”enamel”.

2.2
Enamel should more properly be called ”porcelain and vitreous enamel”.

2.3
There is no standard accepted definition of porcelain and vitreous enamel in the English language.

2.4
The most generally accepted definition is:
**”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, be bonded chemically and physically to the metal substrate.”**

2.5
The process is porcelain and vitreous enamelling.

2.6
The material produced by fritting is a porcelain and vitreous enamel frit.

2.7
The department carrying out the process is the vitreous or porcelain enamelling department.

2.8
The personnel involved in the process are often referred to as vitreous or porcelain enamellers.

2.9
The coated metal is porcelain and vitreous enamelled e.g. porcelain and vitreous enamelled steel.

2.10
An exception to these definitions is an enamel which is applied to glass and fused to the glass surface.

2.11
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”.

2.12
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 PORCELAIN AND VITREOUS ENAMELLED PRODUCTS WITH THE "EUROPEAN ENAMEL ASSOCIATION" LABEL

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.

3.9.1
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.

3.9.2
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.

3.9.3
The porcelain and vitreous enamel coating should have a minimum hardness of 5 on the Mohs (EN15771).

3.9.4

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.

3.9.5

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

3.9.5.1

Cold rolled steel as detailed in EN 10209

3.9.5.2

Hot rolled steel as detailed in EN 10025 or EN 10111

3.9.5.3

Cast iron as detailed in EEA-specification 8.1

## 4.0 TEST METHODS FOR PORCELAIN AND VITREOUS ENAMELLED PRODUCTS WITH THE "EUROPEAN ENAMEL ASSOCIATION" LABEL

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 14127 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 ferrromagnetic 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 $g/m^2$.

### 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 Wegnerpistol, as specified in 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 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 (destructive)**

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 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 $g/m^2$. (This test solution will need to be made up hot as the solubility at 20º 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 steel to hydrogen should be carried out using the methods as specified in EN 10209 Annex A1.

See part 3.3 of EN 14866/December 2003.

**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 20º, 60º and 85º. The USA measure specular gloss of ceramic surfaces at 45º {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 in
15695.

**4.19 Determination of colour difference**

The determination of colour difference should be carried out using the methods as specified in ISO 11664and 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 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 3.3 of EN 14866.

**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 ISO 6370-1 and ISO 6370-2 can be used.

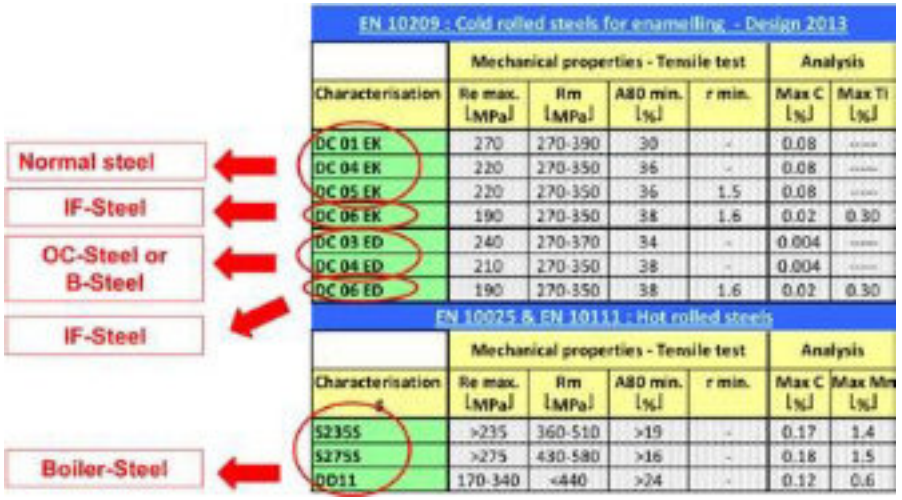
**4.27 Determination of the steel surface activity (pickling speed, weight loss)**

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**

The determination of the quality of steel for enamelling should be carried out using the methods as specified in EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel.

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




EN 10209 : Cold rolled steels for enamelling - Design 2013

| | Mechanical properties - Tensile test | | | | Analysis | |
|---|---|---|---|---|---|---|
| Characterisation | Re max. [MPa] | Rm [MPa] | A80 min. [%] | r min. | Max C [%] | Max Ti [%] |
| DC 01 EK | 270 | 270-390 | 30 | - | 0.08 | ---- |
| DC 04 EK | 220 | 270-350 | 36 | - | 0.08 | ---- |
| DC 05 EK | 220 | 270-350 | 36 | 1.5 | 0.08 | ---- |
| DC 06 EK | 190 | 270-350 | 38 | 1.6 | 0.02 | 0.30 |
| DC 03 ED | 240 | 270-370 | 34 | - | 0.004 | ---- |
| DC 04 ED | 210 | 270-350 | 38 | - | 0.004 | ---- |
| DC 06 ED | 190 | 270-350 | 38 | 1.6 | 0.02 | 0.30 |

EN 10025 & EN 10111 : Hot rolled steels

| | Mechanical properties - Tensile test | | | | Analysis | |
|---|---|---|---|---|---|---|
| Characterisation | Re max. [MPa] | Rm [MPa] | A80 min. [%] | r min. | Max C [%] | Max Mn [%] |
| S235S | >235 | 360-510 | >19 | - | 0.17 | 1.4 |
| S275S | >275 | 430-580 | >16 | - | 0.18 | 1.5 |
| DD11 | 170-340 | <440 | >24 | - | 0.12 | 0.6 |

**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 Lead and Cadmium release for hot water tanks**

The determination of the release of lead and cadmium should be carried out using the methods as specified in DIN 4753 and the UBA-Assessment Guideline for enameled 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 vapour**

The determination of the chemical corrosion rate in hydrochloric acid vapour 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 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 methods as specified in EN ISO 28706-2/14 and 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.

**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 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 ISO4534.

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

Method as specified in EN ISO 20274 and 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 coat ing 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

| | |
|---|---|
| ASTM | American Society for Testing Materials |
| ASQ | German Working Association for Statistical Quality Control |
| BAM | Federal Institution for Testing of Materials |
| BS | British Standard |
| BSI | British Standards Institute |
| CEN | European Committee for Standardization |
| CIE | International Commission for Lighting |
| DEV | German Enamel Association |
| DIN | German Institute for Standardization |
| DNA | German Committee for Standards (within DIN) |
| EC | Executive Committee EEA |
| EEA | European Enamel Associati |
| 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 |
| 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 |
| RAL | Committee for Terms of Delivery and Quality Assurance |
| RKW | Rationalizing Curatorship of the German Economy |
| SE | Stichting Email Enamel Foundation The Netherlands/Belgium |
| sig.diff. | significantly different |
| TC | Technical Committee EEA |
| TrinkwV | Trinkwasserverordnung (Germany) |
| TÜV | Association for Technical Supervision (Germany) |
| UBA | Umweltbundesamt (Germany) |
| VEA | Vitreous Enamel Association |

## 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 ºC (special porcelain and vitreous enamels: -273,15 ºC)
- It is thermally stable to + 450 ºC (special porcelain and vitreous enamels: +900 ºC)
- 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 mentioned application areas. The relevant requirements carry the number of the hereunder mentioned application areas.

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

This norm is applicable for cookware of enamelled cast iron or steel plate, such as:

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

7.1.2 Test methods

| Item | Name | Comparable standards |
|---|---|---|
| 4.2 | measurement of the thickness of the base substrate metal | EN 14127 |
| 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 | 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 |
| 4.21 | determination of the resistance to heat | ISO 4530 |
| 4.28 | determination of the quality of steel for enamelling | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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 |

Items 4.1 - 4.49

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<br>troughs, baking trays and external parts min. 0,70 mm<br>switch panels min. 0,60 mm<br>baking ovens min. 0,50 mm | | determination during design |
| 4.3 thickness enamel | coating cast iron burner caps and pan supports max. 0.60 mm<br>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 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"<br>according to EEA 8.6.3 | may be done on test sheets (see 4.1) | in production 1 x a day |
| 4.17 gloss degree | max. allowed difference at a measuring angle of 60 is:<br>+ 4 at gloss 0 - 30<br>+ 6 at gloss 30 - 70<br>+ 8 at gloss 70 - 100 | for burner caps, hobs,<br>control panels and outside panels | when taking into production a sig.diff. enamel recipe, but at least 1x a year |
| 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 | may by 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)<br>hobs 200 °C (5x)<br>baking platies 260 °C (5x) | for pan supports only<br>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

This norm is applicable for enamelled steel and enamelled stainless steel sinks.

