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Anodized aluminium and aluminium alloys — Measurement of specular reflectance and specular gloss at angles of 20°, 45°, 60° or 85°

Aluminium et alliages d'aluminium anodisés — Mesurage des caractéristiques de réflectance et de brillant spéculaires à angle fixe de 20°, 45°, 60° *ou* 85°

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Foreword

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Anodized aluminium and aluminium alloys — Measurement of specular reflectance and specular gloss at angles of 20°, 45°, 60° and 85°

0 Introduction

Specular reflectance, like specular gloss, is not a unique physical property of a surface. It varies with the angle of measurement and with the aperture dimensions that define the incident and the specular beams, so that the measurement is not independent of the apparatus being used.

The specular reflectance of most surfaces increases with the angle of measurement and accounts for the use of reflectometers with various angles as, for example, in ISO 2813 for painted surfaces. The specular reflectance characteristics of anodized aluminium, however, do not always behave in the normal manner, because of its property of double reflection, the reflected light coming partly from the film surface and partly from the underlying metal. It is advisable to measure the specular reflectance characteristics at all angles to obtain a complete understanding of the specular reflectance properties of the anodized surface, and careful thought should be given to which method or methods are most relevant in any particular situation. The narrow-angle geometry of method E, for example, is intended for bright-anodized aluminium with a mirror finish.

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1 Scope and field of application

This International Standard specifies methods for the measurement of specular reflectance and specular gloss of flat samples of aluminium or anodized aluminium and its alloys using geometries of 20° (method A), 45° (method B), 60° (method C) and 85° (method D), and of specular reflectance by an additional 45° (method E) employing a narrow acceptance angle.

These methods are intended mainly for use with clear anodized surfaces. They can be used with colour-anodized aluminium, but then only for similar colours.

2 Definitions

2.1 specular reflectance: The ratio of the luminous flux reflected in the specular direction for a specified source and receptor angle to the luminous flux of the incident light.

The result is normally expressed as a percentage.

2.2 specular gloss: The ratio of the luminous flux reflected from an object in the specular direction for a specified source and receptor angle to the luminous flux reflected from glass with a refractive index of 1,567 in the specular direction. To set the specular gloss scale, polished black glass with a refractive index of 1,567 is assigned the value of 100 for geometries of 20°, 45°, 60° and 85°.

NOTE — The phenomenon of light reflection by anodized aluminium is very different to that of black glass and the choice of a black glass standard is arbitrary and made to allow comparison of different qualities of anodized aluminium.

3 Principle

The specular reflectance and specular gloss of anodically oxidized coated surfaces are measured under defined conditions using, as required, geometries of 20°, 45°, 60° or 85°.

4 Apparatus

4.1 Components

The apparatus shall consist of a light source and housing with a lens that directs a parallel, or very slightly converging, beam of light on to the surface under test, means for locating the specimen surface in the correct position for measurement, and a receptor housing containing a lens, a receptor aperture and a photoelectric cell to receive the cone of reflected light.

NOTE — Since specular reflection is in general spectrally non-selective, the spectral characteristics of the light source and the detector need not be critically controlled for the measurement of normal uncoloured anodized surfaces.

Approximate comparisons between surfaces of the same colour may be made, but a proper measurement requires the combination of light source, photoelectric cell and associated colour filters to give a spectral sensitivity approximating to the CIE photopic luminous efficiency function, weighted for CIE standard illuminants C or D_{65}.

4.2 Geometric conditions

The incident angle ε_1, which is the angle between the axis of the incident beam and the perpendicular to the surface under test, shall have the following tolerance:

for method A: 20° ± 0,5°

for method B: 45° ± 0,2°

for method C: 60° ± 0,2°

for method D: 85° ± 0,1°

for method E: 45° ± 0,1°

The axis of the receptor shall, as far as possible, coincide with the mirror image of the axis of the incident beam; the receptor angle ε_2, which is the angle between the axis of the receptor and the perpendicular to the surface under test, shall for all methods be such that

$$|\varepsilon_1 - \varepsilon_2| < 0{,}1°$$

With a flat piece of polished black glass or other front-surface mirror in the test panel position, an image of the source shall be formed at the centre of the receptor aperture. The width of the illuminated area of the test panel shall be not less than 10 mm.

