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COMMISSION INTERNATIONALE DE L'ÉCLAIRAGE
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TECHNICAL REPORT

RETROREFLECTION DEFINITION AND MEASUREMENT

CIE 54 - 1982

CIE 54.1-1996 Revision 1

UDC: 353.312
353.346.1
353.39

Descriptor Reflection
Reflectivity

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Ce report a été préparé par le Comité Technique 2.3 Matériaux de la CIE. Il a été approuvé par la majorité du Comité Technique et il est recommandé pour étude et application. Ce rapport n'est pas une Recommandation officielle de la CIE, approuvée par les Comités Nationaux des Pays Membres de la CIE. Il doit être noté que toute recommandation y figurant est donnée à titre de conseil et non d'obligation. En ce qui concerne la situation présente de ce Rapport et d'éventuelles modifications, il faut consulter le plus récent Compte Rendu de Session ou Journal de la CIE.

Dieser Bericht wurde vom Technischen Komitee 2.3 Baustoffe der CIE ausgearbeitet. Er wurde durch die Mehrheit des Technischen Komitees gebilligt und wird zum Studium und zur Anwendung empfohlen. Dieser Bericht ist keine offiziell anerkannte CIE-Empfehlung, der die Nationalen Komitees der Mitgliedsländer der CIE zugestimmt haben. Es sei darauf hingewiesen, dass jede Empfehlung in diesem Bericht als Anleitung dient und nicht verbindlich ist. Was den gegenwärtigen Status dieses Berichtes und mögliche Nachfolge-Ausgaben angeht, ziehe man die neuesten CIE-Tagungsberichte oder das CIE Journal zu Rate.

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SUMMARY

In this report the following items have been considered in detail :

— Recommended terminology, including main definitions and units, which is needed for characterizing the specific effects of retroreflection.

— A new CIE angular reference system, including an appropriate goniometer for laboratory testing and conversion formulae for systems previously in use. This new system is well-known in Europe and has already been officially accepted in the United States and Canada.

— Photometry, including consideration of calibration techniques and the accuracy of measurement. It is pointed out that the apertures of the source and photometer head are important for a correct measurement and that the adjustment of the observation angle requires particular care, especially when narrow retroreflected beams are examined.

— Colorimetry, including advice for obtaining reliable measurement of colour, which may depend upon the geometric configuration of the observation conditions.

RÉSUMÉ

RETROREFLEXION

Les questions suivantes ont été prises en compte dans ce rapport :

— La terminologie recommandée, incluant les définitions principales et les unités, requise pour caractériser les effets propres à la rétroréflexion.

— Un nouveau système CIE de référence angulaire et la description d'un goniomètre approprié pour les essais en laboratoire. Sont jointes, les formules de conversion pour des systèmes antérieurement en usage. Le nouveau système est bien connu en Europe et il a déjà été officiellement admis aux Etas-Unis d'Amérique et au Canada.

— La photométrie des rétroréflecteurs avec des indications sur les techniques de calibrage et sur la précision des mesures. Il a été en particulier souligné que, pour effectuer de bonnes mesures, ce ne sont pas seulement les ouvertures angulaires de la source et de la tête photométrique qui jouent un rôle important mais qu'il faut également soigneusement veiller à l'ajustage de l'angle d'éclairage, surtout lorsque le faisceau de lumière rétroréfléchie est très étroit.

— La colorimétrie des rétroréflecteurs avec des indications propres à assurer des mesures colorimétriques correctes, mesures qui peuvent dépendre des paramètres géométriques de l'observation.

ZUSAMMENFASSUNG

RETROREFLEXION

In diesem Bericht werden folgende Punkte im einzelnen behandelt :

— Empfohlene Begriffsbestimmungen einschliesslich der wesentlichen Definitionen und Einheiten, die zur Kennzeichnung der besonderen Wirkungen der Retroreflexion benötigt werden.

— Ein neues CIE-Winkel-System einschliesslich eines geeigneten Goniometers für Labormessungen und Umrechnungsformeln für früher verwendete Systeme. Das neue System ist in Europa bekannt und wurde bereits offiziell in den USA und Kanada angenommen.

— Photometrie einschliesslich Aussagen über die Kalibriertechnik und die Messgenauigkeit. Es wird ausgeführt, dass nicht nur die Aperturen der Lichtquellen und des Photometerkopfes für eine genaue Messung wichtig sind, sondern dass die Justage des Beobachtungswinkels besondere Sorgfalt erfordert, besonders wenn eng gebündelte, retroreflektierte Strahlung zu prüfen ist.