### 7.2.2 Test methods

| Item | Name | Comparable standards |
|---|---|---|
| 4.2 | measurement of the thickness of the base substrate metal | EN 14127 |
| 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 | ISO 4532 |
| 4.10 | determination of the adherence of the enamel to the substrate | EN 10209 Annex C |
| 4.26 | determination of abrasion resistance | ASTM C501, ISO 6370-1 and ISO 6370-2 |
| 4.28 | determination of the quality of steel for enamelling | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for steel forgings for pressure applications |

Item 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$^2$ 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$^2$ 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 may be 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 may be conform to EN ISO 28764 | in production 1 x a day |
| 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 (exclusive colour oxides) but at least 1x a year |
| 4.28 steel quality | in accordance with norm EN 10209 | | is recommended: DC04EK / DC05EK / DC06EK | determination during design |

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

### 7.3.1 Application area

This norm is 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 | Comparable standards |
|---|---|---|
| 4.2 | measurement of the thickness of the base substrate metal | EN 14127 |
| 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 | ISO 4532 |
| 4.10 | determination of the adherence of the enamel to the substrate | EN 10209 Annex C |
| 4.28 | determination of the quality of steel for enamelling | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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<br>interior lining 0.30 mm<br>outside panels and vegetable tray 0.40 mm | interior lining:<br>thickness counts for one-layer-system<br>outside panels and vegetable tray:<br>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 may be conform to EN ISO 28764 | in production 1 x a day |
| 4.28 steel quality | in accordance with norm EN 10209 | is recommended:<br>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

This norm is applicable for enamelled external steel parts of:

- toasters
- barbecues
- hot-plates
- baking forms

### 7.4.2 Test methods

| Item | Name | Comparable 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 | ISO 4532 |
| 4.10 | determination of the adherence | EN 10209 Annex D |
| 4.28 | determination of the quality of steel for enamelling | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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 |
| 4.28 steel quality | in accordance with norm EN 10209 | is recommended: DC04EK | determination during design |

## 7.5. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED STEEL HOLLOW WARE

### 7.5.1 Application area

This norm is applicable for enamelled steel hollow ware, which is suitable for electrical as well as for gas cooking and existing out of the following categories:

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

### 7.5.2 Test methods

| Item | Name | Comparable 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 | 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 | ISO 2747 |
| 4.23 | requirements, measurements and tests for cookware, ovenware (& 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 EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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 | exclusive 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$^2$ per 2 1/2 hours<br>exterior max. 10 g/m$^2$ 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$^2$ per 24 hours | on test sheets conform EN ISO 28764<br>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$^2$ per 24 hours | on test sheets conform EN ISO 28764<br>duration test 48 hours | |
| 4.8 release of toxic elements | conform requirements national laws | | when taking into production a sig.diff. enamel recipe |
| 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 |
| 4.28 steel quality | in accordance with norm EN 10209 | is recommended:<br>DC04EK / DC05EK / DC06EK | determination during design |

7.5.4 Remarks

Except from the quality requirements mentioned here above, also the requirements as mentioned in 4.23 need to be met. For the testing frequency at 4.9, 4.10 and 4.11 applies that these tests can be carried out on the same three pans, taking into account that the tests are carried out in the sequence 4.11 - 4.9 - 4.10.

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

### 7.6.1 Application area

This norm is applicable for hollow ware 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 | Comparable 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 | ISO 4532 |
| 4.11 | determination of the resistance to thermal shock | ISO 2747 |
| 4.23 | requirements, measurements and tests for cookware, ovenware (& 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<br>external max. 0.70 mm | exclusive 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:<br>max. 10 g/m² 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<br>water vapour | internal weight loss: max. 5 g/m² per 24 hours<br>internal weight loss: max. 10 g/m² per 24 hours | on test sheets conform EN ISO 28764<br>test duration 48 hours | when taking into production a sig.diff. enamel recipe, but at least 2 x a year<br>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,<br>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 |
| 4.9 impact resistance | at 20 N no damages > 2 mm diameter after 24 hours | | daily min. 3 pans/casseroles/pots |
| 4.11 thermal shock resistance | 220 °C | not applicable for lids | daily min. 3 pans/casseroles/pots |
| 4.39 adherence | min. ”good” | | daily min. 3 pans/casseroles/pots |

7.6.4 Remarks

Except from the quality requirements mentioned here above, also the requirements as mentioned in 4.23 need to be met.

For the testing frequency at 4.9, 4.10, 4.11 and 4.23 applies that these tests can be carried out on the same three pans/casseroles/pots, taking into account that the tests are to be carried out in the sequence 4.23, 4.11, 4.9 and 4.10.

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

### 7.7.1 Application area

This norm is applicable for exterior enamelled parts of:

- frying-pans, casseroles and pots
- saucepans.

### 7.7.2 Test methods

| Item | Name | Comparable 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 |
| 4.29 | 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) | 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, but at least 1 x a year |
| 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 | ISO 13805 | | when taking into production a sig.diff. enamel recipe, but at least 1 x a year |

7.7.4 Remarks

Except from 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

This norm is 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 | Comparable standards |
|---|---|---|
| 4.2 | measurement of the thickness of the base substrate metal | EN 14127 |
| 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 | 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 | ISO 2747 |
| 4.28 | determination of the quality of steel for enamelling | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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:<br>washing machines: drums 0,9 mm<br>centrifugal drum: 0,8 mm<br>cover plates and outer cladding: 0,7 mm<br>wash boiler: Ø < 460 mm 1,0 mm, Ø > 460 mm 1,25 mm<br>dish-washers: rinsing area 0,9 mm<br>outer cladding: 0,7 mm<br>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,<br>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<br>water vapour | water: weight lost max. 5 g/m² per 24 hours<br>water vapour: weight lost max. 10 g/m² per 24 hours | test duration 48 hours<br>test duration 48 hours<br>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<br>when taking into production a sig.diff. enamel recipe, but at least 1 x a year |
| 4.7 detergent solution | weight lost: max. 20 g/m² 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 may be conform to EN ISO 28764 in production 1 x a day | |
| 4.11 thermal shock resistance | washing kettles: 240 °C | on test sheets may be conform to EN ISO 28764 | when taking into production a sig.diff. enamel recipe, but at least 1 x a year |
| 4.28 steel quality | in accordance with norm EN 10209 | is recommended:<br>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

This norm is 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 | Comparable standards |
|---|---|---|
| 4.2 | measurement of the thickness of the base substrate metal | EN 14127 |
| 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 | ISO 4532 |
| 4.10 | determination of the adherence of the enamel to the substrate | EN 10209 Annex C |
| 4.26 | determination of abrasion resistance | ASTM C501, ISO 6370-1 and ISO 6370-2 |

Items 4.1 - 4.49

7.9.3 Quality requirements

| Test method | Requirement | Remarks | Frequency |
|---|---|---|---|
| 4.2 material thickness | min. thickness for:<br>chamber pot and rinse bucket: 0,75 mm<br>wash basins and sinks, humidifier and water tanks: 0,90 mm,<br>bathtubs: 2,00 mm, shower basins: 1,50 mm | | determination during design |
| 4.3 thickness enamel coating | max. thickness 0.60 mm<br>min. thickness 0.20 mm | | S4/AQL 6.5 |
| 4.4 cold citric acid<br><br><br><br>cold sulphuric acid | min. class A +<br>humidifiers and cisterns min. class A;<br>medical bathtubs class AA<br>min. class A +, medical bathtubs class AA | | when taking into production a sig.diff.<br>enamel recipe, but at least 1 x a year |
| 4.5 boiling citric acid | max. 5 g/m² per 2.5 hours, | | when taking into production a sig.diff.<br>enamel recipe, but at least 1 x a year |
| 4.6 boiling water | 10 g/m² per 24 hours | test duration 48 hours | when taking into production a sig.diff.<br>enamel recipe, but at least 1 x a year |
| 4.7 detergent solution | wash-bowls, rinsing-tubs and bathtubs<br>max. 8 g/m² per 2.5 hours | test duration 2,5 hours | when taking into production a sig.diff.<br>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.<br>enamel recipe, but at least 1 x a year |
| 4.10 adherence | < 2 mm min. 3,<br>for medical bathtubs min. 2, > 2 mm min. 2 | on test sheets may be conform<br>to EN ISO 28764 | in production 1 x a day |
| 4.26 abrasion resistance | max. 0.1 gram | in accordance with ASTM C501<br>sandpaper S33/1kg/1000 rotations | when taking into production a sig.diff.<br>enamel recipe (exclusive colour oxides)but at least 1 x a year |
| 4.28 steel quality | in accordance with norm EN 10209 | is recommended:<br>DC04EK / DC05EK / DC06EK | determination during design |

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

### 7.10.1 Application area

This norm is applicable for cast iron bathtubs and shower basins for household and medical applications.

