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Vitreous and porcelain enamel finishes — Selection of test methods for vitreous and porcelain enamelled areas of articles

*Finitions des émaux vitrifiés — Choix des méthodes d'essai applicables
aux surfaces émaillées de pièces*



Reference number
ISO 4528:2000(E)

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 4528 was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*.

Introduction

Standard test methods are required for measuring and controlling the properties and hence also the quality of vitreous and porcelain enamelled finishes.

To ensure that these finishes meet the requirements of various applications, test methods should be chosen to measure the properties that are important to the function of a specific enamelled article.

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Vitreous and porcelain enamel finishes — Selection of test methods for vitreous and porcelain enamelled areas of articles

1 Scope

This International Standard is a guide to the selection of test methods for evaluating the performance of vitreous and porcelain enamelled finishes in different applications. It references the test methods available for measuring the properties of these finishes, and correlates these properties to requirements of specific enamelled articles.

It is limited for the most part to test methods that are described in ISO International Standards and does not provide acceptance criteria or performance limits for the properties.

This International Standard applies to all enamelled articles irrespective of their basis metals.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 2178, *Non-magnetic coatings on magnetic substrates — Measurement of coating thickness — Magnetic method.*

ISO 2360, *Non-conductive coatings on non-magnetic basis metals — Measurement of coating thickness — Eddy current method.*

ISO 2722, *Vitreous and porcelain enamels — Determination of resistance to citric acid at room temperature.*

ISO 2742, *Vitreous and porcelain enamels — Determination of resistance to boiling citric acid.*

ISO 2743, *Vitreous and porcelain enamels — Determination of resistance to condensing hydrochloric acid vapour.*

ISO 2744, *Vitreous and porcelain enamels — Determination of resistance to boiling water and water vapour.*

ISO 2745, *Vitreous and porcelain enamels — Determination of resistance to hot sodium hydroxide.*

ISO 2746, *Vitreous and porcelain enamels — Enamelled articles for service under highly corrosive conditions — High voltage test.*

ISO 2747, *Vitreous and porcelain enamels — Enamelled cooking utensils — Determination of resistance to thermal shock.*

ISO 4530, *Vitreous and porcelain enamelled manufactured articles — Determination of resistance to heat.*

ISO 4531-1, *Vitreous and porcelain enamels — Release of lead and cadmium from enamelled ware in contact with food — Part 1: Method of test.*

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ISO 4532, *Vitreous and porcelain enamels — Determination of the resistance of enamelled articles to impact — Pistol test.*

ISO 4533, *Vitreous and porcelain enamels — Determination of resistance to hot detergent solutions used for washing textiles.*

ISO 6370-2, *Vitreous and porcelain enamels — Determination of the resistance to abrasion — Part 2: Loss in mass after sub-surface abrasion.*

ISO 8289, *Vitreous and porcelain enamels — Low voltage test for detecting and locating defects.*

ISO 8290, *Vitreous and porcelain enamels — Determination of resistance to sulfuric acid at room temperature.*

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

3 Selection of test methods

The properties of enamelled surfaces are listed in Table 1, along with the numbers of the ISO test methods by which they may be measured. The table identifies the tests that should be performed to assess the performance of 30 specific enamelled articles. Suitable standard test methods are selected by noting the specific tests recommended in the column for each of the enamelled articles.

The following symbols are used in Table 1.

- + Testing may be performed by the method cited;
- (+) The test method that is cited may need to be modified to take into account special requirements of a specific application;
- The test is not applicable and/or the test method is not suitable.