The angular dimensions of the receptor field apertures shall be measured from the receptor lenses. The dimensions and tolerances of the sources and receptors shall be as indicated in tables 1 and 2. Figures 1, 2 and 3 give generalized illustrations of the dimensions. Table 1 gives both angles and corresponding dimensions calculated for lenses of a focal length of 50 mm for methods A, B, C and D. Table 2 gives the angles and aperture dimensions for method E. The angles are mandatory and the aperture sizes have been calculated from the corresponding angle δ as $(2f \times \tan \delta/2)$, where f is the focal length of the receptor lens.

4.3 Vignetting

There shall be no vignetting of rays that lie within the field angles specified in 3.2.

4.4 Receptor meter

The receptor measuring device shall be capable of giving an indication proportional to the light flux passing the receptor aperture within 1 % of the full-scale reading. Spectral corrections are not usually required (see the note to 4.1).

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Table 1 — Angles and dimensions of source image and receptor apertures for methods A, B, C and D

Method(s)		In plane of measurement		Perpendicular to plane of measurement	
		Angle δ_1 (degrees)	Dimension[1] (mm)	Angle δ_2 (degrees)	Dimension[1] (mm)
A, B, C and D	Source image size Tolerance (±)	0,75 ($\delta_{1\alpha}$) 0,25	0,65 0,22	2,5[2] ($\delta_{2\alpha}$) 0,5	2,18[2] 0,44
A	20° Receptor aperture Tolerance (±)	1,80 ($\delta_{1\beta}$) 0,05	1,57 0,04	3,6 ($\delta_{2\beta}$) 0,1	3,14 0,09
B	45° Receptor aperture Tolerance (±)	4,4 ($\delta_{1\beta}$) 0,1	3,84 0,09	11,7 ($\delta_{2\beta}$) 0,2	10,25 0,17
C	60° Receptor aperture Tolerance (±)	4,4 ($\delta_{1\beta}$) 0,1	3,84 0,09	11,7 ($\delta_{2\beta}$) 0,2	10,25 0,17
D	85° Receptor aperture Tolerance (±)	4,0 ($\delta_{1\beta}$) 0,3	3,49 0,26	6,0 ($\delta_{2\beta}$) 0,3	5,24 0,26

1) Calculated for a focal length of 50 mm. For any other focal length f these dimensions shall be multiplied by $f/50$.

2) 0,75° ± 0,25° corresponding to dimensions of 0,65 ± 0,22 mm, that is the same as those in the plane of measurement, is also recommended.

Table 2 — Angles and dimensions of source image and receptor aperture for 45° reflectometer of method E[1]

	Angle δ (degrees)	Dimension[2] (mm)
Source image size Tolerance (±)	3,44 0,23	1,5 0,1
45° Receptor aperture Tolerance (±)	3,44 0,23	1,5 0,1

1) Both source and receptor apertures are circular.

2) Calculated for a focal length of 25,4 mm. For any other focal length f, the aperture diameter $= 2f \times \tan \delta/2$.

5 Standards

5.1 Reference standards

5.1.1 Black glass

The primary reference standard shall be either highly polished black glass (refractive index 1,567) or clear glass with back and edges roughened and coated with black paint, the top surface being plane to within two fringes per centimetre as measured by optical interference methods. Information on the effect of refractive index on specular reflectance and specular gloss values is given in the annex.

The glass surface shall be kept in a clean condition and free from surface scratches or damage.