### 7.10.2 Test methods

| Item | Name | Comparable standards |
|---|---|---|
| | cast iron quality | DIN 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 EN ISO 28706-2,<br>- test solution according EN ISO 28706-3/9 |
| 4.9 | determination of the resistance to impact | ISO 4532 |

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<br><br>cold sulphuric acid | - citric acid class A +, for medical bathtubs and shower basins class AA enamel<br>- sulphuric 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 |
| 4.5 boiling citric acid resistance | weight loss: max. 5 g/m$^2$ per 2.5 hours | | enamel recipe, but at least 1 x a year |
| 4.6 boiling water | weight loss: max. 10 g/m$^2$ per 24 hours | test duration 48 hours | when taking into production a sig.diff. |
| 4.7 detergent solution | weight loss: max. 8 g/m$^2$ per 2.5 hours, | test duration 2,5 hours | when taking into production a sig.diff.<br>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.<br>enamel recipe, but at least 1 x a year |

## 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

This norm is 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 | Comparable standards |
|---|---|---|
| 4.2 | measurement of the thickness of the base substrate metal | EN 14127 |
| 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 | 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 | ISO 4530 |
| 4.28 | determination of the quality of steel for enamelling | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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<br>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:<br>not acid resistant upper side: class A<br>geysers: class A<br>combustion areas gas fired: not acid resistant<br>oil fired: class A | on test sheets conform EN ISO 28764<br>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 may be conform to EN ISO 28764 | in production 1 x a day |
| 4.13 defects | heat-exchangers normal: max. 20 defects/$m^2$ according to method A<br>heat-exchangers low temperature: max. 20 defects/$m^2$ according to method A | not applicable for borders<br>not valid in case cermet is applied<br>not valid for borders<br>not valid in case cermet is applied | in production 1 x a day<br>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)<br>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 show so-called drain lines, then the enamel layer may 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

This norm is 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 with a magnesium anode (that can or not be foreseen 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 | Comparable 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 |
| 4.6 | determination of the resistance to chemical corrosion by boiling water and/or water | EN ISO 28706-2/14, EN ISO 28706-2/6 |
| 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 | 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 Lead and Cadmium release for hot water tanks | UBA-guideline + national laws (see also clause 4.8) + DIN 4753-3 |
| 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<br>test duration 1 hour | when taking into production a sig.diff. enamel recipe, but at least 1x a year |
| 4.6 boiling water | max. 8.5 g/m$^2$ | testing time: 2 periods of 3 weeks,<br>on test sheets may<br>be conform to EN ISO 28706 | 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 > 1.5 mm diameter after 24 hours | on test sheets may be conform to<br>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 may be conform to<br>EN ISO 28764, fire conditions should be specified. | in production 1 x a year |
| 4.28. steel quality | in accordance with norm EN 10025<br>in accordance with the new EN-design<br>“hot rolled enamelling steels for one-sided enamelling”<br>in accordance with EN 10111<br>For certain non-critical parts, also qualities<br>DC02EK / DC04EK in accordance with EN 10209 are used | is recommended: S235J / S275J<br>is recommended: S235EK1, S275EK1<br><br>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 | **See § risk based testing program of the 4MS document on the Certification and approval of products in contact with drinking water** |
| 4.40 thermal shock resistance | 3 tests: 200 °C, repeat 5 x | on test sheets may be conform<br>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

This norm is 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 | Comparable standards |
|---|---|---|
| 4.2 | measurement of the thickness of the base substrate metal | EN 14127 |
| 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 | 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 (destructive) | ISO 2746 |
| 4.13 | determination, detection and location of defects (non-destructive) | EN ISO 8289 |
| 4.18 | determination of scratch resistance | EN ISO 15695 |
| 4.26 | determination of abrasion resistance | ASTM C501, ISO 6370-1 and ISO 6370-2 |
| 4.28 | determination of the quality of steel for enamelling | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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<br>(when coil production,1 x per 100 $m^2$) |
| 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/$m^2$ 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<br>> 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 may be conform to EN ISO 28764 | in production 1 x a day |
| 4.12 porosity<br>or:<br>4.13 determination of defects | max. 10 defects per $m^2$<br>max. 10 defects per $m^2$ or<br>max. 5 defects per $m^2$ | in accordance with EN ISO 8289 method B<br>in accordance with EN ISO 8289 method A | in production min. 1 %<br>in production min. 1 %<br>in production min. 1 % |
| 4.18 scratch resistance | min. 7 N<br>min. 4 N for metallic finishes and silk-screened finishes | | when taking into production a sig.diff. enamel recipe (exclusive colour oxides), but at least 1 x a year |
| 4.26 abrasion resistance | max. 0.1 gram | in accordance with ASTM C501 sandpaper S33/1kg/1000 rotations ISO 6370-1 and ISO 6370-2 | when taking into production a sig.diff. enamel recipe (exclusive colour oxides) but at least 1 x a year |
| 4.28 steel quality | in accordance with norm EN 10209 | is recommended:<br>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.

Appearance (colour, structure and brightness of the products) must be equal to the appearance of an enamelled sample that has been approved of by the interested partners. The inspection frequency for this additional requirement during production is 100 % of the material.

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

This norm is 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 | Comparable 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 | 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 |
| 4.26 | determination of abrasion resistance | ASTM C501, ISO 6370-1 and ISO 6370-2 |
| 4.28 | determination of the quality of steel for enamelling | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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<br>(when coil production, 1 x per 100 $m^2$) |
| 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 may be conform to EN ISO 28764 | in production 1 x a day |
| 4.18 scratch resistance | 7 N<br>min. 4 N for metallic finishes and silk-screened finishes | | when taking into production a sig.diff. enamel recipe (exclusive colour oxides), but at least 1 x a year |
| 4.26 abrasion resistance | max. 0.1 gram | conform to ASTM C 501<br>sandpaper S33/1kg/1000 rotations<br>ISO 6370-1 and ISO 6370-2 | when taking into production a sig.diff. enamel recipe (exclusive colour oxides), but at least 1 x a year |
| 4.28 steel quality | in accordance with norm EN 10209 | is recommended:<br>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.

Appearance (colour, structure and brightness of the products) must be equal to the appearance of an enamelled sample that has been approved of by the interested partners. The inspection frequency for this additional requirement during production is 100 % of the material.

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

This norm is 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 | Comparable 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 | 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, ISO 6370-1 and ISO 6370-2 |
| 4.28 | determination of the quality of steel for enamelling | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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<br>(in coil production 1 x per 100 $m^2$) |
| 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 may be conform to EN ISO 28764 | in production 1 x a day |
| 4.17 gloss degree | 2-20 | measuring angle 60° | S4/AQL 6.5<br>(in coil production 1 x per 100 $m^2$) |
| 4.26 abrasion resistance | max. 0.1 gram | conform to ASTM C 501<br>sandpaper S33/1kg/1000 rotations<br>ISO 6370-1 and ISO 6370-2 | when taking into production a sig.diff. enamel recipe (exclusive colour-oxides), but at least 1 x per year |
| 4.28 steel quality | in accordance with norm EN 10209 | is recommended:<br>DC01EK / DC04EK / DC04ED | determination during design |

7.15.4 Remarks

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 latex sponge.

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

7.16.1 Application area

This norm is applicable for enamelled projection boards of which the basic material consists of steel or laminated steel.

7.16.2 Test methods

| Item | Name | Comparable 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 | 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, ISO 6370-1 and ISO 6370-2 |
| 4.28 | determination of the quality of steel for enamelling | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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<br>(in coil production 1 x per 100 $m^2$) |
| 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 may be conform to EN ISO 28764 | in production 1 x a day |
| 4.17 gloss | 5-90 | measuring angle 60° | S4/AQL 6.5<br>(in coil production 1 x per 100 $m^2$) |
| 4.26 abrasion resistance | max. 0.1 gram | conform to ASTM C 501<br>sandpaper S33/1kg/1000rotations<br>ISO 6370-1 , ISO 6370-2 | when taking into production a sig.diff. enamel recipe (exclusive colour-oxides), but at least 1 x per year |
| 4.28 steel quality | in accordance with norm EN 10209 | is recommended:<br>DC01EK / DC04EK / DC04ED | determination during design |

7.16.4 Remarks

The white surface must be suitable for projection applications.

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

### 7.17.1 Application area

This norm is 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 | Comparable 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 | 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 | ISO 11664, ISO 18314 |
| 4.26 | determination of abrasion resistance | ASTM C501, ISO 6370-1 and ISO 6370-2 |
| 4.28 | determination of the quality of steel for enamelling | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for steel forgings for pressure applications |

Items 4.1 - 4.49

7.17.3 Quality requirements

| Test method | Requirement | Remarks | Frequency |
|---|---|---|---|
| 4.3 thickness enamel coating | max. 0.25 mm | | S4/AQL 6.5<br>(in coil production 1 x per 100 $m^2$) |
| 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 may be conform to EN ISO 28764 | in production 1 x a day |
| 4.17 gloss | min. 35 | measuring angle 60° | S4/AQL 6.5<br>(in coil production 1 x per 100 $m^2$) |
| 4.18 scratch resistance | min. 7 N<br>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 cleanability | $\Delta E^* < 0,5$ | after a thorough wet cleaning, the surface contamination or colour fading under influence of the marker pigment may 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<br>sandpaper S33/1kg/1000 rotations<br>ISO 6370-1, ISO 6370-2 | when taking into production a sig.diff. enamel recipe (exclusive colour oxides), but at least 1 x per year |
| 4.28 steel quality | in accordance with norm EN 10209 | is recommended:<br>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

This norm is applicable for the steel, the enamel and the enamel and the enamelled profiled heat-exchanger plates, before as well as after packing in baskets (See 4.43 EN 14866).