Table 1 — Test methods for assessing the properties of enamelled articles

No.	Property	ISO test method	Number and description of enamelled article			
			1 Cookers – top plate	2 Cookers – baking compartment ^a , grills, burner caps, pan supports, accessories	3 Cookers – other components (excluding cookware)	4 Room heating equipment
Methods of assessing resistance to chemical attack in various solutions						
1	Cold citric acid	2722	+	+	+	+
2	Cold sulfuric acid	8290	-	-	+ ^b	+ ^b
3	Boiling citric acid	2742	-	-	-	-
4	Condensing hydrochloric acid vapour	2743	-	-	-	-
5	Hot sodium hydroxide	2745	-	-	-	-
6	Boiling water	2744	-	-	-	-
7	Water vapour	2744	-	-	-	-
8	Hot detergent	4533	-	-	-	-
9	Liquid cleaners	c	+	+	+	+
10	Weathering resistance	d	-	-	-	-
11	Special corrosive substances	c, e	-	-	-	-
12	Release of lead and cadmium	4531-1	-	+ ^f	-	-
Methods of assessing thickness and other properties						
13	Thickness	2178, 2360	+	+	+	+
14	Reflectivity and gloss	c	-	-	-	-
15	Waviness	c	-	-	-	-
16	Colour	c	+	+	+	+
17	Continuity and porosity ^g – Visual inspection		+	+	+	+
18	Continuity and porosity ^g – Low voltage test	8289	-	-	-	-
19	Continuity and porosity ^g – High voltage test	2746	-	-	-	-
20	Resistance to thermal shock	2747	-	-	-	-
21	Resistance to thermal shock	c, h	+	+	-	+
22	Resistance to heat	4530	+	+	+	+
23	Resistance to impact	4532	+	+	+	+
24	Adhesion	c, i	+	+	+	+
25	Abrasion resistance	c	+	+	+	-
26	Subsurface abrasion resistance	6370-2	-	-	-	-

Table 1 (continued)

No.	Property	ISO test method	Number and description of enamelled article			
			5 Cookware – inside surfaces and utensils	6 Cookware – outside surfaces	7 Cookware – lids	8 Tableware
Methods of assessing resistance to chemical attack in various solutions						
1	Cold citric acid	2722	+	+	+	+
2	Cold sulfuric acid	8290	-	-	-	-
3	Boiling citric acid	2742	+	-	+ j	-
4	Condensing hydrochloric acid vapour	2743	-	-	-	-
5	Hot sodium hydroxide	2745	-	-	-	-
6	Boiling water	2744	+	-	+ j	-
7	Water vapour	2744	+	-	+ j	-
8	Hot detergent	4533	-	-	-	-
9	Liquid cleaners	c	+	+	+	+
10	Weathering resistance	d	-	-	-	-
11	Special corrosive substances	c, e	+	+	+	+
12	Release of lead and cadmium	4531-1	+	-	+ j	+
Methods of assessing thickness and other properties						
13	Thickness	2178, 2360	+	+	+	+
14	Reflectivity and gloss	c	-	-	-	-
15	Waviness	c	-	-	-	-
16	Colour	c	+	+	+	+
17	Continuity and porosity ^g – Visual inspection		+	+	+	+
18	Continuity and porosity ^g – Low voltage test	8289	-	-	-	-
19	Continuity and porosity ^g – High voltage test	2746	-	-	-	-
20	Resistance to thermal shock	2747	+	+	-	-
21	Resistance to thermal shock	c, h	-	-	-	-
22	Resistance to heat	4530	-	-	-	-
23	Resistance to impact	4532	+	+	+	+
24	Adhesion	c, i	+	+	+	+
25	Abrasion resistance	c	+	+	+	+
26	Subsurface abrasion resistance	6370-2	-	-	-	-

Table 1 (continued)

