

# Vitreous and porcelain enamels — Regenerative, enamelled and packed panels for air-gas and gas-gas heat exchangers — Specifications

The European Standard EN 14866:2005 has the status of a  
British Standard

ICS 25.220.50

## National foreword

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The UK participation in its preparation was entrusted to Technical Committee STI/36, Vitreous enamel coatings, which has the responsibility to:

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English Version

## Vitreous and porcelain enamels - Regenerative, enamelled and packed panels for air-gas and gas-gas heat exchangers - Specifications

Emaux vitrifiés - Echangeurs thermiques pour réchauffeurs air-gaz et gaz-gaz à empilement de panneaux émaillés remplaçables et démontables - Spécifications

Emails und Emailierungen - Regenerative, emailierte und gepackte Bleche für Luft-Gas- und Gas-Gas-Wärmeaustauscher - Anforderungen

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## Foreword

This European Standard (EN 14866:2005) has been prepared by Technical Committee CEN/TC 262 "Metallic and other inorganic coatings", the secretariat of which is held by BSI.

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## 1 Scope

This European Standard specifies the minimum requirements and the functional characteristics of enamel coatings applied by any enamel process, such as: wet dipping, wet flow-coating, wet spraying, wet electrostatic spraying, wet electro deposition or dry powder electrostatic spraying, to profiled steel heat exchanger panels in regenerative heat exchangers, before and after packing in baskets.

NOTE For very severe service conditions, or to obtain extended operation life, more stringent limits may be agreed between customer and supplier.

## 2 Normative references

The following referenced documents are indispensable for the application of this European Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 10204:2004, *Metallic products — Types of inspection documents*

EN 10209:1996, *Cold-rolled low carbon steel flat products for vitreous enamelling — Technical delivery conditions*

EN 14483-2:2004, *Vitreous and porcelain enamels — Determination of resistance to chemical corrosion — Part 2: Determination of resistance to chemical corrosion by boiling acids, neutral liquids and/or their vapours*

EN 14863, *Vitreous and porcelain enamels — Determination of the edge covering on enamelled steel plate to be used in heat exchangers*

EN ISO 105-J03, *Textiles — Tests for colour fastness — Part J03: Calculation of colour differences (ISO 105-J03:1995, including Technical Corrigendum 1:1996)*

EN ISO 2178, *Non-magnetic coatings on magnetic substrates — Measurement of coating thickness — Magnetic method (ISO 2178:1982)*

EN ISO 8289:2001, *Vitreous and porcelain enamels — Low voltage test for detecting and locating defects (ISO 8289:2000)*

ISO 2723, *Vitreous and porcelain enamels for sheet steel — Production of specimens for testing*

ISO 4534, *Vitreous and porcelain enamels — Determination of fluidity behaviour — Fusion flow test*

ISO 7991, *Glass — Determination of coefficient of mean linear thermal expansion*

## 3 Terms and definitions

For the purpose of this European Standard, the following terms and definitions apply.

### 3.1

#### **blisters**

localised bubbles under the surface of the fired enamel

### 3.2

#### **burn-off**

localised areas of rough black oxide erupting through the enamel coating

**3.3****chipping**

fracturing and detachment of particles from a vitreous enamelled surface

**3.4****copperheads**

small freckle or pimple-like reddish brown spots occurring in ground-coats, or direct-on enamels applied to sheet metals

**3.5****cracking**

laminar interruptions in the fused coating running vertical to the surface

NOTE 1 The laminar interruptions can also occur at different angles.

NOTE 2 Their causes are mainly the result of tensile stresses within the enamel coating.

**3.6****crazing**

fine cracks in the enamel coating

**3.7****fire tool marks****(fire marks)**

small indentations similar in appearance to shallow pinholes

**3.8****fishscaling**

small half-moon shaped defects occurring in the vitreous enamelled surface

NOTE Fishscaling can occur immediately on cooling or after some time has elapsed following firing. These defects originate from super saturation of the substrate with hydrogen (acquired during firing) that suddenly fractures the enamel coating in order to relieve the pressure that has accumulated with time at the enamel-steel interface.