5.1.2 Glass prism (for method E only)

An alternative reference standard, recommended for method E and suitable only for 45° reflectometers, is provided by the hypotenuse face of a right-angled glass prism having dimensions of 25 mm × 25 mm × 35,3 mm and optically worked faces. This uses the principle of total internal reflection for angles greater than the critical angle, but there are losses on entering the prism faces. These can also be calculated from Fresnel's equation (see clause A.1 in the annex) to give the absolute specular reflectance values given in table 3.

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Table 3 — Specular reflectance values for glass prism

Refractive index	Specular reflectance for 45° angle (%)
1,500	92,16
1,523	91,59
1,567	90,48
1,600	89,63

The glass shall be in a perfectly clean condition, maintained free from grease and scratches and with the hypotenuse face accurately located in the correct plane.

5.2 Working standards

5.2.1 Description

Working standards shall comprise anodized aluminium surfaces of uniform appearance and good planarity which have been calibrated against a primary standard (4.1) for an indicated area and direction of illumination, which shall be clearly marked on the standard. Working standards shall be checked periodically by comparison with primary standards. The working standards shall be uniform and stable, and shall be calibrated by technically competent organizations. At least two standards, of different specular reflectance or specular gloss levels, shall be available for each geometry.

5.2.2 Zero point check

A black box or velvet shall be used for checking the zero point of the display.

6 Preparation and calibration of apparatus

6.1 Preparation of apparatus

Calibrate the apparatus at the start of every period of operation and during operation at intervals sufficiently frequent to ensure that the instrument response is essentially constant. The apparatus shall have a sensitivity control for setting the photocell current to any desired value on the instrument scale or digital indicator.

6.2 Calibration of apparatus

Using a primary reference standard, or the higher of two working standards, adjust the instrument reading to the correct or selected value in the upper part of the scale. If a black glass standard is used, the instrument shall indicate the relevant specular reflectance as indicated in table 4 for the specular reflectance measurement, or the relevant specular gloss as indicated in table 5 for the for the specular gloss measurement. If a glass prism is used for method E, set it to the correct value as indicated in table 3.

Next take a secondary working standard of known specular reflectance or specular gloss for the angle being used, but having a value in the lower half of the scale, and make a measurement with the same control settings.

For the specular reflectance measurement, if the reading for the secondary working standard is within 1 scale division of its assigned value the proportionality requirement of 3.4 is complied with. For the specular gloss measurement, if the reading for the secondary working standard in method A, B and C is within 1 gloss unit of its assigned value, the proportionality requirement of 4.4 is complied with. For method D, that for the secondary working standard with a 60° gloss lower than 10 gloss units shall be within 1 gloss unit of its assigned value, but that for the secondary working standard with a 60° gloss higher than 10 gloss units may be within 2 gloss units of its assigned value.

If this is not the case, the instrument shall be adjusted by the manufacturer, or in accordance with the manufacturer's instructions, and the calibration procedure repeated until the second standard can be measured with the required accuracy.

NOTE — It is assumed that the standards have not altered in any way or deteriorated by damage or distortion. The most common cause of incorrect results is lack of flatness, dirt or failure to locate the surface in the correct plane for measurement.

7 Measurement of specular reflectance and specular gloss

7.1 General

The specular reflectance and specular gloss of the test sample are measured by placing a sample in firm contact with the instrument so that the plane of incidence and reflection is parallel to the direction of rolling or machining. In special cases, measuring can be carried out in a plane normal to this direction if the anisotropy of the surface under examination is to be assessed.

7.2 Measurement of specular reflectance

NOTE — Specular reflectance values which are encountered in practice can cover a very wide range from 90 % to less than 0,1 % and only in the case of bright finishes or with the 85° method is it practicable to obtain a direct reading of specular reflectance.

For surfaces of low specular reflectance, set the primary black glass reference standard to read 10 times the relevant specular reflectance in table 3, and multiply each reading by 1/10.