No.	Property	ISO test method	Number and description of enamelled article			
			9 Sinks	10 Refrigerators – inside surfaces	11 Refrigerators – outside surfaces	12 Washing machines – drum
Methods of assessing resistance to chemical attack in various solutions						
1	Cold citric acid	2722	+	+	+	+
2	Cold sulfuric acid	8290	-	-	-	-
3	Boiling citric acid	2742	+	-	-	-
4	Condensing hydrochloric acid vapour	2743	-	-	-	-
5	Hot sodium hydroxide	2745	-	-	-	-
6	Boiling water	2744	+	-	-	+
7	Water vapour	2744	-	-	-	+
8	Hot detergent	4533	+	-	-	+
9	Liquid cleaners	c	+	+	+	-
10	Weathering resistance	d	-	-	-	-
11	Special corrosive substances	c, e	-	-	-	-
12	Release of lead and cadmium	4531-1	-	-	-	-
Methods of assessing thickness and other properties						
13	Thickness	2178, 2360	+	+	+	+
14	Reflectivity and gloss	c	+	-	-	-
15	Waviness	c	-	-	-	-
16	Colour	c	+	+	+	-
17	Continuity and porosity ^g – Visual inspection		+	+	+	+
18	Continuity and porosity ^g – Low voltage test	8289	-	-	-	+
19	Continuity and porosity ^g – High voltage test	2746	-	-	-	-
20	Resistance to thermal shock	2747	-	-	-	-
21	Resistance to thermal shock	c, h	-	-	-	-
22	Resistance to heat	4530	-	-	-	-
23	Resistance to impact	4532	+	+	+	+
24	Adhesion	c, i	+	+	+	+
25	Abrasion resistance	c	+	-	-	+
26	Subsurface abrasion resistance	6370-2	-	-	-	-

Table 1 (continued)

No.	Property	ISO test method	Number and description of enamelled article			
			13 Washing machines – box (outside)	14 Dishwashers – rinsing container (inside)	15 Dishwashers – box (outside)	16 Bathtubs and articles for sanitary use – households
Methods of assessing resistance to chemical attack in various solutions						
1	Cold citric acid	2722	+	+	+	+
2	Cold sulfuric acid	8290	-	-	-	+
3	Boiling citric acid	2742	-	-	-	-
4	Condensing hydrochloric acid vapour	2743	-	-	-	-
5	Hot sodium hydroxide	2745	-	+	-	-
6	Boiling water	2744	-	+	-	(+)
7	Water vapour	2744	-	+	-	-
8	Hot detergent	4533	+	+	-	(+)
9	Liquid cleaners	c	+	-	+	+
10	Weathering resistance	d	-	-	-	-
11	Special corrosive substances	c, e	-	+	-	-
12	Release of lead and cadmium	4531-1	-	-	-	-
Methods of assessing thickness and other properties						
13	Thickness	2178, 2360	+	+	+	+
14	Reflectivity and gloss	c	-	-	-	-
15	Waviness	c	-	-	-	-
16	Colour	c	+	-	+	+
17	Continuity and porosity ^g – Visual inspection		+	+	+	+ ^k
18	Continuity and porosity ^g – Low voltage test	8289	-	+	-	-
19	Continuity and porosity ^g – High voltage test	2746	-	-	-	-
20	Resistance to thermal shock	2747	-	-	-	-
21	Resistance to thermal shock	c, h	-	-	-	-
22	Resistance to heat	4530	-	-	-	-
23	Resistance to impact	4532	+	+	+	+
24	Adhesion	c, i	+	+	+	+
25	Abrasion resistance	c	-	-	-	+
26	Subsurface abrasion resistance	6370-2	-	-	-	-

Table 1 (continued)