— Farbmessung einschliesslich Hinweise, um zuverlässige.
Farbmessergebnisse zu erhalten, die von der.
Beobachtungsgeometrie abhängen können.

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1. FOREWORD

The results of the work carried out by the former CIE Committee W-3.3.5, Automobile Headlights and Signal Lights, were published in the Proceedings of the 14th Session of the CIE (CIE Publication No. 1, 1959, pages 566-571) under the title of General Recommendations for Reflex Reflector Photometry.

In 1974 a subgroup, Photometry, of the CIE Committee TC-4.7, Automobile Lighting, reconsidered these recommendations in order to bring them into better agreement with the prevailing practice. This subgroup proposed the introduction of another type of measuring goniometer, which was deemed to be of sufficient importance for a revision of the previous recommendations.

Also in 1974, CIE Committee TC-1.6, Visual Signalling, completed three draft documents on retroreflection. One of these documents, on Terminology, included a proposal for an intrinsic geometric system for describing retroflection. Thus in 1974 three geometric systems were under consideration by various CIE committees.

In 1975 a CIE Harmonizing Group on Retroreflection was established to make a more general study of the terminology and the definitions in the field of retroreflection for universal use by the CIE. This group prepared, in 1976, a document on names and units and another one on systems of angular reference. Apart from these documents the Harmonizing Group paid considerable attention to other important items, such as dimensional and physical specifications for the equipment, calibration techniques in measuring retroreflection and fundamentals of the colorimetry of retroreflectors.

Retroreflection at a macroscopic scale, if not at a microscopic one, may be considered as a particular kind of reflection. Therefore, in 1977, the study of retroreflection and of the corresponding measuring techniques was assigned to the CIE Committee TC-2.3 Materials whose terms of reference are : To study and develop methods for photometric and radiometric characterization of materials.

The process of retroreflection is widely used for increasing the visibility of objects and information for road traffic at night. The corresponding devices, or retroreflectors, may be divided into three broad categories, namely retroreflective signs, retroreflectors for road vehicles and retroreflective road markings. Since their application interests primarily three other CIE technical committees, TC-1.6, Visual Signalling, TC-4.7, Automobile Lighting, and TC-4.6, Road Lighting, coordination of the work and cooperation between these technical committees and TC-2.3 had to be established, respecting however the necessity for harmony concerning common fundamental questions.

The subcommittee, Retroreflection, was set up within the framework of TC-2.3 and studied the fundamental questions relating to retroreflection. These questions refer to :

Terminology and symbols
Instrumentation
Methods for photometry
Methods for colorimetry
Problems of accuracy.

This part of the work covered all categories of retroreflectors in order to secure the required harmonization for the basic parameters which are common to all types.

This subcommittee has also worked on and documented the special problems of the photometry at grazing incidence and view of flat horizontal retroreflective material such as road markings. However, this work is not contained in this report, since it will be further studied in a new subcommittee, Road Markings, of Committee TC-1.6.

It is the province of the relevant CIE technical committees to determine the performance requirements for the types of retroreflectors they have to deal with. This includes the selection of the most appropriate geometrical conditions under which the retroreflectors are to be tested.

The subcommittee, Retroreflection, his of the opinion that this technical report provides well defined measuring procedures and useful advice, which are important for persons who are working with these materials in test laboratories or for others who have an immediate interest in the results of tests.

The general improvement in accuracy of test data, which can result by following the contents of this report, should also lead to more correct assessment of product compliance with specified requirements.

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2. TERMINOLOGY AND COORDINATE SYSTEM FOR RETROREFLECTION

This section contains definitions which describe the properties of retroreflectors. The general definitions define retroreflection as a phenomenon without regard to the luminosity function. The principle photometric terms are quantities recommended for the specification and description of retroreflectors used in visual signalling applications. Both the general definitions and the principle photometric terms appear in the International Lighting Vocabulary (4th edition, to be published).

2.1. GENERAL DEFINITIONS

2.1.1. Retroreflection

Reflection in which the reflected rays are preferentially returned in directions close to the opposite of the direction of the incident rays, this property being maintained over wide variations of the direction of the incident rays.

2.1.2. Retroreflector

A surface or device from which most of the reflected radiation is retroreflected.

2.1.3. Observation Angle α

Angle by which the direction of observation of the retroreflector departs from the direction of the incident light. (See 2.4.4.).

