INTERNATIONAL

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Standard Test Method for Measurement of Retroreflective Pavement Marking Materials Using a Mobile Retroreflectometer Unit (MRU) [1]

This standard is issued under the fixed designation E3320; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers measurement of the retroreflective properties of horizontal pavement marking materials containing retroreflecting optics, such as traffic stripes and surface symbols, using a mobile retroreflectometer unit that can be operated at traffic speed, mounted on a vehicle to measure the retroreflection at a prescribed geometry.

1.2 The entrance and observation angles of the MRU affect the readings. As specified by the European Committee for Standardization (CEN) and in Test Method E1710, the entrance and observation angles shall be 88.76° and 1.05°, respectively.

1.3 This test method is intended to be used for field measurement of pavement markings at traffic speed.

1.4 This test method is intended to be used for retroreflectivity measurement of dry pavement markings.

1.5 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.6 This standard does not purport to address regulatory and safety regulations of the MRU and its use. It is the responsibility of the manufacturer to fulfill regulatory standards. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

[1] This test method is under the jurisdiction of ASTM Committee E12 on Color and Appearance and is the direct responsibility of Subcommittee E12.10 on Retroreflection.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

D7585 Practice for Evaluating Retroreflective Pavement Markings Using Portable Hand-Operated Instruments

E284 Terminology of Appearance

E808 Practice for Describing Retroreflection

E1710 Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer

2.2 *Other Standards:*

CEN EN 1436 Road Marking Materials—Road Marking Performance for Road Users and Test Methods[3]

CIE publication No. 54.2 Retroreflection – Definition and Measurement[4]

ISO 10526 CIE standard illuminants for colorimetry[5]

3. Terminology

3.1 The terminology used in this test method generally agrees with that used in Terminology E284.

3.2 *Definitions*—The delimiting phrase "in retroreflection" applies to each of the following definitions when used outside the context of this or other retroreflection test methods:

3.2.1 *actual measuring distance, D, n*—the actual horizontal distance from the MRU to the center of the measuring areas of the pavement marking.

3.2.2 *coefficient of retroreflected luminance, R_L, n*—the ratio of the luminance, L, of a projected surface to the normal

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from European Committee for Standardization (CEN), Avenue Marnix 17, B-1000, Brussels, Belgium, http://www.cen.eu.

[4] Available from U.S. National Committee of the CIE (International Commission on Illumination), C/o Alan Laird Lewis, 282 E. Riding, Carlisle, MA 01741, http://www.cie-usnc.org.

[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

illuminance, E', at the surface on a plane normal to the incident light expressed in candelas per square meter per lux ($cd \cdot m^{-2} \cdot lx^{-1}$).

3.2.2.1 *Discussion*—Because of the low luminance of pavement markings, the units used commonly are millicandelas per square meter per lux ($mcd \cdot m^{-2} \cdot lx^{-1}$).

3.2.3 *co-entrance angle, β_C, n*—the complement of the entrance angle (90° − β).

3.2.4 *co-viewing angle, v_C, n*—the complement of the viewing angle (90° − v).

3.2.5 *entrance angle, β, n*—the angle between the illumination axis and the retroreflector axis.

3.2.5.1 *Discussion*—The retroreflector axis for pavement markings is normal to the marking.

3.2.6 *entrance angle components, n—β_1* and β_2 are the entrance angle components as defined in CIE publ. 54.2 and Practice E808.

3.2.7 *instrument standard, n*—working standard used to calibrate the MRU.

3.2.8 *intended measuring distance, D_0, n*—the intended horizontal distance from the MRU to the center of the measuring areas of the pavement marking.

3.2.9 *longitudinal measurement field, L, n*—longitudinal dimension of the measuring field.

3.2.10 *mobile retroreflectometer unit (MRU), n*—refers to a measurement system that can be mounted on a vehicle to measure the coefficient of retroreflected luminance with a prescribed geometry at traffic speed.

3.2.11 *observation angle, α, n*—the angle between the illumination axis and the observation axis.

3.2.12 *presentation angle, γ, n*—the angle between the observation half-plane and the half-plane that originates on the illumination axis and that contains the retroreflector axis.

3.2.13 *retroreflection, n*—a reflection in which the reflected rays are returned preferentially 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.

3.2.14 *rotation angle, ε, n*—the angle in a plane perpendicular to the retroreflector axis from the observation half-plane to the datum axis, measured counterclockwise from a viewpoint on the retroreflector axis; according to Practice E808.

