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A REVIEW OF PUBLICATIONS ON PROPERTIES AND REFLECTION VALUES OF MATERIAL REFLECTION STANDARDS

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A REVIEW OF PUBLICATIONS ON PROPERTIES ANDREFLECTION VALUES OF MATERIAL REFLECTION STANDARDSPreface

This report has been prepared by the CIE Technical Committee on Materials (TC-2.3) and is the work of the Subcommittee on Standards and Techniques under chairmanship of W. Erb of PTB. This project was initiated several years ago in the Subcommittee on Reflectance with CIE TC-1.2 (Photometry).

The Subcommittee has prepared several drafts of this report and the final one has been distributed and discussed at the CIE, TC-2.3 meeting in Troy, New York, on July 9, 1977. It was decided at that meeting that a CIE Technical Report on this work be issued.

Although most of the work presented in this report has been carried out through the TC-2.3 Subcommittee on Standards and Techniques, the list of all members who have been on the Committee's roster during the period (1975-1979) are given below.

The bulk of the work in compiling these data has been done by the Subcommittee's chairman, W. Erb, in cooperation with the members of his Subcommittee. Their names are listed separately as consultants.

This report is intended for general use and does not contain any officially agreed upon CIE recommendations.

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A REVIEW OF PUBLICATIONS ON PROPERTIES AND
REFLECTION VALUES OF MATERIAL REFLECTION STANDARDS

Summary

It has long been recognized that in order to provide better uniformity and consistency of measurements in the fields of radiometry, photometry and colorimetry, more accurate and reproducible standards are needed. Commercial instruments for reflectance measurements are not capable of measuring reflectance or other reflectance quantities directly, but can only compare the reflectance of a sample with that of the reference standard. For this reason, the properties and reflectance values of the latter are of great practical importance.

For a long time, smoked magnesium oxide was used as recommended by the CIE as the reference standard. A reflectance value of 100 % (or 1) was assigned to it for all wavelengths. There have, however, been many attempts to measure its absolute reflectance. Consideration of these investigations has led to the recommendation that the perfect reflecting diffuser be ultimately adopted as the primary standard in reflectometry. It is defined as the ideal uniform diffuser according to Lambert's law with a reflectance that equals unity and can therefore not be approximated by a material standard. That is, the realization of the primary standard of reflectance has to be replaced by standard physical methods of absolute reflectance measurements. A reflectance scale can then be transferred by secondary standards calibrated by these methods.

Such standards should first of all have some specific basic properties. This is essential for such standards if the results from the measurements are to be dependable, reproducible and accurate. It is, as experience shows, impossible to find one material for all kinds of application, that is for exchange purposes and for calibration of "relative" instruments.

This report contains information on the optical and physical properties of those reflectance materials that are now widely used as reference standards of reflectance. The optical and physical properties of these materials are of general interest and it is therefore fitting to compile these data in a CIE Technical Report.

REVUE DES PUBLICATIONS RELATIVES AUX PROPRIETES ET
AU FACTEUR DE REFLEXION DES ETALONS DE REFLEXION

Résumé

Il a été reconnu depuis longtemps qu'il était nécessaire de disposer d'étalons plus précis et plus reproductibles, afin d'améliorer l'homogénéité et la reproductibilité des mesures en radiométrie, en photométrie et en colorimétrie. Les instruments commerciaux destinés aux mesures du facteur de réflexion ne peuvent pas mesurer directement, ni le facteur de réflexion, ni d'autres grandeurs liées à la réflexion, mais peuvent seulement comparer ces grandeurs relatives à un échantillon avec celles d'un corps de référence. Pour cette raison, les propriétés et les valeurs du facteur de réflexion de ce dernier sont de la plus haute importance en pratique.