### 7.18.2 Test methods

| **A.** | **Steel base** | |
|---|---|---|
| **Item** | **Name** | **Comparable standards** |
| 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.** | **Enamel frits** | |
|---|---|---|
| **Item** | **Name** | **Comparable standards** |
| 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 |

Items 3.0 - 3.9

Items 4.1 - 4.49

| C. Enamelling | | |
|---|---|---|
| **Item** | **Name** | **Comparable standards** |
| 3.5 | visual assessment | 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 |

| D | Package | |
|---|---|---|
| **Item** | **Name** | **Comparable standards** |
| 3.5 | visual assessment | 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

| **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 |
| 4.16 /4.43 hydrogen permeability | > = 120 | does not apply for steel types DC06EK and DC06ED | 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.** | **Enamel frits** | | |
|---|---|---|---|
| The enameller has to use checked enamel frits for this object.<br>The guarantee should be given by the frit manufacturer in a certificate<br>The requirements and the test recipes are determined in consultation between enameller and frit manufacturer.<br>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<br>air-gas: 20 g/m²/48h; gas-gas: 6 g/m²/48h | | per 10,000 kg |
| 4.35 resistance against boiling sulphuric acid | air-gas: 10 g/m²/48h; gas-gas: 2 g/m²/48h | | 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 14866 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 | 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 150 µm ± 30 µm, 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 600 µm (i.e. 2 sides of 300 µm) plus thickness of the substrate. 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. 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 80 µm | for measuring method: see § 4<br>ISO 1463 | 1 % in production<br>measurements other than those on the indicated position points shall be determined using a microscope |
| 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 |

| C. | Enamelling (cont.) | | |
|---|---|---|---|
| **Test method** | **Requirement** | **Remarks** | **Frequency** |
| 3.5 visual assessment | fundamental defects may not occur | fundamental defects are: blisters, burn-o', chipping, copper heads, cracking, crazing fish scales, spalling and tearing as described in EN 14866 part 3 & 6.4. | 100 % |
| 4.13 open defects<br>in accordance with method B | maximum number of open defects:<br>air-gas heaters: 50/$m^2$<br>gas-gas heaters: 15/$m^2$ | defects in form of cracks<br>are not permitted | in a random check op 10 pairs of panels out of a production of 1000 pair 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 | for air-gas heaters requirements in consultation with the enameller and the end user<br>for gas-gas heaters if required by the customer<br>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:<br>air-gas heaters: 10.0 g/$m^2$<br>gas-gas heaters: 2.0 g/$m^2$ | 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 150 µm + 20µm | 1 x per 5 tons frit |
| 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 150 +/- 20 µm. The sheets are cooled down in water of 20 °C | 1 x per order |

| D. Package | | | |
|---|---|---|---|
| **Test method** | **Requirements** | **Remarks** | **Frequency** |
| 3.5 visual assessment | for air-gas heaters requirements in consultation with the enameller and the end user<br>for gas-gas heaters: a visual examination should be carried out for defects such as chipping, cracking or spalling (see Clause 3). 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) | 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 | for air-gas heaters requirements in consultation with the enameller and the end user<br>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 ≥ 95 % | | once per ring |
| 4.36 package pressure | 5000 - 8000 (± 1000) kg/m$^2$ | 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 complied with.

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

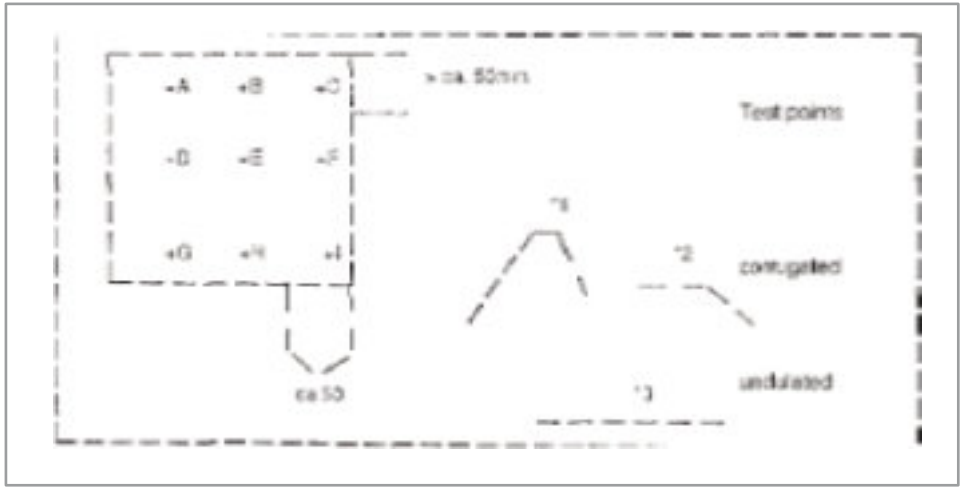
Contrary to chapter 4.3 the measurement shall be carried out from point A to I (see figure).

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

The measuring points on the corrugated panel are market 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

This norm is applicable for the steel and the enamel coating of the heat exchanger sheet pairs and tubes in recuperative exchangers.

7.19.2 Test methods

| **A.** | **Steel-base** | |
|---|---|---|
| **Item** | **Name** | **Comparable standards** |
| 3.9.5.1 | steel analysis | EN 10209 |
| 4.16/4.43 | determination of the permeability to hydrogen | EN 10209 Annex A1, See part 3.3 of EN 14866 (12/2003)/ See EN ISO 28763 |
| or | | |
| 4.22/4.43 | determination of the resistance to fish scaling | EN 10209 Annex A2; See part 3.3 of EN 14866/ See EN ISO 28763 |
| 4.27 | determination of the steel surface activity (pickling speed, weight loss) | EN 10209 Annex B |

| **B.** | **Enamelling** | |
|---|---|---|
| **Item** | **Name** | **Comparable standards** |
| 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 | 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 | ISO 13807 |
| 4.40 | determination of thermal shock resistance of enamelled articles into water | EEA Specification 8.6.4 |

Items 4.1 - 4.49

Items 3.9 - 3.9

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 and DC06ED | 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<br>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 - 400 µm | | 2 % in production |
| 4.9 impact resistance | at 20 N no damages > 2.0 mm diameter after 24 hours | on test sheets may be 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 may be conform to EN ISO 28764 | in production 1 x a day |
| 4.13 defects | external < 25 / $m^2$ per individual sheet according to method B; average < 10 / $m^2$ 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/$m^2$ | 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 150 µm ± 20 µm. | 1 x per 10 tons enamel |
| 4.40 thermal shock resistance | 5 x 350 °C | on test sheets may be conform to ISO 2723, the resistance is tested on sheets of 100 mm x 100 mm with an enamel coating thickness of 150 + 20 µm. The sheets are cooled down in water of | 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

### 7.20.1 Application area

This norm is applicable for enamelled panels for industrial tanks (not chemical vessels). The steel quality must be suitable for enamelling and is to be agreed upon between the enameller and the steel manufacturer / supplier.

### 7.20.2 Test methods

| Item | Name | Comparable standards |
|---|---|---|
| 3.5 | visual assessment | EEA 8.7 |
| 3.9.3 | determination of the hardness referring to Mohs | EN 101 |
| 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 | 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 (destructive) | ISO 2746 |
| 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 | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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 |

Items 4.1 - 4.49

Items 3.9 - 3.9

7.20.3 Quality requirements

| Test method | Requirement | Remarks | Frequency |
|---|---|---|---|
| 3.5 visual assessment | internal 0 defects<br>external max. 5 defects/$m^2$ (*) | | in production 100 % |
| 3.9.3 hardness | hardness Mohs ≥ 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 | 0.34 ± 0.16 mm | | S4 AQL 2.5 |
| 4.4 cold citric acid<br>cold sulphuric acid<br>cold hydrochloric acid | min. class A<br>min. class A<br>min. class A | EN ISO 28706-1<br><br>solution 10 %<br>test duration 15 minutes | in production 1 x per month<br>in production 1 x per month<br>in production 1 x per month |
| 4.5 boiling citric acid | weight loss: max. 5 g/ $m^2$ per 2.5 hours | on test sheets conform to EN ISO 28764,<br>test duration 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 | weight loss: max. 10 g/$m^2$ per 48 hrs. vapour phase<br>weight loss: max. 5 g/$m^2$ per 48 hrs. liquid phase | on test sheets conform to EN ISO 28764,<br>test duration 48 hours, EN ISO 28706-2 | when taking into production a sig.diff. enamel recipe, but at least 1 x a year |
| 4.7 detergent solutions | weight loss: max. 5 g/$m^2$ per 24 hours | EN ISO 28706-3 | when taking into production a sig.diff. enamel recipe, but at least 1 x a year |
| 4.9 impact resistance | max cracking: at 20 N no damage > 2 mm ø<br>after 24 hours | ISO 4532 | when taking into production a sig.diff. enamel recipe, but at least 1 x a year |
| 4.10 adherence<br>or 4.39 | min. 2<br>min. ”good” | on test sheets conform to EN ISO 28764<br>on test sheets conform to EN ISO 28764 | in production 1 x a month<br>in production 1 x a month |
| 4.12 porosity | internal 0 defects | EN 14430 | in production 100 % |
| 4.25 sodium hydroxide 80° C | max. 8 g/$m^2$ per 24 hours | test duration 24 hours<br>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 enamel grade steel quality<br>or suitable construction steel for applied processing | | |

(*) Defects at the outside: 5 defects of max. 1 mm diameter (on a test surface of 1 $m^2$);
Max. 5 defects are allowed to be repaired, for example by means of a sealing kit.