2.1.4. Entrance Angle β

Angle characterizing the angular position of the retroreflector with respect to the direction of the incident light. (See 2.4.7., 2.4.9. and 2.4.10.).
Note : For a plane retroreflector, the entrance angle corresponds generally to the angle of incidence.

2.2. PRINCIPAL PHOTOMETRIC TERMS

2.2.1. Coefficient of Luminous Intensity

The quotient of the luminous intensity (I) of the retroreflector in the direction of observation by the illuminance ($E_\perp$) at the retroreflector on plane perpendicular to the direction of the incident light.

Symbol R

$$R = \frac{I}{E_\perp}$$

Note 1 : In the photometry of retroreflectors this coefficient is expressed in candelas per lux (cd lx^{-1}).

Note 2 : For accurate measurements of R, care must be taken that the angular extent of the retroreflector at the point of observation, of the source aperture at the retroreflector and of the aperture of the photometer head (the part of a physical photometer containing the detector and means for spectral and spatial corrections of the detector) at the retroreflector are each sufficiently restricted. The restriction needed depends upon both the distribution of the retroreflected light and the measurement geometry. (See Sections 3-1 to 3-3).

Note 3 : For accurate measurements of R the illuminance ($E_\perp$) must be sufficiently uniform over the useful area of the retroreflector. (See Section 3-6).

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2.2.2. Coefficient of Retroreflection (of plane retroreflecting surface)

The quotient of the coefficient of luminous intensity (R) of a plane retroreflecting surface by its area (A).

Symbol R′ $$R' = \frac{R}{A} = \frac{I/E_\perp}{A}$$ (see 2.2.1)

Note 1 : The coefficient of retroreflection is expressed in candelas per lux per square metre (cd $lx^{-1}m^{-2}$).

Note 2 : This quantity is especially useful for describing materials in sheet form. For such materials the measurements are customarily made with the direction of illumination, the direction of observation, and the normal to the surface all in the same plane.

2.3. THE CIE ANGULAR REFERENCE SYSTEM FOR DESCRIBING, SPECIFYING AND TESTING RETROREFLECTORS

In this section an angular reference system is presented, the use of which is recommended when dealing with retroreflection. A retroreflector is usually illuminated with nearly collimated light and the reflected light of interest is directed nearly parallel to the direction of the incident light. These circumstances make it natural to regard the direction of illumination as the principal direction and to regard the direction of observation and the orientation of the retroreflector in terms of the direction of illumination. The CIE (angular reference) system for describing, specifying and testing retroreflectors has been developed from this basis (Venable and Johnson, 1980). It coincides with the way in which retroreflection is visualised. In the case of road vehicles, in which the retroreflectors are often considered as luminous sources, it can be regarded as describing the orientation of such a source in what is essentially the viewer's frame of reference.

In describing the angular quantities, the source of illumination, the retroreflector and the photometer head are all treated as points. Actual measurements involve light sources and photometer heads which subtend finite solid angles at the retroreflector and retroreflectors with finite physical dimensions. An indication of how these finite angles and dimensions affect the measurements and what restrictions must be placed on them is given in section 3 on the photometry of retroreflectors.

The angular reference system for retroreflectors uses no more reference points, planes, axes, and angles than are needed to fully describe the phenomena of retroreflection. Within the angular limits prescribed, the system is complete but not redundant. Each configuration of the source, retroreflector and photometer head can be described by one and only one set of four angles. (The four angles are α, β_1, β_2 and ϵ. The entrance angle β may always be derived from β_1 and β_2). The angular limits allow for all possible configurations of the retroreflector, source and photometer head. However, since most retroreflectors have one face only, the total allowable angular range is normally not used. The sign convention applied here is such that the positive direction of each axis and the positive sense of each angle are as indicated by the directions of the arrows in Figures 1 and 2. This system is completely defined in section 2.4.

2.4. GEOMETRIC DEFINITIONS

2.4.1. Reference Centre

A point on or near a retroreflector which is designated to be the centre of the device for the purpose of specifying its performance.

Note 1 : Designating the reference centre (2.4.1.), the reference axis (2.4.6.) and the datum mark (2.4.12.) establishes coordinates fixed with respect to the retroreflector by means of which its location and angular orientation can be specified. (For a retroreflective device, these geometrical parameters are usually designated by the manufacturer). This coordinate system is related to the intended use of the retroreflector. The location of the reference centre is chosen to be on or near the retroreflecting surface and central with respect to it. When symmetry exists, the reference axis usually coincides with the axis of symmetry of the retroreflector. When required, a datum mark not on the reference axis serves to indicate the orientation of the retroreflector about the reference axis.