**3.9****spalling**

spontaneous fracturing and detachment of particles of enamel from within the coating layer

NOTE Spalling often occurs on corners, sharp radii, or panel edges; the result of too low enamel coefficient of expansion for the substrate, the external radii and the enamel thickness concerned. Thermal stresses can aggravate the spalling.

**3.10****tearing**

short breaks or cracks in the enamel bisque that have healed during firing

**3.11****air-gas heater**

heat exchangers used to heat up the air needed for combustion in the boiler using the combustion gases from the boiler as the hot fluid

NOTE 1 The maximum temperature of the hot gases entering the heat exchanger is 450 °C with a normal operating temperature from 380 °C to 320 °C.

NOTE 2 Air-gas heat exchangers in which gas fluid from DENOx installations pass through should be considered as Gas-gas heaters for the purpose of this European Standard

### **3.12**

#### **gas-gas heater**

heat exchangers used in the de-sulphuration plants to reheat the gases treated in the scrubber to obtain the proper draft in the stack

NOTE 1 The hot fluids are the untreated gases going to the scrubber.

NOTE 2 The maximum temperature of the hot gases entering the heat exchanger is 200 °C with a normal operating temperature from 160 °C to 120 °C.

## **4 Steel substrates**

### **4.1 Delivery**

The steel for enamelling shall conform to the requirements of EN 10209 and shall be delivered with a certificate in accordance with 3.1 of EN 10204:2004.

### **4.2 Analysis**

The chemical composition shall be determined by a ladle analysis and shall conform to the requirements of EN 10209:1996, Table 2. On request of the enameller, other elements as mentioned in Table 2 shall be agreed with the steel manufacturer. For the grades DCO3ED and DCO4ED the carbon content of the product shall be determined and shall conform to EN 10209:1996, Table 2.

### **4.3 Hydrogen permeability**

The hydrogen permeability shall have a minimum TH value of 100, calculated in accordance with EN 10209:1996, B.1.8, Equation (1), or shall give the result of a minimum of 8 min in accordance with EN 10209:1996, B.1, calculation in accordance with B.1.8 Equation (2).

In the absence of a certificate, from the steel supplier, confirming the above minimum hydrogen permeability and with prior agreement between the customer and the supplier the fish-scale resistance shall then be determined as described in 4.4.

The hydrogen permeability method is not acceptable for the steel grades DCO6EK and DCO6ED (see EN 10209:1996, Table 2). For these grades, the fish scale test described in 4.4 shall be used.

### **4.4 Fish scale test**

The fish scale test shall be carried out in accordance with EN 10209:1996, B.2, method B.2. The test sheet (150 mm × coil width) shall be pre-treated without a nickel dip. The front and back shall be coated with enamel prepared in accordance with the supplier's milling formula and applied to produce a fired thickness of 100 µm to 130 µm. After drying, the coated test sheet shall be fired for 5 min at 820 °C. The test sheet shall then be subjected to thermal treatment at 60 °C to 80 °C for 24 h and then inspected for fish scales. No fish scales are allowed.

### **4.5 Pickling speed**

If required by the enameller, the pickling speed shall be determined in accordance with EN 10209:1996, Annex C and shall be agreed with the steel manufacturer.



## 5 Enamel frit(s)

### 5.1 Delivery

Enamel frit(s) shall be ordered by the enameller with a certificate conforming to the requirements of 3.1 of EN 10204:2004, including the results for the items given under 5.5 and 5.7.

The tests 5.4 and 5.6 shall be carried out whenever there is a change in the frit or a change in the milling formula.

NOTE When taking delivery of "ready to use" enamel, enamel slip or enamel powder the enameller can ask for additional requirements for the application properties in the certificate.

Any other requirements and the test recipes shall be determined by consultation between enameller (and/or customer) and frit manufacturer.