### 7.20.4 Remarks

Depending on the application, additional requirements can be demanded.

The visual final inspection of the tanks is to take place after mounting (assembling).

In case not specifically recorded, the above mentioned requirements are applicable as well for the internal as for the external enamel coating.

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

### 7.21.1 Application area

This norm is applicable for parts of cast iron in contact with raw water and drinking water.

### 7.21.2 Test methods

| Item | Name | Comparable 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 101 |
| 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 | 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 | ISO 7724 Pt. 1, Pt. 2 and Pt. 3 |
| 4.26 | determination of abrasion resistance | ISO 6370-1 and ISO 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

Items 3.0 -3.9

7.21.3 Quality requirements

| Test method | Requirement | Remarks | Frequency |
|---|---|---|---|
| 3.9 hardness | hardness Mohs scale ≥ 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 µm (flat area)<br>≥ 150 µm (edge covering) | the coat thickness depends on the intended use | S4/AQL 6.5 |
| 4.4 cold citric acid | class AA<br>suitable for soil class III | soil class III | each lot<br>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 ≥ 100°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 ≤ 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 ≥ 80°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 ≥ 80°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 ≥ 80°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 ≥ 80°C | when taking into production a sig.diff. enamel recipe, but at least 1 x a year |

## 7.22. QUALITY REQUIREMENTS FOR ARMATURES, FORM PARTS, PIPES, VALVES AND AGITATORS FOR THE CHEMICAL INDUSTRY

### 7.22.1 Application area

This norm is applicable for:

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

### 7.22.2 Test methods

| Item | Name | Comparable 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 | ISO 13807 |

Items 4.1 - 4.49

7.22.3 Quality requirements

| Test method | Requirement | Remarks | Frequency |
|---|---|---|---|
| 4.3 thickness enamel coating | 0.8 - 2.5 mm (cast iron)<br>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 | ≤ 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 | ≤ 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 | ≥ 190 °C | | when taking into production a sig.diff. enamel recipe, but at least 1 x a year |

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

7.23.1 Application area

This norm is applicable for cast iron waste-pipes.

7.23.2 Test methods

| Item | Name | Comparable standards |
|---|---|---|
| 3.9.5.3 | cast iron quality | DIN 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 | ISO 4532 |

Items 4.1 - 4.49

Items 3.0 -3.9

7.23.3 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<br>cold sulphuric acid | class AA<br>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$^2$ per 24 hours | 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$^2$ per 24 hours | 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<br>> 2 mm diameter after 24 hours | | when taking into production a sig.diff. enamel recipe, but at least 1 x a year |

## 7.24. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED SILOS FOR ANIMAL FEED

### 7.24.1 Application area

This norm is applicable for enamelled silos for animal feed, made from steel.
This norm is **n o t** applicable for enamelled dung silos and industrial tanks.
For these silos apply 7.20 and 7.25.

7.24.2 Test methods

| Item | Name | Comparable standards |
|---|---|---|
| 3.5 | visual assessment | EEA 8.7 |
| 3.9.3 | determination of the hardness referring to Mohs | EN 101 |
| 4.2 | measurement of the thickness of the base substrate metal | EN 14127 |
| 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 | 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, EN ISO 8289-2 |
| 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 | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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 |

Items 4.1 - 4.49 Items 3.0 - 3.9

7.24.3 Quality requirements

| Test method | Requirement | Remarks | Frequency |
|---|---|---|---|
| 3.5 visual assessment | internal 0 defects, external max. 5 defects/$m^2$ | | in production 100 % |
| 3.9.3 hardness | hardness Mohs ≥ 5 | on test sheets | when taking into production a sig.diff. enamel recipe, but at least 1 x a year |
| 4.2 material thickness | in accordance with the requirements as to the strength | | when taking into production |
| 4.3 thickness enamel coating | inner and outer 0.34 ± 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/$m^2$ 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/$m^2$ 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 $m^2$ 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/$m^2$ 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 |

## 7.25. QUALITY REQUIREMENTS FOR PORCELAIN AND VITREOUS ENAMELLED DUNG SILOS

### 7.25.1 Application area

This norm is applicable for enamelled panels for dung silos.
The appropriate steel quality is to be agreed upon between the enameller and the steel manufacturer.

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 101 |
| 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 | 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, EN ISO 8289-2 |
| 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 | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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 |

Items 4.1 - 4.49

Items 3.0 - 3.9

7.25.3 Quality requirements

| Test method | Requirement | Remarks | Frequency |
|---|---|---|---|
| 3.5 visual assessment | internal 0 defects, external max. 5 defects/$m^2$ | | in production 100 % |
| 3.9.3 hardness | hardness Mohs ≥ 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 | 0.34 ± 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 | weight loss: max.7 g/$m^2$ per 2.5 hours | on test sheets may be conform to EN ISO 28764, EN ISO 28706-2 | when taking into production a sig.diff. enamel recipe, but at least 1 x a year |
| 4.6 boiling water | weight loss: max. 7 g/$m^2$ per 48 hours liquid phase | EN ISO 28706-2 on test sheets may be conform be conform to EN ISO 28764, 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 damage > 2.0 mm diameter after 24 hours | on test sheets may be conform to EN ISO 28764, ISO 4532 | 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 $m^2$ according to EN ISO 8289 and no defects > 1 mm diameter, Reparations (touch up) are allowed | conform to EN ISO 8289 | S4/AQL 2.5 see remarks 7.25.4 |
| 4.25 sodium hydroxide 80 °C | max. 8 g/$m^2$ 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 | two-side enamelling quality steel 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 |

### 7.25.4 Remarks

One per 10 panels is to be inspected. When during this inspection defects are found, they may be repaired with the appropriate materials.
When defects are found all following panels are to be inspected until 20 panels come up to the requirements. Max. 5 repairs per $m^2$ are allowed.

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

### 7.26.1 Application area

This norm is applicable for enamelled cattle water-troughs in cast iron.

### 7.26.2 Test methods

| Item | Name | Comparable standards |
|---|---|---|
| 4.2 | measurement of the thickness of the base substrate metal | EN 14127 |
| 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 | ISO 4532 |
| 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

7.26.3 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 may be 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

This norm is applicable for enamelled signs and advertising boards of which the base material consists of steel.

### 7.27.2 Test methods

| Item | Name | Comparable standards |
|---|---|---|
| 4.2 | measurement of the thickness of the base substrate metal | EN 14127 |
| 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 | 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 (destructive) | 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 |
| 4.26 | determination of abrasion resistance | ASTM C501 |
| 4.28 | determination of the quality of steel for enamelling | EN 10209 for cold rolled steel and EN 10025 or EN 10111 for hot rolled steel or EN 10149 for HSLA steels and EN 10222-1 for 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<br>(when coil production, 1 x per 100 $m^2$) |
| 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/$m^2$ 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<br>> 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 may be conform to EN ISO 28764 | in production 1 x a day |
| 4.12 porosity | max. 10 defects per $m^2$ | only for outdoor application | in production min. 1 % |
| or: | | | |
| 4.13 determination of defects | max. 10 defects per $m^2$<br>or max. 5 defects per $m^2$ | in accordance with EN ISO 8289 method B<br>in accordance with EN ISO 8289 method A | in production min. 1 %<br>in production min. 1 % |
| 4.18 scratch resistance | min. 4 N | | when taking into production a sig.diff. enamel recipe (exclusive colour oxides), but at least 1 x a year |
| 4.26 abrasion resistance | max. 0.1 gram<br>sandpaper S33/1kg/1000 rotations | in accordance with ASTM C501 | when taking into production a sig.diff. enamel recipe (exclusive colour oxides), but at least 1 x a year |
| 4.28 Steel quality | in accordance with norm EN 10209 | is recommended:<br>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.