3.2.15 *transverse measurement field, T, n*—dimension of the width of the measurement field in the traverse direction in order to fully measure the width of the road marking(s).

3.2.16 *viewing angle, v, n*—the angle between the retroreflector axis and the observation axis.

4. Summary of Test Method

4.1 This test method involves the use of MRU for determining the coefficient of retroreflected luminance of horizontal coating materials used in pavement markings, at traffic speed.

4.2 The entrance angle is fixed at 88.76° (co-entrance angle 1.24°). See Fig. 1.

4.3 The observation angle is fixed at 1.05°. See Fig. 1.

4.4 The entrance angle component β_2 (the side angle) measured between the longitudinal direction of the road marking and the vertical plane containing the direction of view shall be within ±10°. Measurement uncertainty increases as β_2 increases. See Fig. 1.

4.5 The MRU uses for calibration an external white standard, an external beaded horizontal panel, or a diffuse reflection tilted panel of known coefficient of retroreflected luminance.

4.6 The retroreflectometer is mounted to the vehicle, ensuring the pavement marking(s) to be measured is(are) within its field-of-view.

4.7 The vehicle is driven down the road with the flow of traffic collecting data on the pavement marking(s) as it goes. Data collection is averaged over a given distance driven (typically 0.1 miles or 100 m) and saved with GPS coordinates.

4.8 Other peripheral data such as vehicle speed, calendar date, time of day, road conditions, pavement marking contrast, width, color, etc. may also be collected by the MRU.

4.9 Measurements shall be taken and averaged in each direction of traffic for a centerline.

5. Significance and Use

5.1 The quality of the pavement marking is determined by the coefficient of retroreflected luminance, R_L, and depends on the materials used, age, wear pattern, application method, pavements surface, and other conditions.

5.2 Under the same conditions of illumination and viewing, larger values of R_L correspond to higher levels of visual performance in dark conditions.

5.3 Retroreflectivity of pavement (road) markings degrades with traffic wear and requires periodic measurement to ensure that sufficient line visibility is provided to drivers.

5.4 MRUs are used to measure R_L values of road markings while moving at traffic speed, and can be used for longer stretches of road than portable instruments and in cases where the use of portable instruments require extensive precautions, in particular on motorways.

5.5 The measurement geometry of the MRU is based on a viewing distance of 30 m, a headlight mounting height of 0.65 m directly over the stripe, and an eye height of 1.2 m directly over the marking according to CEN 1436 and Test Method E1710.

5.6 MRUs are to be calibrated, maintained, and operated according to instructions by the instrument supplier or manufacturer.