Pendant longtemps, la fumée d'oxyde de magnésium a été utilisée comme étalon de référence, ainsi que l'avait recommandé la CIE. Un facteur de réflexion de 100 % (soit 1) lui était assigné pour toutes les longueurs d'onde. Il y eut cependant un grand nombre de tentatives pour mesurer son facteur de réflexion absolu. La prise en considération de ces investigations conduisit à la recommandation d'adopter finalement le diffuseur parfait comme étalon primaire en réflectométrie. Il est défini comme le diffuseur uniforme idéal, selon la loi de Lambert, avec un facteur de réflexion qui égale l'unité et ne peut, de ce fait, être réalisé par aucun matériau de référence. Ce qui veut dire, que la réalisation d'un étalon primaire de réflexion doit laisser place à des méthodes physiques normalisées de mesures absolues par réflexion. Une échelle de facteurs de réflexion peut alors être transférée par des étalons secondaires, évalués à l'aide de ces méthodes.

De tels étalons doivent avoir, avant tout, un certain nombre de propriétés fondamentales. Ceci est essentiel pour de telles références si les résultats des mesures

doivent être fiables, reproductibles et précis. Ainsi que l'expérience le montre, il est impossible de trouver un matériau unique pour toutes les sortes d'applications, c'est à dire aussi bien pour les échanges que pour le calibrage des instruments "relatifs".

Ce document contient des informations sur les propriétés optiques et physiques des matériaux diffusants qui sont maintenant largement utilisés comme matériaux de référence en réflectométrie. Les propriétés optiques et physiques de ces matériaux sont d'intérêt général et il est de ce fait convenable de rassembler tous ces éléments dans un Rapport Technique CIE.

Übersicht über Veröffentlichungen die sich auf Eigenschaften und Reflexionswerte der Reflexionsnormalen beziehen

Zusammenfassung

Es besteht seit längerem Einvernehmen darüber, daß genauere und reproduzierbarere Normale notwendig sind, um eine größere Einheitlichkeit und Übereinstimmung der Meßergebnisse auf den Gebieten der Radiometrie, Photometrie und Farbmessung zu erreichen. Mit kommerziellen Geräten für Reflexionsmessungen können der Reflexionsgrad oder andere Reflexions-Kennzahlen einer Probe nicht direkt, sondern nur relativ zu einem Bezugsnormal bestimmt werden. Deshalb haben die Eigenschaften und Reflexionswerte dieser Normale eine große praktische Bedeutung.

Über viele Jahre war von der CIE aufgerauchtes Magnesiumoxid als Bezugsnormal empfohlen worden. Ihm wurde der wellenlängen-unabhängige Reflexionsgrad 100 % (oder 1) zugeordnet. Es gibt jedoch eine Reihe von Arbeiten, die sich mit der Messung von Absolutwerten dieses Materials beschäftigen. Die Ergebnisse dieser Untersuchungen führten schließlich dazu, für die Reflektometrie den vollkommen mattweißen Körper als Primärnormal zu empfehlen. Er ist dadurch definiert, daß er die auftreffende Strahlung entsprechend dem Lambertschen Kosinusgesetz vollkommen diffus und außerdem vollständig reflektiert, d.h. den Reflexionsgrad 1 hat. Da es kein Material mit diesen Eigenschaften gibt, kann der vollkommen mattweiße Körper nicht materiell, sondern nur durch (absolute) physikalische Reflexionsmeßmethoden realisiert werden. Eine Reflexions-Skala wird dann durch Sekundärnormale weitergegeben, die mit diesen Methoden kalibriert worden sind.

Solche Sekundärnormale sollen vor allem einige spezielle Grundeigenschaften besitzen, um zuverlässige, reproduzierbare und richtige Meßergebnisse zu ermöglichen. Die Erfahrung hat gezeigt, daß es kein für alle Anwendungsfälle (Vergleichs-

messungen, Kalibrierung der verschiedensten Relativmeßgeräte) gleich gut geeignetes Material gibt.

Dieser Bericht informiert über die optischen und physikalischen Eigenschaften der Materialien, die heute weithin als Reflexionsnormale eingesetzt werden. Die optischen und physikalischen Eigenschaften dieser Materialien sind von allgemeinem Interesse, so daß es gerechtfertigt scheint, die vorliegenden Daten in einem Technischen Bericht der CIE zusammenzustellen.

INTRODUCTION

This report summarizes properties and reflection values of

- smoked magnesium oxide (A)
- pressed powder of magnesium oxide (B)
- pressed powder of barium sulfate (C)
- glasses, tiles and plastics. (D)

Each of the parts (A)....(D) is in itself closed and arranged according to the scheme:

properties - reflection values - references.