Appearance (colour, structure and brightness of the products) must be equal to the appearance of an enamelled sample that has been approved of by the interested partners. The inspection frequency for this additional requirement during production is 100 % of the material.

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 enameled articles. However they are not valid for artistically free designed enameled 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 | |

Saturation value: Sc = min. 1.04 max. 1.08

The silicon content plays an important role. Low silicon contents, below 2.5 %, are slowing down the ferritisation 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.

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

| | | | **Ferritic** | **Ferritic/Perlitic** |
|---|---|---|---|---|
| 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) | Aluminum | 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 Sulfide. This Magnesium Sulfide 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 skillful 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 cooled (20 $^0$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 Ammoniumsulphate and 5 drops Bromocresol green, titrate with 0.1 n NaOH until the colour changes from orange to blue.

**ml consumption 0.1 n NaOH x 4.9 = g $H_2SO_4$ / l pickling solution**

Required reagents:

Ammoniumsulphate

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 $^0$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 $KMnO_4$-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 KMnO4 x 1.1 = g $Fe^{2+}$ / l pickling solution**

Required reagents:

Reinhardt-Zimmermann-solution:

67 g $MnSO_4$ x 4 $H_2O$, 138 ml $H_3PO_4$ (density 1.70) and
130 ml $H_2SO_4$ ( density 1.82 ) are to be filled up with 1000 ml distilled water.

0.1 n 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 $^0$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 $NiSO_4$ x $7H_2O$ / l nickel bath solution**

Required reagents:

Ammonium chloride

54 g $NH_4Cl$ 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 bisodium salt of the ethylenediaminetetra 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 $^0$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 n $K_2Cr_2O_7$ x 0.04 = g $Fe^{2+}$/ 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 ironhydroxide 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.

$$\frac{\text{ml consumption 0.01m Complexion-III-solution X 5.87}}{\text{cm}^2\text{ sample surface}} = \text{g Ni/m}^2 \text{ steel surface}$$

List of reagents:

10% nitric acid Tartaric
acid Dimethylglyoxime
solution

2 g dimethylglyoxime are dissolved in alcohol

Murexid

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 |
|---|---|---|---|---|---|---|---|---|---|---|
| $MoO_3$ | $Cr_3O_3$ | $K_2O$ | $B_2O_3$ | $Na_2O$ | $TiO_2$ | $SiO_2$ | $ZrO_2$ | CoO/ NiO | $Al2O_3$ | MgO |

As a comparison, the surface tension of:

| | |
|---|---|
| Aluminum 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 > 60 µm in powder enamels affects the application properties in the enamelling shop. It can be determined by the known PRINCE test sieve (screen aperture 0.06 mm = 60 µm = 10000 mesh/cm$^2$).

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

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 mea-measured by the SAMES fluidity meter type AS100 or comparable.

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

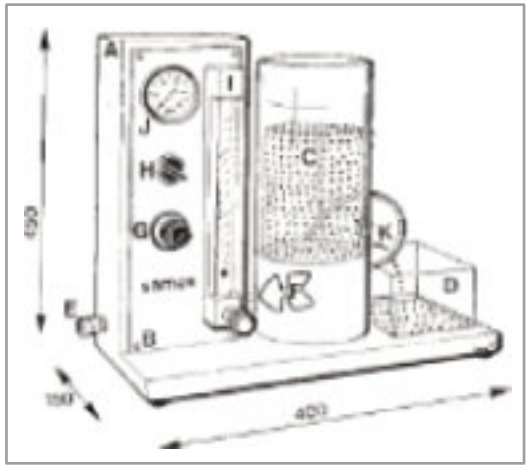
a. the regularity of the powder
b. the temperature and humidity of the air stream
c. the velocity of the air stream
d. the geometry of the fluidizing bottom and the powder outlet

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 swill 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



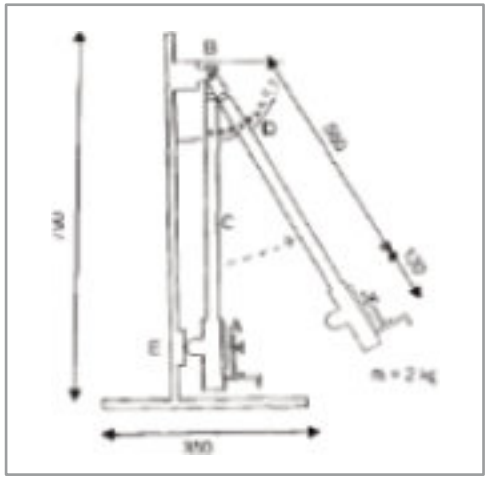
8.4.3 Testing of powder adhesion

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 pow- der 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. Standard- ized 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.

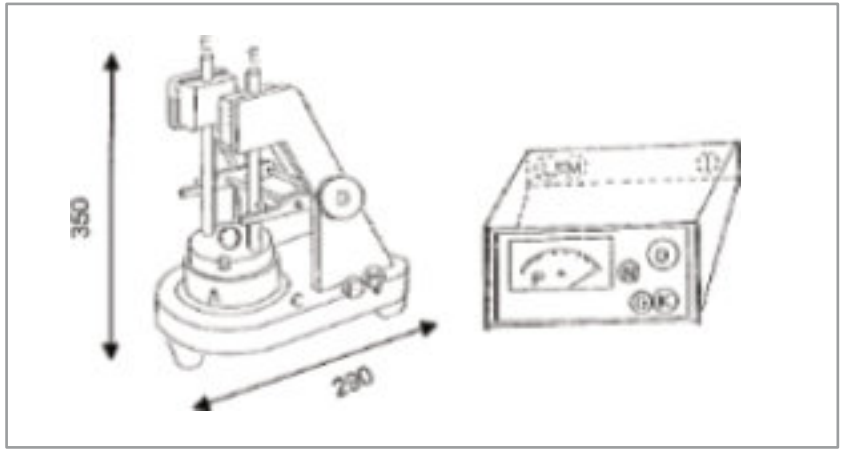
As the current always chooses the way of the lowest resistance, it flows principally along the surface. This means, that the determined Ω-value is identical to the **surface resistance** of the powder. Multiplication of this value with the quotient of the electrode area (stamp) in $cm^2$ and the thickness of the powder layer gives the **specific surface resistance** in the dimension Ω • 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 used for the characterization of powders of low density and surface conductivity. Therefore, the surface resistance in Ω • 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 a effective comparison of different electrostatic powders.

<u>Correlation between surface resistance and powder adhesion</u>
A good powder adhesion prerequisites, 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 a 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!

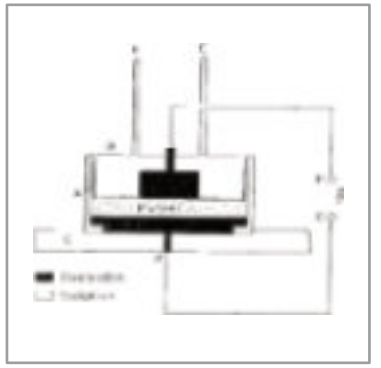
The surface resistance is a measure of the efficiency of the particle coating. Moreover, it indicates whether the coated powder withstands any attack by humidity out of the air after ageing. Powders with a high surface resistance (>$10^{14}$ Ω) result in good figures for the powder adhesion.

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 $^0$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 $H_2SO_4$ 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 absorp 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.

$$\frac{(25x3.2)+(ax1.6)}{\text{g weight of sample}} = \text{mg methylene blue per 1 g clay}$$

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 $^0$C; 3 minutes).

In order to determine the colour co-ordinates use a Hunterlab 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 (=100 µm 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 $^0$C. Put this solution in a 1000 ml measuring flask and fill up at 20 $^0$C with distilled water.

Methylene blue solution (II)

Dissolve 1.6 g methylene blue in 500 ml distilled water of about 70 $^0$C. Put this solution in a 1000 ml measuring flask and fill up at 20 $^0$C with distilled water.

6n sulphuric acid

Mix 167 ml concentrated $H_2SO_4$ (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.

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. The to be used water 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 $CaCO_3$ per 1000 ml water):

Germany:

$1^0$GH = German degree of hardness = 10 mg CaO per 100 ml water

$1^0$GH = $1.78^0$FH = $1.25^0$BH = 17.8 ppm = 0.357 mval/kg

France:

$1^0$FH = French degree of hardness = 10 mg $CaCO_3$ per 1000 ml water

$1^0$FH = $0.56^0$GH = $0.7^0$BH = 10 ppm = 0.2 mval/kg

Great Britain:

$1^0$BH = British degree of hardness = 1 grain $CaCO_3$ per gallon = 14.3 mg $CaCO_3$ per 1000 ml water

$1^0$BH = $0.8^0$GH = $1.43^0$FH = 14.3 ppm = 0.286 mval/kg

USA:

ppm = 1 part per million = 1 mg $CaCO_3$ per 1000 ml water

1 ppm = $0.056^0$GH = $0.1^0$FH = $0.07^0$BH = 0.02 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 a 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 PRINCE 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 100 µm mesh aperture = 3600 mesh per $cm^2$, for electrostatic applications, blue sieves of 75 µm mesh aperture = 6400 mesh per $cm^2$ are in use. Aluminum enamels are even finer ground. Test white sieves of 40 µm mesh aperture = 16900 mesh per $cm^2$ are essential. The sieves are standardized in accordance with ISO3310/1

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.[1)]

[1)] The widespread method to press the slip through the test sieve by means of a strongjet 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.