### 5.2 Coefficient of expansion

If required by the enameller, the coefficient of expansion shall be determined in accordance with the house test of the manufacturer of the enamel frit (base material for "ready to use", enamel slip or powder enamel), or in accordance with ISO 7991.

### 5.3 Fusion flow

If required by the enameller, the fusion flow shall be determined in accordance with the house test of the manufacturer of the enamel frit (base material for ready to use, enamel slip or powder enamel), or in accordance with ISO 4534.

### 5.4 Boiling water vapour resistance

If required by the enameller, the water vapour resistance shall be determined in accordance with EN 14483-2:2004, Clause 13

When determined in accordance with EN 14483-2:2004, Clause 13, the enamel coating shall have a maximum mass loss as given in Table 1.

**Table 1 — Maximum mass loss**

Heater type	Mass loss max.
Air-gas	20 g/m <sup>2</sup> /48 h
Gas-gas	6 g/m <sup>2</sup> /48 h

### 5.5 Acid resistance

The boiling sulphuric acid resistance shall be determined in accordance with EN 14483-2:2004, Clause 11.

### 5.6 Thermal shock resistance

If required by the enameller, the thermal shock resistance shall be determined in accordance with Annex A at a test temperature of 350 °C

After testing five times at the test temperature, the test specimens shall show no damage.

## **5.7 Adherence**

The adherence shall be determined in accordance with EN 10209:1996, Annex D, using test specimens with a known pickling speed (see 4.5) in accordance with ISO 2723.

The method of pre-treatment, application and firing of the enamel shall be described.

## **6 Characteristics of the enamel coating**

### **6.1 Adherence**

Test specimens for the determination of adherence shall be prepared in accordance with ISO 2723, and shall be pre-treated and enamelled under the same circumstances as the production of the heat exchanger panels.

When determined in accordance with EN 10209:1996, Annex D, the adherence of the enamel shall be at least level 2.

Test shall be carried out on every pre-treated batch of panels.

### **6.2 Thickness**

The thickness shall be determined in accordance with EN ISO 2178. Adjustment of the measuring equipment shall be carried out on the profile concerned. Measurements shall be carried out from point A to point I (see Figure 1) on the front and reverse sides of the panel. The test points shall be situated at least 50 mm from the edge. The measuring points on the corrugated panel shall be as marked with numbers 1 and 2, on the undulated panel with 3. This shall result in 54 measurements from each pair of panels tested, 36 from each corrugated panel, and 18 from each undulated panel.