In writing this report it was tried to quote literally if possible. However, in doing this consequently the report would become too extensive. Therefore a condensed review had to be selected. The reflection values given in this summary originate only from tables of the references. Papers giving data as curves could not be taken into account. because the uncertainties of interpolation are too high.

For the selection of material as a (secondary) reflection standard, the most important properties to be considered are:

1. Transportable and with a mechanically robust surface:
it must be possible to place exactly that standard at the user's disposal for which the reflection values are evaluated by absolute measurements (i.e., relative to the perfect reflecting diffuser as primary standard of reflectance). The surface should not be brittle and should resist scratching, mechanical wear and handling over a period of years of use. Cleaning must therefore be possible.
2. Stable against usual ambient conditions met in practice including a recommended method of cleaning.
3. Uniform, flat surface.
4. Easy to clean.

5. Opaque:
 - a) No interference with the background of the sample
 - b) no edge-losses, i.e., the lateral diffusion of radiation within the sample should be small.
6. Capable of being prepared with a mat or polished surface
 - a) sample with a mat finish should approximate the uniform diffuser
 - b) sample with a polished finish should approximate the uniform diffuser except at angles near regular reflection.
7. Spectral selectivity very small especially in the visible and near ultraviolet spectral region.
8. No luminescence excited by wavelengths greater than 300 nm.
9. Absolute and spectral reflection properties independent of incident radiation, temperature and humidity.

All these criteria are important in one way or another. However, in each specific case one has to decide which criteria are the more important and which are less so. All the criteria cannot be fulfilled simultaneously and tend to be mutually incompatible. The best compromise will depend on the application to some extent. Each of the above mentioned properties must be understood to be "as far as possible and necessary".

DEFINITIONS & SYMBOLS

The definitions and symbols of the reflection quantities are taken from the International Lighting Vocabulary, 3rd Edition (1970). The numbers used in the Vocabulary are given in parentheses.

Reflectance; reflection factor (45-20-040)

Ratio of the reflected radiant or luminous flux to the incident flux.

symbol: ρ

Radiance [luminance] factor (45-20-200)

(at a point on the surface of a non-self radiating body, in a given direction, under specified conditions of irradiation [illumination]) Ratio of the radiance [luminance] of the body to that of the perfect reflecting diffuser identically irradiated [illuminated].

symbol: β

Reflectance factor (45-20-201)

(at a point of a surface, for the part of the reflected radiation contained in a given cone with apex at the point of the surface, and for incident radiation of given spectral composition and geometrical distribution)

Ratio of the radiant [luminous] flux reflected in the directions delimited by the cone to that reflected in the same directions by the perfect reflecting diffuser identically irradiated [illuminated].

symbol: R (according to the CIE TC-2.3 publication
"Radiometric and Photometric Characteristics

of Materials and Their Measurement"; Publication
CIE Nr. 38 (TC-2.3) 1977)

Note: If the solid angle of the cone approaches zero or 2π sr, the reflectance factor approaches radiance [luminance] factor, or reflectance, respectively.

When the three quantities defined above are considered for monochromatic radiation, they are designated by writing the name of the quantity preceded by the adjective "spectral", and by writing its symbol followed by λ in parentheses (e.g., $\beta(\lambda)$). These quantities are functions of wavelength λ .

In this report the angles of irradiation [illumination] and viewing are denoted by two subscripts, separated by a slash (e.g., 45/0). The first subscript indicates the angle between the direction of irradiation [illumination] and the normal to the surface. The second subscript indicates the angle between the direction of viewing and the normal to the surface. It is assumed that the directions of irradiation [illumination] and viewing, and the normal to the surface all lie in one plane.

The symbol d is used as a subscript to indicate hemispherical irradiation [illumination] or viewing by means of an integrating sphere.

A. SMOKED MAGNESIUM OXIDE

I. Properties

ref. _____ review _____

- A 2 Coatings of smoked MgO obtained on polished copper have a higher reflection factor than those obtained on two coats of a hard mat white enamel. Efforts to increase the thickness of the oxide coating by prolonged smoking showed that there is still room for considerable error due to unevenness in the coating. Coatings on silver-plated copper were easily reproducible provided that a thickness of roughly 0.3 mm at least was aimed at.

