



SURFACE VEHICLE STANDARD

J1757™-1

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(R) Standard Metrology for Vehicular Displays

RATIONALE

A new line was introduced in Table 1A and clarifications related to reflections from white cloth in critical light source cone area (CLSC). A new image and method were added for cross talk luminance non-uniformity (LNU) determination.

FOREWORD

This SAE Standard defines a consistent terminology and metrology for vehicular flat panel displays (FPD). It will allow the user to measure the automotive compliance of the FPD.

NOTE: All definitions and units are for the metric system (SI) unless noted otherwise.

1. SCOPE

The scope of this SAE Standard is to provide methods to determine display optical performance in all typical automotive ambient light illumination, with focus on high ambient contrast ratio, which is critical for display legibility in a sunshine environment. It covers indoor measurements and simulated outdoor lighting.

It is not the scope of this document to set threshold values for automotive compliance. However, some recommended values are presented for reference. The present revision does not address the usage of polarized sunglasses.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 CIE Publications

Available from CIE Central Bureau, Babenbergerstrasse 9/9A, 1010 Vienna, Austria, Tel: +43 1 714 31 87, www.cie.co.at.

CIE 85 Technical Report - Solar Spectral Irradiance

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Documents

Document Sharing Hub

2.1.2 ISO Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ISO 4513 Road Vehicles - Visibility - Method for Establishment of Eye-Ellipses Location

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP1782 Photometric and Colorimetric Measurement Procedures for Airborne Direct View CRT Displays

SAE J941 Motor Vehicle Drivers' Eye Locations

2.2.2 CIE Publications

Available from CIE Central Bureau, Babenbergerstrasse 9/9A, 1010 Vienna, Austria, Tel: +43 1 714 31 87, www.cie.co.at.

CIE 15.2 Recommendations on Uniform Color Spaces, Color Differences Equations, Psychometric Color Terms

CIE 17.4 Recommendations - CIE International Lighting Vocabulary

CIE S 003/E Spatial Distribution of Daylight - CIE Standard Overcast Sky and Clear Sky

2.2.3 MIL Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MIL-87213 Military Handbook - Electronically/Optically Generated Airborne Displays

2.2.4 ISO Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ISO-DIS15008 ISO TC22 SC13 WG8 DIS15008 - Display Legibility Standard

2.2.5 ICDM Publications

Available from SID organization at Society of Information Display, 1475 S. Bascom Ave, Ste 114, Campbell, CA 95008; Tel: (408) 879-3901, www.sid.org; or directly on the ICDM web page: www.icdm-sid.org (downloads/IDMS1 - free download).

IDMS1 Information Display Measurements Standard

2.2.6 SID Publications

Available from Society for Information Display, 610 S. 2nd Street, San Jose, CA 95112-4006, Tel: 408-977-1013, www.sid.org.

SID-DE 1995	FPD Evaluation for Automotive Applications
SID-DE 1998	Optical Specification for Automotive FPD
SID-DE 1999	An Analysis of Direct View FPD for Automotive Multi-Media
SID-DE 1999	Haze Complications in FPD Reflection Performance Measurements
SID-DE 2013	White Shirt Reflections and Ambient Illumination Challenges in Determining Automotive Display Legibility Performance
SID-DE 2014	Experimental Characterization of Measuring Automotive Display Performance Based on White Shirt Reflection Method and Light Transmission Method

3. DEFINITIONS

3.1 Important Notation Clarifications

For this document, we will use the following notations:

$L_{[amb-d,k]}$ = Luminance [due to high diffuse illumination, black display image]

$L_{[amb-d,w]}$ = Luminance [due to high diffuse illumination, white display image]

$L_{[amb-s,w]}$ = Luminance [due to high specular illumination/glare, white display image]

$L_{[amb-s,k]}$ = Luminance [due to high specular illumination/glare, black display image]

$L_{[dark,k]}$ = Luminance [in dark room, black image]

$L_{[dark,w]}$ = Luminance [in dark room, white image]

To avoid other common notations, such as “b” for black, “w” denotes white and “k” denotes black.

If both specular (glare) and diffuse illumination are present, we use $L_{[amb-ds,x]}$, where x is the color displayed.