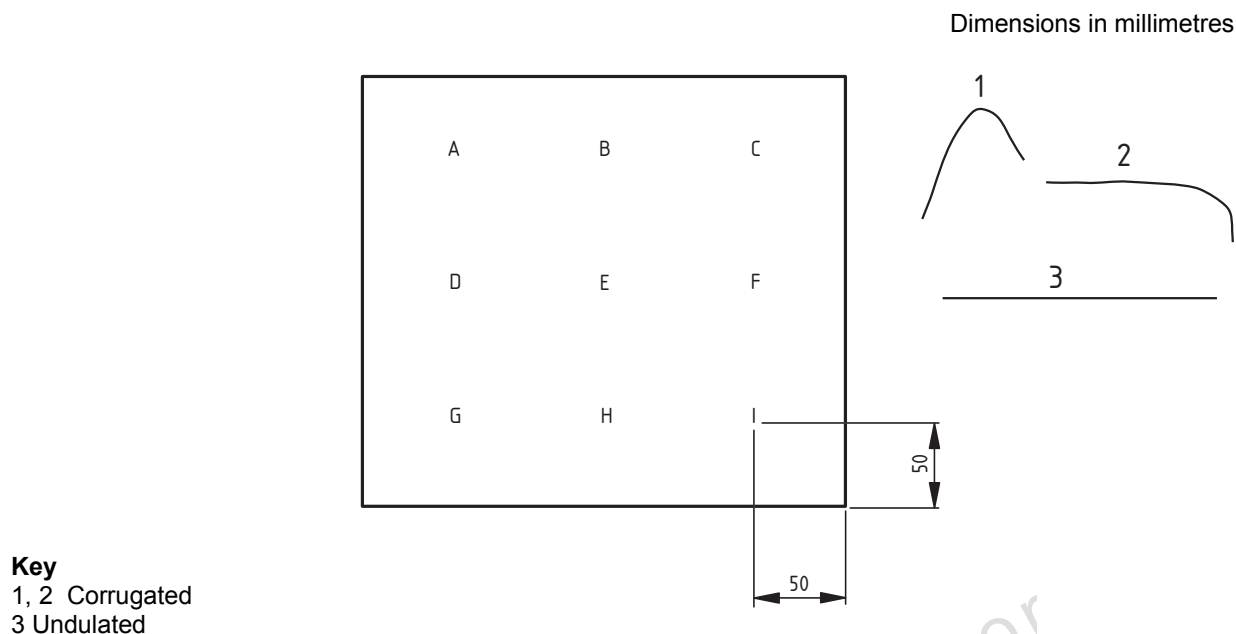
The mean of the 54 measurements (36 measurements at point number 1 and point number 2 of the corrugated panel plus the 18 measurements at point number 3 of the undulated panel) shall be  $150 \mu\text{m} \pm 30 \mu\text{m}$ , unless a different mean is agreed between customer and supplier at the time of ordering.

Along the area bordering the edge of the panel the total thickness may measure up to  $600 \mu\text{m}$  (i.e. 2 sides of  $300 \mu\text{m}$ ) 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 and 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  $80 \mu\text{m}$ .

Measurements other than those on the indicated position points shall be determined using a microscope.

The test shall be carried out on a 2 h cycle.



**Figure 1 — Measuring points for thickness determination**

### 6.3 Thermal shock resistance

Test specimens for the determination of thermal shock resistance shall be prepared in accordance with ISO 2723 and shall be pre-treated and enamelled under the same circumstances as the production of the heat exchanger. They shall have an enamel layer thickness of  $150 \mu\text{m} \pm 20 \mu\text{m}$ .

The thermal shock resistance shall be determined on at least three test pieces in accordance with Annex A at a test temperature of  $350 \text{ }^\circ\text{C}$ .

After testing five times at the test temperature, the test specimens shall show no damage.

The test shall be carried out on every 5 t of enamel frit.

### 6.4 Fundamental defects

A 100 % visual examination of the enamelled surface shall be carried out for fundamental defects. The enamelled surface shall be free of fundamental defects such as blisters, burn-off, chipping, copper heads, cracking, crazing, fish scales, spalling and tearing (see Clause 3). The enamelled surface shall be visually examined from a minimum distance of 1,5 m, in either natural light or artificial daylight D65 in accordance with EN ISO 105-J03.

NOTE Fire tool marks may be accepted.

### 6.5 Open defects

Open defects down to the basis metal shall be detected in accordance with EN ISO 8289:2001, method B.

In a random check of 10 pairs of panels out of a production of 10 000 pair of panels, the average number of open defects shall be as given in Table 2. This sampling is sufficiently representative of the production whenever the results are within the specified norm. If the results differ from the specified norm then the sampling can be extended to between 2 and 5 per thousand.

Table 2 — Maximum numbers of open defects

Heater type	Open defect max.
Air-gas	50/m <sup>2</sup>
Gas-gas	15/m <sup>2</sup>

Alternatively, if the production process demands the number of defects on pairs of heat exchanger panels may be determined by checking 1 % of production on a 2 h cycle.

## 6.6 Edge covering of gas-gas heaters

If required by the customers the edge covering of the panels of gas-gas heaters shall be determined in accordance with EN 14863. The mean shall be agreed between the customer and supplier at the time of ordering.