From the measurements it is seen that with a normally incident beam the smoked MgO layer is equivalent to the perfect reflecting diffuser when the angle of view is 45°.

- A 4 A possible hypothesis to account for the alleged yellowness of smoked MgO is the assumption that a small amount of magnesium nitride might be deposited with the oxide. The nitride is notably yellow. It is formed when magnesium is burned in air with insufficient draft to supply an adequate amount of oxygen.

- A 5 It is shown by a graph that smoked MgO has a reflectance ($\rho_{5/d}$) greater than 0.95 for the wavelengths region $290 \text{ nm} < \lambda < 450 \text{ nm}$.

- A 6,7 The reflectance of MgO is independent of its hygroscopic content. Any variations that occur may be due to variations in the manufacturing process. MgO is a good reflector also in the region 240 nm to 400 nm.

A. SMOKED MAGNESIUM OXIDE

<u>ref.</u>	<u>review</u>
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A 8 The best manner of coating a surface with MgO has been the subject of some controversy but all agree that a polished metal surface is to be preferred and that it should be carefully cleaned before coating. The surfaces used by the authors were of polished silver, plated on brass and were cleaned with a water soluble detergent and finally rinsed with methanol. The following ways of coating were used:

- i) short lengths (about 10 cm) of magnesium ribbon were burned about 15 cm below the surface. The operation was performed in a laboratory fume cabinet with the exhaust adjusted to the lowest air-speed necessary to keep the room free of smoke.

- ii) (this method was practised at the National Bureau of Standards, Washington: Nat. Bur. Standards (U.S.) Letter Circ. LC 547 (March 17, 1939)) magnesium turnings are burned in a zirconium silicate dish, being raked into a "clinker" before the smoke is allowed to impinge on the surface to be coated.

There seems to be little difference between surfaces produced by the two methods.

Ageing effects: the reflectance decreases with time

Effect of ultraviolet irradiation: strong ultraviolet radiation might be acting in such a way as to bleach the coating. It is most likely that the bleaching is due to the decomposition of magnesium nitride which is also formed in small amounts by burning magnesium in air.

A. SMOKED MAGNESIUM OXIDE

ref.	review
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- A 11 To avoid ageing effects, it would seem necessary to protect coatings from the action of carbon dioxide ("unpublished work at NPL indicates the formation of some 5 % of carbonate in coatings exposed to saturated CO₂ for 24 hours.") and of ultra-violet radiation and probably also of moisture.
- A 12 Reflectance measurements in the near infrared show absorption bands at 1400 nm, 1900 nm and 2350 nm. The relative amount of absorption in the first two bands agrees quite well with that calculated from data for water, but the experimental reflectance decreases rapidly beyond 2200 nm. It is known that brucite, Mg (OH), has absorption maxima at 1400 nm, 2140 nm, 2320 nm and 2460 nm in the wavelength range discussed. The band at 2140 nm is relatively weak, and its appearance in these measurements was not certain. The band found at 2350 nm corresponds satisfactorily with 2320 nm. Because of the lack of sensitivity the results at 2500 nm only suggest that there is strong absorption also. The decrease at 1400 nm and 1900 nm could be caused by an increase in the water held by the surface, but the decrease at 2200 nm is too large to be attributed to this. The overall decrease of reflectance is thought to be caused by the slow formation of brucite. It seems reasonable to assume that absorbed water will react with MgO.
- A 13 Uniform coatings from thicknesses of 0.2 mm and 8.0 mm were readily obtained on glasses by an electrostatic deposition method. The electrostatic field served a two fold purpose: it dispersed the column of smoke and deposited the particles on the glass. Very thick MgO layers were necessary to obtain the reflectance of this material.