5.7 It shall be the responsibility of the user to employ an MRU fulfilling the required specifications in this standard.

6. MRU System

6.1 *Vehicle Mounted Retroreflectometer System:*

6.1.1 The MRU shall be mountable on a vehicle and operated at traffic speed. Alignment to establish the specified

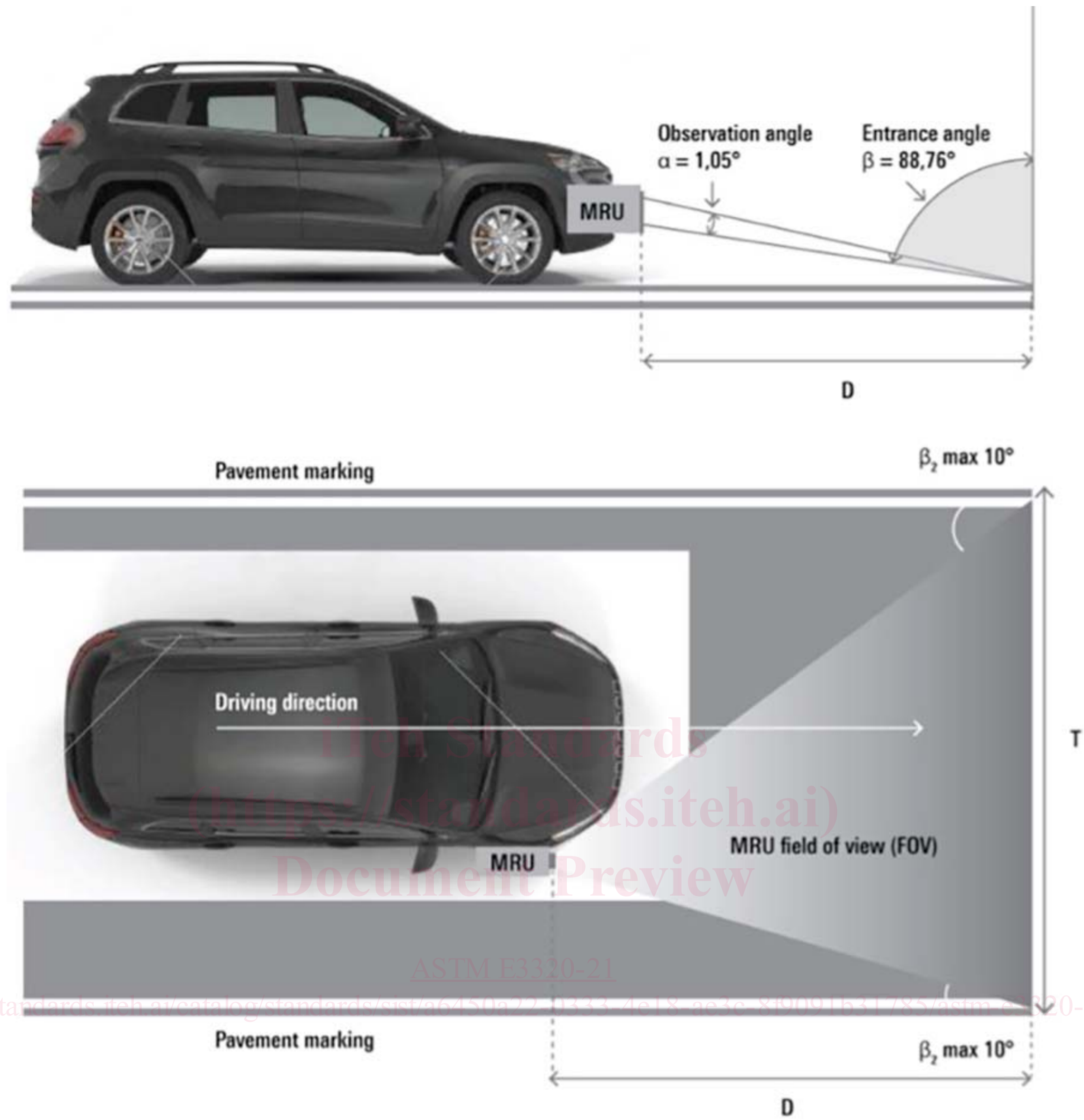

FIG. 1 The Entrance Angle (β), the Observation Angle (α), and the Side Angle-entrance Angle Component (β_2), Intended Measurement Distance (*D*), Transverse Measurement Field (*T*)

measurement geometry and calibration shall be done stationary or adjusted during motion/operation.

6.2 *Light Source and Receiver Geometry Requirements:*

6.2.1 The aperture angle of the light source as determined from the center of the measurement area shall not be larger than a rectangle subtending 10 min of arc in the vertical direction (0.17°) by 20 min of arc in the horizontal direction (0.33°).

6.2.2 Rectangle aperture dimensions are given with the first side parallel to the observation half plane.

6.2.3 The aperture of the receiver as determined from the center of the measurement area shall not be larger than a square subtending 20 min of arc (0.33°) by 20 min of arc (0.33°).

6.3 *Measurement Geometry:*

6.3.1 The standard measurement geometry should comply with the 30 m geometry specified for portable instruments in Test Method E1710 and EN 1436. The geometry is intended to simulate a visual distance of 30 m for the driver of the car with a headlamp mounted 0.65 m above the road surface and the eye of the driver 1.2 m above the road.

6.3.2 The illumination and observation angles correspond to the 30 m geometry. The observation angle shall be 1.05º. See Fig. 1.

6.3.3 The entrance angle of the MRU shall be 88.76°. See Fig. 1.

6.3.4 The geometry may be reversed in the sense that light is put through the optics of the measuring system and reflected light is received and measured through the optics of the illumination system.

6.4 *Measurement Geometry - Sensitivity to Deviations During Operation:*

6.4.1 Compared to portable instruments where a direct physical contact between the instruments and the road marking defines the illuminations and observation angles, the MRU is mounted and aligned relative to the vehicle following the manufacturer's instructions, in order to obtain the specified geometry according to 6.3.

6.4.2 During operation the MRUs are tilted and shifted in height relative to the pavement marking surface. This will, without a compensation, result in deviations from the nominal measurement geometry defined in 6.3.