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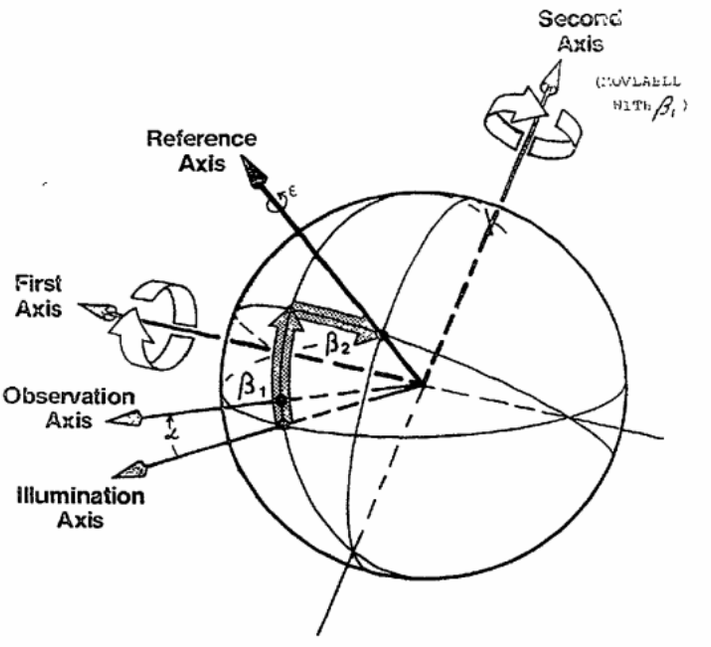

Figure 1. — The CIE angular reference system for specifying and measuring retroreflectors. The first axis is perpendicular to the plane containing the observation axis and the illumination axis. The second axis is perpendicular both to the first axis and to the reference axis. All axes, angles, and directions of rotation are shown positive.

Notes

a) The *principal fixed axis* is the Illumination Axis.
b) The First Axis is *fixed* perpendicular to the plane containing the Observation and Illumination Axis.
c) The Reference Axis is *fixed* in the retroreflector and moveable with β_1 and β_2.

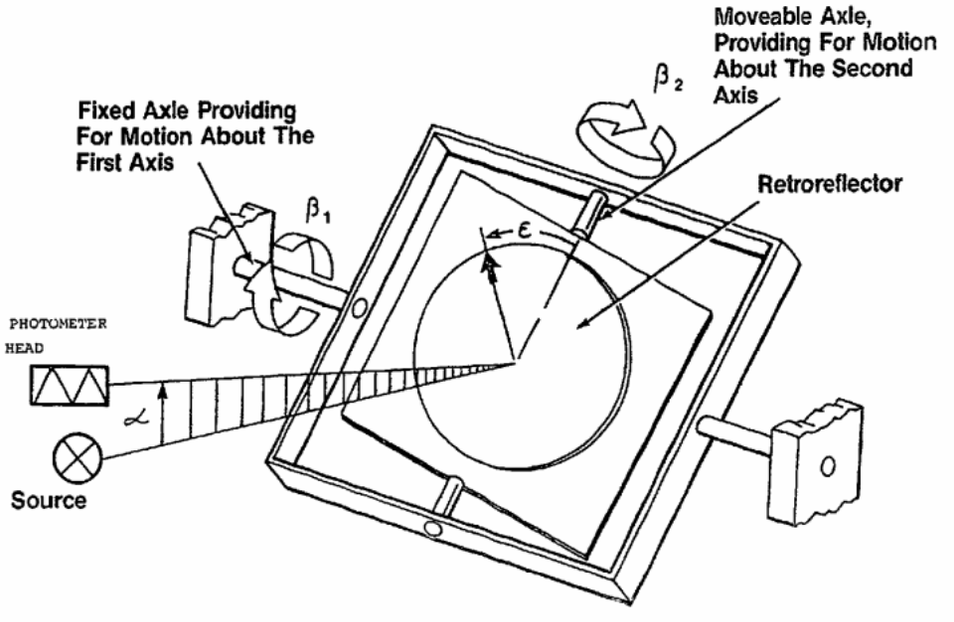

Figure 2. — A representation of a goniometer mechanism embodying the CIE angular reference system for specifying and measuring retroreflectors. All angles and directions of rotation are shown positive.

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