A. SMOKED MAGNESIUM OXIDE

ref.	review
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- A 14 Scattering coefficients (from Kubelka's equations) computed for electrostatically prepared coatings (ref.A13) are as low as one-tenth that for the NBS method of preparation (NBS Letter Circular 547, 1939 and review of ref.A8). Electron micrographs of MgO smoke crystals show that a large range of crystal sizes is obtainable. Selective collection of these crystals will affect the scattering coefficient and thus the reflectance of the layer.
- A 15 Goniophotometric measurements of smoked MgO were made with polarized light. Repeated measurements showed that MgO is not stable with time, and that from different batches of Mg ribbon MgO layers with different properties were produced.
- A 16 It is supposed that the reflectance of smoked MgO could depend not only on impurities, but also on other parameters (e.g., on the grain size). If this can be verified by finding such a parameter, it follows that for very accurate photometric or spectrophotometric measurements the measurements must be made relative to reflection standards the reflectances of which are measured by an absolute method.
- A 17 The fact that it is difficult to reproduce MgO surfaces to give the same reflectance makes MgO a poor reference standard. Furthermore MgO surfaces are rather fragile and do not have a long time stability.
- A 18 MgO is deposited on polished silver disks by electrostatic precipitation from burning Mg ribbon. The disks are fitted into Al cylinders to form cups 2 mm deep. At intervals the beds of powder are compared with one another, and also separately with an opal glass. Further deposition is carried

A. SMOKED MAGNESIUM OXIDE

ref.	review
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(continued)

- A 18 out until the beds show equal reflectance and the relative reflectance of the opal glass shows a minimum value at every wavelength in the spectral range 0.3 μm -2.6 μm . The depth of bed required to attain these results lies between 1.7 mm and 2.0 mm. Such standards can be used in dust-free conditions for about 2 weeks before replacement is necessary. The method of preparation is highly reproducible. When such a bed is compacted under a pressure of 6900 kPa there is a marked loss of reflectance in the UV and near IR regions and the water absorption bands at 1.4 μm and 1.9 μm become noticeable.
- A 19 Chunks of Mg as large as 2.5 cm cubes instead of turnings were burned. MgO standards prepared in a nitrogen-free atmosphere frequently had higher reflectances than those prepared in air.
- A 21 Goniophotometric data of a smoked MgO coating (about 1 mm thick) at the wavelength of 507 nm are presented. Depending on the angle of incidence, MgO scatters predominantly in the forward direction. The measurements show that forward scattering increases with increasing angle of incidence. For an incident angle of 75° the radiance increased by 250 % between angles of reflection of 15° and 75°. These measurements agree well with the measurements of ref.A15.
- A 22 Differences in the spectral reflectance are believed to result from differences in particle size of the deposited particles (formed by burning magnesium ribbon) and in contamination from air.

A. SMOKED MAGNESIUM OXIDEref.review

- A 26 Polarization of the incident radiation affects the reflection properties. Smoked MgO (2 mm thick) does not obey the cosine law perfectly. The extent to which this material departs from the cosine law varies considerably with the linear polarization states of source and receiver. The forward scatter characteristic is stronger when the source is polarized perpendicular with respect to the incidence (and reflection) plane. The reflection from MgO does not completely depolarize plane-polarized incident radiation. That is, when the source used is polarized perpendicular with respect to the principal plane, it is found that the reflected radiation (in the principal plane) is not unpolarized but has a dominant vector also perpendicular to that plane. When smoked MgO is irradiated with an unpolarized source at 40° incidence angle and viewed at 0° , the received radiation is essentially unpolarized; in the backscatter region the percent polarization (for definition see equation (2) or ref.A26) will have slightly negative values and in the forward region they may reach + 10 %.
- A 27 A decrease of reflectance with time is almost entirely due to atmospheric moisture and progresses slowly after the first two weeks. Thick coatings of smoked MgO have a higher reflectance (than pressed MgO), are more stable with time, are more depolarizing, and more diffuse.
- A 28 In the 240-500 nm range, a great decrease of reflectance factor with time is observed. The MgO layer is fairly stable with respect to considerable temperature variations (77 to 293 K), does not crumble, provides a good quality coating, but is mechanically weak.

A. SMOKED MAGNESIUM OXIDE

<u>ref.</u>	<u>review</u>
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- A 29 The goniophotometric curve of freshly-smoked MgO deviates more than that of BaSO₄ from the Lambertian diffuser at all angles of incidence between 30° and 80°. At high angles of incidence (near grazing), MgO exhibits a "specular envelope" much like that seen with BaSO₄ but, at the same angle of incidence, more pronounced.