PRINCE and FERRO 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 PRINCE | and FERRO |
|---|---|
| 0.5 | 3.5 |
| 1 | 5.5 |
| 2 | 7.3 |
| 3 | 8.7 |
| 4 | 10.0 |

The test method PRINCE requires a sample of 12.5 ml, whereas the test with the conical FERRO 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 contamination 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 relative 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 liquidfied 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$^3$. 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$^3$ 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 PRINCE 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 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$^2$, 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 PRINCE 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 • 4 cm with ten holes with steadily increasing diameters from 5 - 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).

Unsuitable for the judgement of application properties of enamel slips are the DIN or Ford-beaker and the Lehmann-Viscosity meter.

### 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, be- tween 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 de- vices. 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 $s^{-1}$.

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 enamelling of devices and receptacles, that have to face repetition of stress by means of boiling or hot water, is tested for its constancy by a long-term exposure. Because of the high expenditure of time that is necessary for the test according to EN ISO 28706-2/13, one has to - especially for hot water tanks - take some peculiarities into account.

Method of testing

The tests will be made according to EN ISO 28706-2 and the DIN 4753. Deviating from the, under 7.3 mentioned boiling period, the testing time is set for 6 weeks, but during the vapour phase a glass-plate (borosilicate glass 3.3 according to DIN 3585). The testing solution is completely desalinated water of 1 mS/m conductance maximum. The water is to be renewed according to the following scheme:

| | | |
|---|---|---|
| 1. to 5.day | daily water-replacement | (1. week) |
| 6. and 7.day | no water-replacement | |
| 8. to 12. day | daily water-replacement | (2. week) |
| 13. and 14.day | no water-replacement | |
| 15. to 19. day | daily water-replacement | (3. 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. | |
| 23. to 26. day | daily water-replacement | (4. week) |
| 27. and 28. day | no water-replacement | |
| 29. to 33. day | daily water-replacement | (5. week) |
| 34. and 35. day | no water-replacement | |
| 36. to 40. day | daily water-replacement | (6. week) |
| 41. and 42 | day no water-replacement | |
| 43. day: | The test plates are, just like on the 22. day, cleaned, dried and weighed. | |

Testing-device

Apparatus according to EN ISO 28706-2/5

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, a testing-temperature of 'boiling' is valid.

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 8.5g/m$^2$.

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, molded 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 $^0$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 $^0$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 adhesion

**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 hollowware. The latter applies to DIN 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 $^0$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 quenchings

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 hollowware DIN 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 $^0$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

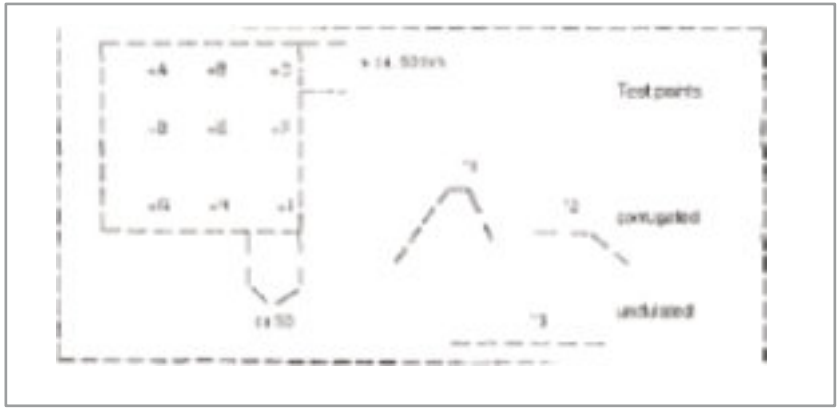
8.6.6. Admissible differences of application thickness on corrugated and undulated pairs of sheet steel panels for heat exchanger

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 µm. A peak thickness on these points of < 300 µm is permissible, but only one measurement, out of the 36, may be 20% above the maximum value. The average thickness on the 18 measuring points No. 3 of the undulated panel must be < 200 µm. The maximum thickness is < 250 µm, merely one measurement can be as high as 300 µm. With the exception of edges and suspension holes, the application thickness should nowhere fall below 80 µm.

On the edge area the entire thickness of the panel may measure 750 µm + thickness of the sheet.

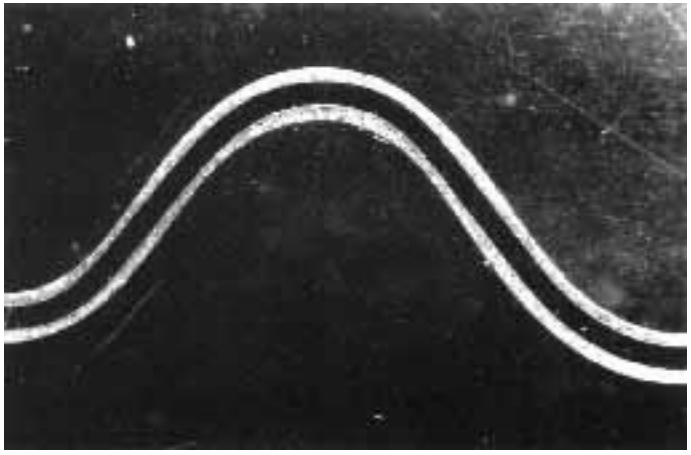


Illustration: Optical layer distribution on undulated sheet steel (enlargement 6 : 1)

### 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 DIN 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 DIN 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 in different production areas | (EEA 8.7.6) |
| 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 $^0$C. By this, reactions with the formation of gasses occur (mainly $H_2$, CO and $CO_2$). 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 utilization 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 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.

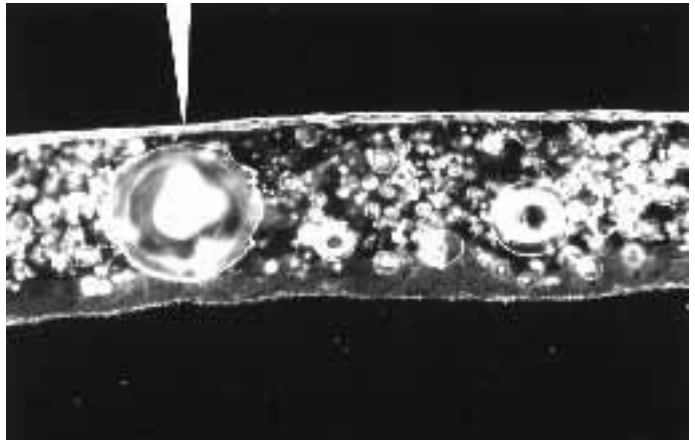


Illustration: Big blister in an enamel layer. Its thin glass-skin can be disturbed by the high voltage test. (enlargement 200 : 1)

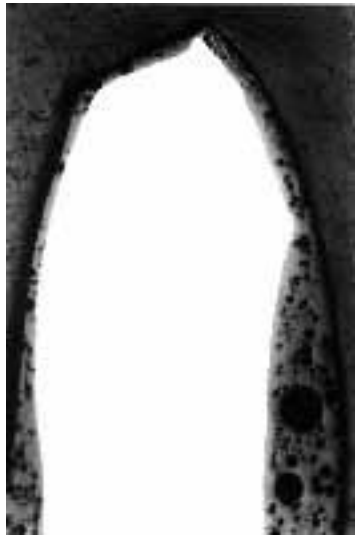
### 8.7.2 Valuation of burn-off on enamellings

Definitionandcause

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 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 $TiO_2$ 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 laminar expansion 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 $cm^2$.

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 enamellings. 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 $^{0}$C) often displays a metallic luster as a resultof the diffusion of metal oxide.