No.	Property	ISO test method	Number and description of enamelled article			
			17 Bathtubs; articles for sanitary use – medical uses	18 Hot water tanks	19 Traffic and other signs, posters	20 Building panels, light reflectors furniture for indoor use
Methods of assessing resistance to chemical attack in various solutions						
1	Cold citric acid	2722	+	(+)	+	+
2	Cold sulfuric acid	8290	+	-	-	-
3	Boiling citric acid	2742	+	-	-	-
4	Condensing hydrochloric acid vapour	2743	-	-	-	-
5	Hot sodium hydroxide	2745	-	-	-	-
6	Boiling water	2744	(+)	(+)	-	-
7	Water vapour	2744	-	(+)	-	-
8	Hot detergent	4533	(+)	-	-	-
9	Liquid cleaners	c	+	-	+	+
10	Weathering resistance	d	-	-	+	-
11	Special corrosive substances	c, e	+	-	-	-
12	Release of lead and cadmium	4531-1	-	+	-	-
Methods of assessing thickness and other properties						
13	Thickness	2178, 2360	+	+	+	+
14	Reflectivity and gloss	c	-	-	+	+
15	Waviness	c	-	-	+	+
16	Colour	c	+	-	+	+
17	Continuity and porosity ^g – Visual inspection		+ ^k	+	+	+
18	Continuity and porosity ^g – Low voltage test	8289	-	+	+	-
19	Continuity and porosity ^g – High voltage test	2746	-	-	-	-
20	Resistance to thermal shock	2747	-	-	-	-
21	Resistance to thermal shock	c, h	-	-	-	-
22	Resistance to heat	4530	-	-	-	-
23	Resistance to impact	4532	+	+	+	+
24	Adhesion	c, i	+	+	+	+
25	Abrasion resistance	c	+	-	+	+
26	Subsurface abrasion resistance	6370-2	-	-	-	-

Table 1 (continued)

No.	Property	ISO test method	Number and description of enamelled article			
			21 Building panels, light reflectors, furniture for exterior use (outside)	22 Petrol pump panels	23 Exhaust pipe silencers and heat exchangers	24 Chemical apparatus and containers
Methods of assessing resistance to chemical attack in various solutions						
1	Cold citric acid	2722	+	+	+	-
2	Cold sulfuric acid	8290	-	-	+	-
3	Boiling citric acid	2742	+	-	-	-
4	Condensing hydrochloric acid vapour	2743	-	-	-	+
5	Hot sodium hydroxide	2745	-	-	-	+
6	Boiling water	2744	-	-	-	+
7	Water vapour	2744	-	-	-	+
8	Hot detergent	4533	-	-	-	-
9	Liquid cleaners	c	+	+	-	-
10	Weathering resistance	d	+	+	-	-
11	Special corrosive substances	c, e	-	-	+ ^l	+
12	Release of lead and cadmium	4531-1	-	-	-	-
Methods of assessing thickness and other properties						
13	Thickness	2178, 2360	+	+	+	+
14	Reflectivity and gloss	c	+	+	-	-
15	Waviness	c	+	+	-	-
16	Colour	c	+	+	-	-
17	Continuity and porosity ^g – Visual inspection		+	+	+	+
18	Continuity and porosity ^g – Low voltage test	8289	+	+	+	-
19	Continuity and porosity ^g – High voltage test	2746	+	-	-	+
20	Resistance to thermal shock	2747	-	-	-	-
21	Resistance to thermal shock	c, h	-	-	+	+
22	Resistance to heat	4530	-	-	+	-
23	Resistance to impact	4532	+	+	+	(+)
24	Adhesion	c, i	+	+	+	+
25	Abrasion resistance	c	+	+	+	-
26	Subsurface abrasion resistance	6370-2	-	-	-	(+)

Table 1 (continued)