II Reflection Values

A. SMOKED MAGNESIUM OXIDE

ref. geometry	reflection spectral distribution of the incident radiation	thickness of the layer	notes
A 1	0/d 0.953 ± 0.005 quasi-monochromatic (Jenaer Farbglass F 4512); $\lambda_{eff}=647$ nm	0.2 mm ... 0.5 mm	angle distribution of the reflected radiation obeys the equation $r_\theta = 1 - 1.3 \sin^4 \theta/2$ instead of $r_\theta = 1$ for the perfect reflecting diffuser for all angles between the optical axis of the viewing beam and the normal to the surface
A 1	$\lambda_{eff} = 647$ nm	"	
	$\lambda_{eff} = 538$ nm	"	
A 2	white light (the authors proved that a specification of the colour temperature for the white light used is unnecessary within the usual limits corresponding to the vacuum and gas-filled types of lamp)	at least 0.3 nm (on a silver-plated copper disk)	
A 3	0/d 0.97	0.4 mm	
	0.984	0.6 mm	MgO containing 0.006 % iron
	0.987	>1 mm	
A 6	d/d 0.991	unknown (on magnesium carbonate)	
A 8	d/d 0.976	the layers were chosen so thick that no further increase in reflectance at 250 nm could be obtained (MgO on polished silver plated on brass)	an analysis of impurities of magnesium used is listed the (absolute) reflectance for white light seems generally to lie between 0.975 and 0.980

A. SMOKED MAGNESIUM OXIDE /Continued/

ref. geometry	d/a	reflection value	spectral distribution of the incident radiation	thickness of the layer	notes
A 9	d/a	mean value of $\beta_{d/a}(\lambda)$ (650nm < λ < 660nm)	100 W incandescent lamp	a few tenths of 1 mm (smoked on CaSO ₄)	the measurements are based on the assumption of the Helmholtz reciprocity law: $\beta_{d/a} = \rho_{a/d}$
		5° 0.958			
		40° 0.960			
		60° 0.964			
		80° 0.969			
A 10	0/45	1.01 ± 0.003	colour temperature of about 2853 K	1.1 mm (upon a silver-plated copper disc)	calculated β for the illuminants A and C: A: $\beta = 1.005$ C: $\beta = 1.005$
		λ nm $\beta(\lambda)$	400 420 440 460 480 550		
		1.015 1.008 1.007 1.007 1.007 1.006			
A 11	0/45	520 540 560 580 600 620		>1 mm (prepared on a silver-plated copper disc)	calculated ρ for the illuminants A and C: A: $\rho = 0.975$ C: $\rho = 0.974$
		1.005 1.005 1.005 1.005 1.005 1.005			
		640 660 680 700 720			
		1.007 1.007 1.010 1.010 1.011			
A 11	d/d	λ nm $\rho(\lambda)$	400 450 500 550 600 650	"	
		0.962 0.969 0.973 0.975 0.975 0.973			
		700 720			
		0.972 0.972			

A. SMOKED MAGNESIUM OXIDE (Continued)

ref.	geometry	reflection value	spectral distribution of the incident radiation	thickness of the layer	notes
A 13	d/d	0.9421	Illuminant A (computed from values of spectral reflectance)	1.0 mm	maximum expected error is ± 0.0014
		0.9830	"	6.0 mm	
		0.9893	"	8.0 mm	
				(electrostatically deposited on glass slides)	
A 17	d/d	0.979 + 0.001	Illuminant C	unknown	the reflection value for the d/d-geometry agrees very well with that for the 45/0-geometry
A 20	0/d	$\frac{\lambda \text{ nm}}{\rho(\lambda)}$ $\frac{420}{0.983}$ $\frac{460}{0.986}$ $\frac{490}{0.986}$ $\frac{530}{0.987}$ $\frac{570}{0.987}$ $\frac{620}{0.988}$ $\frac{680}{0.986}$		about 1 mm (on a substrate of Al)	the reflection values for the d/0 and 0/d-geometry agree well
					calculated ρ for illuminants A and C
					A: $\rho = 0.987$
					C: $\rho = 0.987$
A 23	d/d	$\frac{\lambda \text{ nm}}{\rho(\lambda)}$ $\frac{400}{0.9886}$ $\frac{430}{0.9916}$ $\frac{490}{0.9909}$ $\frac{550}{0.9892}$ $\frac{610}{0.9889}$		1 mm	average values computed from 20 measurements
		S $\frac{670}{0.0021}$ $\frac{720}{0.0014}$ $\frac{750}{0.0021}$			for definition of the estimated standard deviation S see ref.A23
					Ill. A: $\rho = 0.9892$
					Ill. C: $\rho = 0.9894$