## 6.7 Boiling sulphuric acid resistance

Test specimens for the determination of acid resistance shall be prepared in accordance with ISO 2723, and shall be pre-treated and enamelled under the same circumstances as the production of the heat exchanger. They shall have an enamel layer thickness of 150 µm ± 20 µm.

When determined in accordance with EN 14483-2:2004, Clause 11, the enamel coating shall have a maximum mass loss as given in Table 3.

The test shall be carried out on every 5 t of enamel frit

Table 3 — Maximum mass loss

Heater type	Mass loss max.
Air-gas	10,0 g/m <sup>2</sup> /18 h
Gas-gas	2,0 g/m <sup>2</sup> /18 h

## 6.8 Rework

In case of rejected enamelled elements, a maximum of 5 % of rework shall be accepted.

## 7 Characteristics after packing

### 7.1 Packing pressure

The packing pressure applied to the corrugated and undulated plates shall be ± 1 000 kg/m<sup>2</sup>, preferably in the upper limit of the range 5 000 kg/m<sup>2</sup> to 8 000 kg/m<sup>2</sup>. The surface area in m<sup>2</sup> of each filled basket is determined from length x width of the middle pair of plates in the load.

### 7.2 Visual examination

For gas-gas heaters detection, a visual examination shall 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 second, the middle and the last but one pair of panels in the basket) the maximum number of defects/m<sup>2</sup> on the contact points should be agreed between the customer and the supplier.

The visual examination shall be performed after pressurising the basket complete with elements but without the pack being welded.

One basket per rotor ring shall be tested.

### 7.3 Edge covering of gas-gas heaters

If required by the customer the edge covering of gas-gas heaters panels shall be determined in accordance with EN 14863 or by visual examination on the edges in the flow direction.

The edge covering test shall be performed after pressurising the basket complete with elements but without the pack being welded.

## 8 Documentation

On request of the customer, the enameller shall provide test results for the measurements listed in Table 4, together with full details of the process parameters.

Table 4 — Summary required tests

Test	Clause or subclause	Gas-gas heaters	Air-gas heaters
<b>Steel (Clause 4)</b>			
Certificate EN 10204:2004, 3.1	4.1	Required	Required
Analyses	4.2	Required	Required
Hydrogen permeability or fish scale test	4.3	Required	Required
Pickling speed	4.4		
	4.5	If required	If required
<b>Frit(s) (Clause 5)</b>			
Certificate EN 10204:2004, 3.1.B	5.1	Required	Required
Coefficient of expansion	5.2	If required	If required
Fusion flow	5.3	If required	If required
Water vapour resistance	5.4	If required	If required
Acid resistance	5.5	Required	Required
Thermal shock	5.6	If required	If required
Adherence	5.7	Required	Required
<b>Enamel coating (Clause 6)</b>			
Adherence	6.1	Required	Required
Thickness	6.2	Required	Required
Thermal shock	6.3	Required	Required
Visual control	6.4	Required	Required
Defects	6.5	Required	Required
Edge covering	6.6	If required	Not applicable
Acid resistance	6.7	Required	Required
Rework	6.8	Required	Required
<b>After packing (Clause 7)</b>			
Package pressure	7.1	Required	Required
Visual defects	7.2	Required	Not applicable
Edge covering	7.3	If required	Not applicable
<b>Documentation (Clause 8)</b>		If required	If required

**Annex A**  
(normative)

**Method for determining thermal shock resistance of vitreous or  
porcelain enamel coatings**

**A.1 Procedure**

Heat the test piece in a fan assisted hot air oven to the required test temperature and hold at that temperature for 10 min.

Remove the test piece from the heat source and within 5 s plunge it into water at a temperature of 15 °C to 20 °C and completely immersing it for at least 30 s.

Remove the test piece from the water, dry and allow to cool to ambient temperature.

Repeat the procedure four times so that five thermal cycles are completed.

**A.2 Evaluation**

Inspect the test piece for any visible sign of damage such as chipping, cracking, crazing or spalling.

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