No.	Property	ISO test method	Number and description of enamelled article			
			25 Storage and reaction food vessels	26 Tanks for industrial/municipal treatment liquids	27 Silos for general industrial dry bulk storage	28 Agricultural slurry tanks
Methods of assessing resistance to chemical attack in various solutions						
1	Cold citric acid	2722	+	+	+	+
2	Cold sulfuric acid	8290	-	+	-	-
3	Boiling citric acid	2742	+	+	+	+
4	Condensing hydrochloric acid vapour	2743	+ ^m	+	-	-
5	Hot sodium hydroxide	2745	+ ^m	+	+	+
6	Boiling water	2744	+	+	+	+
7	Water vapour	2744	+	+	+	+
8	Hot detergent	4533	-	+	-	-
9	Liquid cleaners	c	+	-	-	-
10	Weathering resistance	d	-	-	-	-
11	Special corrosive substances	c, e	-	-	-	-
12	Release of lead and cadmium	4531-1	+	-	-	-
Methods of assessing thickness and other properties						
13	Thickness	2178, 2360	+	+	+	+
14	Reflectivity and gloss	c	-	-	-	-
15	Waviness	c	-	-	-	-
16	Colour	c	+	+	+	+
17	Continuity and porosity ^g – Visual inspection		+	+	+	+
18	Continuity and porosity ^g – Low voltage test	8289	-	-	+	+
19	Continuity and porosity ^g – High voltage test	2746	+ ^m	+	-	-
20	Resistance to thermal shock	2747	-	-	+	-
21	Resistance to thermal shock	c, h	+	+	-	-
22	Resistance to heat	4530	-	+	+	-
23	Resistance to impact	4532	(+)	+	+	+
24	Adhesion	c, i	+	+	+	+
25	Abrasion resistance	c	-	-	+	-
26	Subsurface abrasion resistance	6370-2	(+)	-	-	-
27	Scratch hardness	c	-	+	+	+

Table 1 (continued)

No.	Property	ISO test method	Number and description of enamelled article	
			29 Chalk boards	30 White boards
Methods of assessing resistance to chemical attack in various solutions				
1	Cold citric acid	2722	-	+
2	Cold sulfuric acid	8290	-	+
3	Boiling citric acid	2742	-	-
4	Condensing hydrochloric acid vapour	2743	-	-
5	Hot sodium hydroxide	2745	-	-
6	Boiling water	2744	-	-
7	Water vapour	2744	-	-
8	Hot detergent	4533	-	-
9	Liquid cleaners	c	-	-
10	Weathering resistance	d	-	-
11	Special corrosive substances	c, e	-	-
12	Release of lead and cadmium	4531-1	-	-
Methods of assessing thickness and other properties				
13	Thickness	2178, 2360	+	+
14	Reflectivity and gloss	c	+	+
15	Waviness	c	+	+
16	Colour	c	+	+
17	Continuity and porosity ^g – Visual inspection		+	+
18	Continuity and porosity ^g – Low voltage test	8289	-	-
19	Continuity and porosity ^g – High voltage test	2746	-	-
20	Resistance to thermal shock	2747	-	-
21	Resistance to thermal shock	c, h	-	-
22	Resistance to heat	4530	-	-
23	Resistance to impact	4532	+	+
24	Adhesion	c, i	+	+
25	Abrasion resistance	c	+	+
26	Subsurface abrasion resistance	6370-2	-	-

- a For self-cleaning finishes, other test criteria are relevant.
- b Only valid for enamelled articles in contact with exhaust gases.
- c An International Standard has not yet been completed. When a standard test method is published, its applicability to all the enamelled articles listed in the table must be determined.
- d The test results obtained with ISO 2722 can be used to assess the weathering resistance of enamelled articles.
- e A + symbol is entered on this line if the article shall satisfy corrosion resistance requirements and if other corrosion tests are not indicated (except for the test method for resistance to liquid cleaners).
- f Only valid for accessories that come in contact with food.
- g The continuity shall be tested by at least one of the three methods.
- h A + symbol is entered on this line if the article shall satisfy thermal shock resistance requirements. A standard test method to measure this property is in preparation.
- i A method of testing the adhesion of enamel to steel is described in annex D of European Standard EN 10209:1996.
- j Only valid for the *inside* of the lid.
- k With the aid of a colouring substance, e.g. eosin.
- l The corrosive solution shall be boiling 30 % (V/V) sulfuric acid in the testing apparatus in accordance with ISO 2733.
- m Only valid for reaction vessels for service under highly corrosive conditions.

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