A. SMOKED MAGNESIUM OXIDE (Continued)

ref.	geometry	reflection value	spectral distribution of the incident radiation							thickness of the layer	notes	
A 23	d/d	λ nm	730	750	800	850	900	1 mm			average values for 18 specimens	
continued		$\rho(\lambda)$	0.9871	0.9860	0.9832	0.9813	0.9802					
		S	0.0024	0.0027	0.0028	0.0032	0.0032					
			950	1000	1050	1080						
			0.9812	0.9798	0.9767	0.9758						
			0.0028	0.0033	0.0043	0.0043						
A 24	6/d	λ nm	400	410	420	430	440	450	460	470	1 mm	these data are based on 16 determinations of absolute reflectance of NBS Reference Vitrolite and 20 determinations of its reflectance relative to 1-mm thick specimens of smoked glass
		$\rho(\lambda)$	0.989	0.990	0.991	0.992	0.992	0.992	0.992	0.992		
			480	490	500	510	520	530	540	550		
			0.992	0.993	0.993	0.993	0.992	0.992	0.992	0.992		
			560	570	580	590	600	610	620	630		
			0.992	0.992	0.991	0.991	0.991	0.990	0.990	0.990		
			640	650	660	670	680	690	700	710		
			0.990	0.990	0.990	0.990	0.989	0.989	0.988	0.987		
			720	730	740	750						
			0.987	0.987	0.987	0.987						

these data are based on 16 determinations of absolute reflectance of a NBS Reference Vitrolite and 20 determinations of its reflectance relative to 1-mm thick specimens of smoked M

A. SMOKED MAGNESIUM OXIDE (Continued)

ref.	geometry	reflection value	spectral distribution of the incident radiation						thickness of the layer	notes
A	25	d/d	λ nm $\rho(\lambda)$	225	250	270	300	325	350	
				0.865	0.926	0.951	0.965	0.967	0.970	the reflection values are based on 15 preparations (fresh prepared)
			375	400	420	440	460	480		
			0.978	0.982	0.984	0.986	0.987	0.987	0.987	average values for the same samples aged 2 mo. are also given in ref.A25
			500	520	540	560	580	600		
			0.986	0.986	0.986	0.983	0.982	0.981		
			620	640	660	680	700	800		
			0.981	0.981	0.981	0.981	0.981	0.981	0.978	Ill. A: $\rho = 0.983$ Ill. C: $\rho = 0.984$
			900	1000	1100	1200	1300	1400		
			0.972	0.966	0.965	0.957	0.956	0.939		
			1500	1600	1700	1800	1900	2000		
			0.922	0.934	0.935	0.921	0.881	0.854		
			2100	2200	2300	2400	2500			
			0.870	0.861	0.847	0.814	0.773			

λ . SMOKED MAGNESIUM OXIDE (Continued)

ref.	geometry	reflection value	spectral distribution of the incident radiation						thickness of the layer	notes
λ 30	d/o	λ nm	400	450	500	550	600	650	about 1 mm (on pyrex glass)	
		$\beta(\lambda)$	0.98	0.985	0.985	0.985	0.985	0.985		
			700	800	900	1000	1100	1200		
			0.98	0.98	0.975	0.97	0.97	0.96		
			1300	1400	1500	1600	1700			
			0.96	0.945	0.955	0.95	0.94			Ill. A: $\beta = 0.985$ Ill. C: $\beta = 0.985$
			1800	1900	2000	2100	2200			
			0.94	0.93	0.925	0.925	0.92			
			2300	2400	2500					
			0.91	0.90	0.87					

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