For surfaces with a high specular reflectance, use one of the following procedures:

a) Using a black-glass standard set the apparatus to the relevant specular reflectance in table 4.

b) Use a glass prism standard (applicable only to method E) and set the reflectometer to indicate the appropriate value indicated in or derived from table 3.

7.3 Measurement of specular gloss

Using a black glass standard, set the apparatus to the relevant specular gloss of table 5.

For surfaces with a high specular gloss in excess of 100, set the black glass at an arbitrary selected value of 1/2, 1/5 or 1/10 of the specular gloss in table 5 and multiply each reading by the corresponding factor (2, 5 or 10 respectively).

8 Calculation of results

8.1 Specular reflectance

If the instrument is set to the relevant specular reflectance of the black glass, then the direct reading is the specular reflectance of the sample under test. If it is set to ten times this value, then the reading shall be multiplied by 1/10.

8.2 Specular gloss

If the instrument is set to the relevant specular gloss value of a polished black glass, then the reading is the specular gloss of the sample under test. If it is set to 1/2, 1/5 or 1/10 of the relevant specular gloss, then the reading shall be multiplied by 2, 5 or 10 respectively.

9 Test report

The test report shall contain at least the following information:

a) identification of the surface tested;

b) reference to this International Standard, which methods are used and whether the specular reflectance or the specular gloss is measured;

c) the test result, expressed as the mean specular reflectance or specular gloss, and, where appropriate, the number, the mean, and the extremes of replicate measurements. Where more than one direction of measurement has been used, it shall be stated;

d) any deviation by agreement or otherwise from the procedure specified;

e) the date of the test.

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Annex

Specular reflectance and specular gloss of black glass

(This annex forms an integral part of the Standard.)

A.1 Specular reflectance

The specular reflectance of the black glass expressed as a percentage is given by Fresnel's equation:

$$\text{Specular reflectance, \%} = \frac{1}{2}\left\{\frac{\sin^2 (i-r)}{\sin^2 (i+r)} + \frac{\tan^2 (i-r)}{\tan^2 (i+r)}\right\} \times 100$$

where

$n \sin r = \sin i$;

n is the refractive index measured using the D line of sodium light;

i is the angle of incidence.

Table 4 gives the calculated specular reflectance values for glass of various refractive indices for each of the measurement angles employed.

The preferred glass has a refractive index of 1,567, but glass with a refractive index of 1,523 has also been used frequently.

A.2 Specular gloss

The specular gloss of the black glass also depends on its refractive index n and glass of refractive index n = 1,567 shall be assigned a specular gloss value of 100 units. If glass of this refractive index is not available, other material of known refractive index n may be used, the specular gloss being raised or lowered according to the equation.

$$\text{Specular gloss} = 100 - k\,(1{,}567 - n)$$

where

k = 270 for method A (20°);

k = 260 for method B (45°);

k = 160 for method C (60°);

k = 14 for method D (85°).

(For example: the specular gloss of black glass having n = 1,523 becomes 88,1 at 20°; 89,4 at 45°; 93,0 at 60°; and 99,4 at 85°.)

Table 5 gives the calculated specular gloss values for glass of various refractive indices for each of the measurement angles employed.

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Table 4 — Specular reflectance values for polished black glass