Test report

In the test report to be mentioned:

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

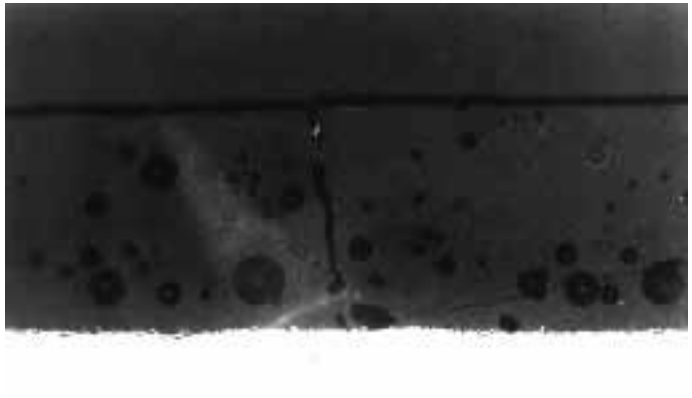
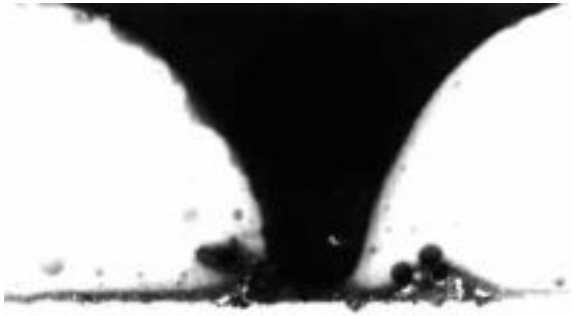


Illustration: Formation of cracks in an enamel layer (enlargement 200 : 1)

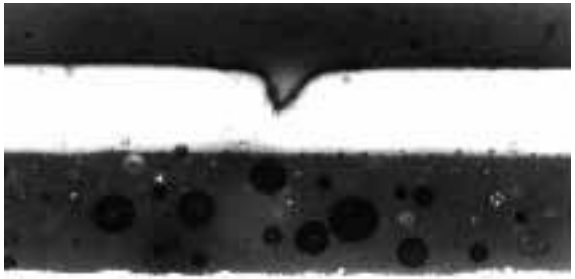
8.7.4 Valuation of pores in enamellings

Definitionandcause

Following the definition of DIN 50903: Pores are locally limited interruptions in the enamelling. 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

Definitionandcause

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 be 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

Definitionandcause

In almost every manufacturing process of the enamelling shop (Raw manufacturing- Metal pretreatment - Milling - Application - Drying - Firing) there are characteristical 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 characteristical 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

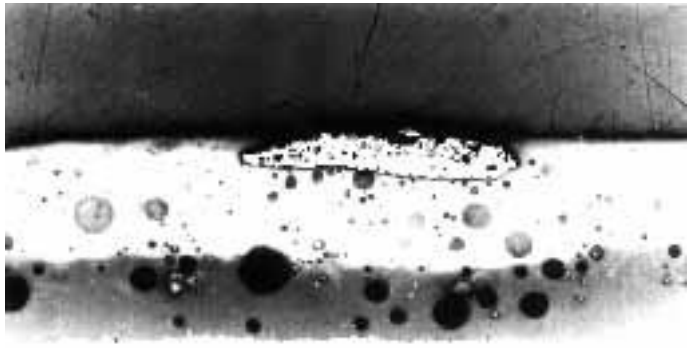
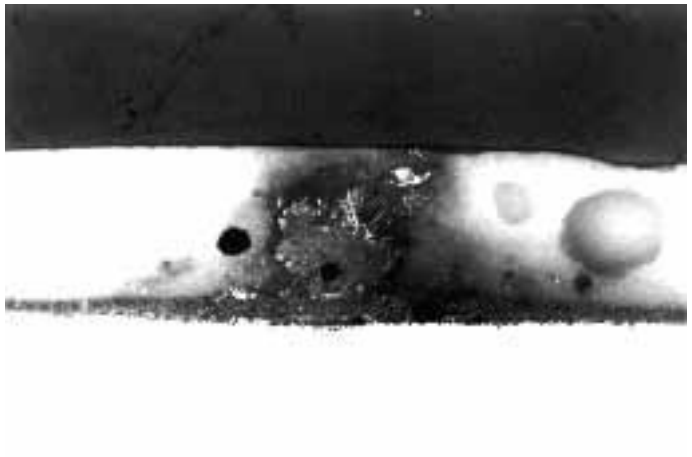


Fig. 4
Sulphate dimple

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 blemishes 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

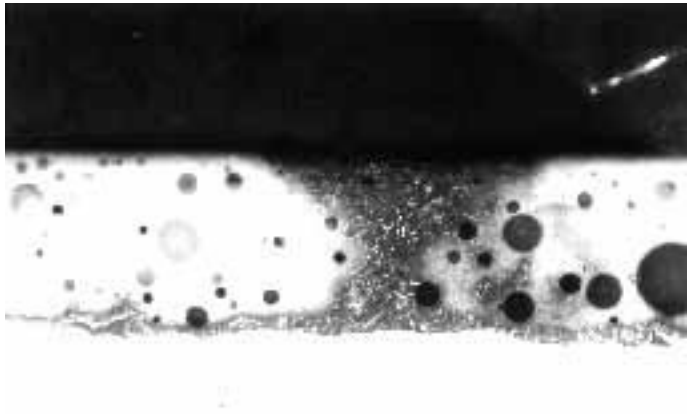
In the test report to be mentioned:

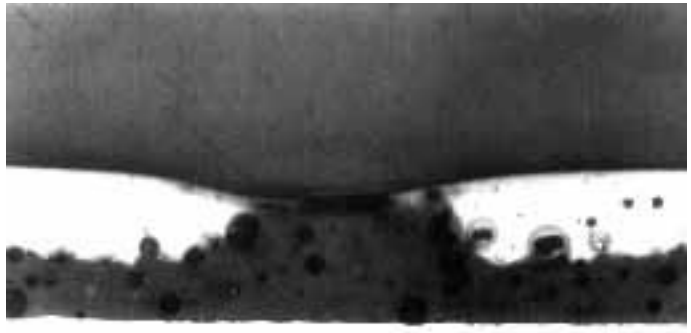
- kind and origin of the test piece
- place and date of testing
- description of defects, number and extent
- complete state of the test piece.

### 8.7.7 Valuation of black specks in the enamelling

Definitionandcause

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 transparent layer (being rich in $FeTiO_3$) 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 $kg/m^2$

$F$ = pressing force in kg

$A$ = pressed area in $m^2$

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

## 9.1 EEA-Members

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**ÖsterreichischerEmail Verband**
Mühlengasse 32,
A-3400 Klosterneuburg (Austria)
**office@emailverband.at**

**Koninklijke Metaal Unie – Stichting Email**
Einsteinbaan 1, NL-3439 NJ
Nieuwegein
**info@metaalunie.nl**

**Vitreous Enamel Association (VEA)**
39 Sweetbriar Way, Heath Hayes
GB-Staffordshire WS 12 2US

**Vitreous Enamellers Society** (part of IOM$^3$) The Institute of Materials, Minerals and Mining
1 Carlton House Terrace, GB-London SW1Y 5DB

**10.2 Addresses to order the Quality Manual.**

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

www. european-enamel-association.eu.

or

from the websites of the national associations (see chapter 9)

**European Enamel Association**
Rue Belliard 12
1040 Brussels, Belgium
info@european-enamel-association.eu
www.european-enamel-association.eu

**11.0 EEA Certified companies**

GLS Tanks International GmbH
Industriestr. 6, A - 3860 Heidenreichstein (AT)
Tel: +43 2862 53187-0, Fax: +43 2862 53187-820
E-Mail: office@glstanks.com / Internet: www.glstanks.com

Riess Kelomat GmbH
Maisberg 47, A - 3341 Ybbsitz (AT)
Tel: +43 7443 863150, Fax: +43 7443 86654
E-Mail: f.riess@riess.at / Internet: www.riess.at

Polyvision N.V.
Zuiderring 56, B - 3600 Genk (B)
Tel.: +32 89 323130, Fax: +32 89 323131
E-Mail : info@.polyvision.com / Internet: www.polyvision.com

Omeras GmbH
Am Emaillierwerk 1 D - 08315 Lauter-Bernsbach (DE)
Tel.: +49 3771 5674-0, Fax: +49 3771 5674-40
E-Mail: info@omeras.de / Internet www.omeras.de

Bergheimer Emaillierwerk GmbH & Co. KG
Glescherstr. 126, D - 50126 Bergheim (DE)
Tel: +49 2271 49007-0, Fax: +49 2271 49007-99
E-Mail: philipp.huber@bew-email.de / Internet: www.bergheimer.de

Stiebel Eltron GmbH & Co. KG
Dr.-Stiebel-Straße 33, D - 37603 Holzminden (DE)
Tel: +49 5531 702-0, Fax: +49 5531 702-480
E-Mail: info@stiebel-eltron.de , Internet: www.stiebel-eltron.de

Ferro Techniek B.V.
Bremstraat 1
NL-7011 AT Gaanderen (NL)
Tel.: +31 315 339811, Fax: +31 315 339899
E-Mail: info@ferrotechniek.com: / Internet : www.ferrotechniek.com

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SK-05801 Poprad, Slovenska Republika (SK)
Tel.: +421 52 7127 150, Fax: +421 52 7731 748
E-Mail: tatramat@tatramat.sk: / Internet : www.stiebel-eltron.sk