6.4.3 The shift in height and tilt during operation can be caused by a number of reasons: offset in height, changes of weight of the vehicle (gradual use of gasoline, or changes on tire pressure), camber or wheel tracks of the road, driving in curves, wind pressure on vehicle, also depending on vehicle speed, local curve up/down the road, bumpiness of the road.

6.4.4 This introduces changes of the actual measuring distance D in comparison to the intended measuring distance D_0, which tends to affect the measured R_L value in proportion to $(D_0/D)^2$.

6.4.5 This also introduces offsets in the ratio of the angles of illumination and measurement ε/α in comparison to the intended ratio of 0.542, which tends to affect the measured R_L value in proportion to $(\varepsilon/\alpha)/0.542$.

6.4.6 The influence of distance can be tested by tilting the instrument by known amounts and observing the change of the measured R_L value. It is best to move the instrument in accordance with the tilt so that the R_L value is measured at the same location.

6.4.7 The influence of the ratio of the angles can be tested by lifting the retroreflectometer by known amounts, while also tilting the instrument so that the measured field does not move, and observing the change of the measured R_L value.

6.5 *Spectral Sensitivity - Spectral Requirements for Light Source and Receiver:*

6.5.1 The combined spectral distribution of the light source and the spectral responsivity of the receiver shall match the spectral distribution of the CIE Standard Illuminant A and the $V(\lambda)$ spectral luminous efficacy function. The match shall ensure correct measurement of at least white and yellow pavement marking materials according to the following criterion:

6.5.2 A white (spectral neutral) reflection standard and two plano parallel long pass absorption filters with pass wavelengths at respectively 515 nm and 550 nm (for example, Schott filter types OG 515 and OG 550 or similar edge filters), providing colors of yellow and amber are used.

6.5.3 The white reflection standard is measured. An absorption filter is inserted in front of either the receiver or the light source apertures.

6.5.4 The ratio of the R_L measured with a filter and the R_L measured without the filter shall be within 5 % of the measured Illuminant A luminous transmittance of the filter.

6.5.5 Filters of colors other than described in 6.5.2 may be used to demonstrate the ability of the MRU to measure such colors.

6.5.6 Other types of light sources resulting in non-compliance with 6.5.1, however they are permissible if:

(a) Calibration is carried out for the color of the road markings to be measured; or

(b) Deviates max 5 % for each color, when compared to readings taken on various white, yellow, and amber pavement markings measured by a portable retroreflectometer with known spectral match according to 6.5.2, 6.5.3, and 6.5.4. The reading taken by the portable retroreflectometer should be corrected for the known spectral match; or

(c) Deviates max 5 % for each color, when compared to laboratory readings on either colored ceramic reflection standards or pavements marking panels.

6.6 *Dynamic Range and Linearity:*

6.6.1 The receiver shall have sufficient sensitivity and range to measure typical coefficient of retroreflection, R_L, values. Preferably, the MRU should have a dynamic range up to 2000 $mcd \cdot m^{-2} \cdot lx^{-1}$.

6.6.2 The linearity over the range of R_L values expected in use shall be adequate for the purpose.

6.6.3 The sensitivity, range, and linearity of MRUs may be tested by means of suitable samples.

6.7 *Ambient Lighting Sensitivity:*

6.7.1 The MRU should be able to operate under daylight conditions. If the MRU can only be operated at night time or day time, this should be clearly stated by the manufacturer.

6.7.2 Daylight conditions incorporate both steady daylight conditions and dynamic light conditions, for example, when driving in and out of shadows.

6.7.3 MRUs operated in daylight shall incorporate means for suppressing daylight effect on the measuring of the R_L value.

6.7.4 For MRUs operated in daylight, most daylight conditions shall not affect the R_L values.

6.8 *Transverse Measurement Field:*

6.8.1 An MRU needs to have a certain width of the measurement field, *T*, in the transverse direction in order to fully measure the width of the road marking and have some tolerance for steering the vehicle. This applies to MRUs that measure one longitudinal line at a time and to MRUs that measure multiple markings across the full width of a road lane.

6.8.2 Within this transverse measurement field, the variation in measured R_L of a pavement marking shall not exceed 5 % from the measured R_L value in the center of the measurement field.

6.8.3 The width of transverse measurement field can be tested by using a tape pavement marking mounted on a rigid plate. The vehicle with mounted MRU in the nominal height and angular orientation is driven on two beams with a thickness of the rigid plate.