Refractive index *n*	Angle of incidence			
	20°	45°	60°	85°
1,400	2,800	3,658	7,200	59,832
1,410	2,917	3,791	7,376	60,012
1,420	3,035	3,925	7,552	60,183
1,430	3,155	4,060	7,728	60,345
1,440	3,276	4,196	7,901	60,499
1,450	3,398	4,332	8,074	60,646
1,460	3,522	4,469	8,245	60,786
1,470	3,646	4,607	8,416	60,919
1,480	3,772	4,746	8,584	61,045
1,490	3,899	4,884	8,752	61,166
1,500	4,027	5,024	8,919	61,280
1,510	4,156	5,164	9,084	61,389
1,520	4,285	5,305	9,248	61,492
1,530	4,416	5,446	9,411	61,591
1,540	4,548	5,587	9,573	61,684
1,550	4,681	5,729	9,734	61,773
1,560	4,814	5,871	9,894	61,858
1,567 *	4,908 *	5,971 *	10,006 *	61,914 *
1,570	4,948	6,014	10,053	61,938
1,580	5,083	6,157	10,211	62,015
1,581	5,102	6,177	10,233	62,025
1,590	5,219	6,299	10,368	62,087
1,600	5,355	6,443	10,524	62,156
1,610	5,493	6,587	10,679	62,221
1,617	5,592	6,691	10,800	62,266
1,620	5,630	6,731	10,833	62,283
1,630	5,769	6,876	10,986	62,342
1,640	5,908	7,020	11,138	62,397
1,648	6,015	7,132	11,255	62,438
1,650	6,048	7,165	11,289	62,449
1,660	6,188	7,310	11,440	62,499
1,670	6,329	7,455	11,590	62,545
1,680	6,470	7,601	11,738	62,589
1,690	6,611	7,746	11,886	62,631
1,700	6,754	7,892	12,034	62,697
1,710	6,896	8,038	12,180	62,706
1,720	7,039	8,183	12,325	62,740
1,730	7,183	8,329	12,470	62,772
1,740	7,327	8,475	12,614	62,802
1,750	7,471	8,621	12,758	62,830
1,760	7,615	8,767	12,901	62,856
1,770	7,760	8,914	13,043	62,879
1,780	7,905	9,060	13,184	62,901
1,790	8,051	9,206	13,324	62,921
1,800	8,197	9,352	13,346	62,940

* Standard reference sample.

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Table 5 — Specular gloss values for polished black glass

Refractive index *n*	Angle of incidence			
	20°	45°	60°	85°
1,400	57,0	61,3	71,9	96,6
1,410	59,4	63,5	73,7	96,9
1,420	61,8	65,7	75,5	97,2
1,430	64,3	68,0	77,2	97,5
1,440	66,7	70,3	79,0	97,6
1,450	69,2	72,6	80,7	98,0
1,460	71,8	74,9	82,4	98,2
1,470	74,3	77,2	84,1	98,4
1,480	76,9	79,5	85,8	98,6
1,490	79,4	81,8	87,5	98,8
1,500	82,0	84,1	89,1	99,0
1,510	84,7	86,5	90,8	99,2
1,520	87,3	88,8	92,4	99,3
1,530	90,0	91,2	94,1	99,5
1,540	92,7	93,6	95,7	99,6
1,550	95,4	95,9	97,3	99,8
1,560	98,1	98,3	98,9	99,9
1,567 *	100,0 *	100,0 *	100,0 *	100,0 *
1,570	100,8	100,7	100,5	100,0
1,580	103,6	103,1	102,1	100,2
1,590	106,3	105,5	103,6	100,3
1,600	109,1	107,9	105,2	100,4
1,610	111,9	110,3	106,7	100,5
1,620	114,3	112,7	108,4	100,6
1,630	117,5	115,2	109,8	100,7
1,640	120,4	117,6	111,3	100,8
1,650	123,2	120,0	112,8	100,9
1,660	126,1	122,4	114,3	100,9
1,670	129,0	124,9	115,8	101,0
1,680	131,8	127,3	117,3	101,1
1,690	134,7	129,7	118,8	101,2
1,700	137,6	132,2	120,3	101,2
1,710	140,5	134,6	121,7	101,3
1,720	143,4	137,1	123,2	101,3
1,730	146,4	139,5	124,6	101,4
1,740	149,3	141,9	126,1	101,4
1,750	152,2	144,4	127,5	101,5
1,760	155,2	146,8	128,9	101,5
1,770	158,1	149,3	130,4	101,6
1,780	161,1	151,7	131,8	101,6
1,790	164,0	154,2	133,2	101,6
1,800	167,0	156,6	134,6	101,7

* Standard reference sample.

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