The usage of word “diffuse” must be carefully considered because it may be:

- “Diffuse” (light) source such as skylight, integrated sphere = property of the illumination (source) $\Leftrightarrow E_{amb}$.
- “Diffuse” reflections of surface = property of the display surface $\Leftrightarrow L_{amb}$.

In this standard, we are measuring L_{amb} to determine E_{amb} value (such as 1526 cd/m² measured off a 0.99 standard diffuser equivalent to 5k lux illumination environment).

3.2 Acronyms

Several acronyms are used and defined by this standard; some important ones are listed below:

C_CSL or CCSL	Central critical specular line (3.9)
C_CSLED or CCSLED	Central critical specular light direction (3.10)
C_LSC or CLSC	Critical light source cone (3.11)
C_SLSC or CSLSC	Critical specular light source cone (3.12)
V_CSL or VCSL	Vehicle critical specular line (3.37)
V_CSLED or VCSLED	Vehicle critical specular light direction (3.38)
V_CSS or VCSS	Vehicle critical specular surface (3.39)

Please see important clarifications at the beginning of Section [4](#).

3.3 ACTIVE AREA

Of the display, the area covered by pixels.

3.4 ADDRESSABILITY

See display addressability ([3.16](#)).

3.5 ASPECT RATIO (W:H)

The active area width-to-height ratio (such as 4:3 for NTSC displays, or 16:9 for wide view displays).

3.6 CANDELA (cd)

The unit of luminous intensity, I , and the luminous flux in lumens emitted per unit solid angle (lm/sr).

3.7 CONTRAST RATIO (CR)

The ratio between the information luminance and background luminance:

$$CR = L_{(\text{information})}/L_{(\text{background})} \quad (\text{Eq. 1})$$

Contrast ratio in high ambient light illumination is defined as CR_d for diffuse (skylight) illumination and CR_h for direct sunlight illumination. See [Table 1](#) for more information.

For this document the information is considered light color $L_{(\text{information})} = L_{[\text{dark},w]}$ and the background is dark color $L_{(\text{background})} = L_{[\text{dark},k]}$. If reverse color is used (dark information over light background), then use reverse notation and Equation 1 in order to be consistent with this document procedures. See also contrast ([3.7](#)).

NOTE: “Light color” maybe white or higher luminance color for some displays and “dark color” may be black or lower luminance color for some displays and some screen designs.

Other colors can be used for color contrast ratio definitions. The CR value is critical to determine display legibility in all ambient light conditions (daylight with and without direct sunlight and night).

3.8 CONTRAST (C)

Defined as:

$$C = (L_{(\text{information})} - L_{(\text{background})}) / L_{(\text{background})} \quad (\text{Eq. 2})$$

Contrast (C) and contrast ratio (CR) are related by the formula:

$$C = CR - 1 \quad (\text{Eq. 3})$$

NOTE 1: Contrast value is influenced by usage of checker board versus full white and black screens. We can use a frustum to focus on the specific white or black surface of the checked board.

NOTE 2: Do not use checker board for C or CR determination.

NOTE 3: Usage of frustum or stray light elimination tube (SLET) or frustum cone should be used. An example for construction of a frustum can be found in the ICDM manual (Appendix A2).

3.9 CENTRAL CRITICAL SPECULAR LINE (CENTRAL CSL)

Defined, in the vehicle, as a line from the center of the display to the center of the driver's cyclopean eye-ellipse (refer to ISO 4513 for eye-ellipse definition). It is also known as "display's design view direction." This line is within the driver's cone, and may be different than vehicle CSL (depends on display position, orientation, and vehicle openings/windows).

3.10 CENTRAL CRITICAL SPECULAR LIGHT DIRECTION (CENTRAL CSLD)

Defined as the line symmetrical to central CSL in respect to the normal direction to the center of the display. It is within critical specular light source cone (CSLSC) and critical light source cone (CLSC). See [Figure 1](#) for more information.

3.11 CRITICAL LIGHT SOURCE CONE (CSLC)

Generated from the critical specular light source cone with the apex angle increased 5 degrees all around (see [Figure 1A](#)). Critical light source cone includes critical specular light source cone, central critical specular light direction (central CSLD), and vehicle critical specular surface. Ambient light coming from directions within this cone toward the display determines the contrast (and legibility).

NOTE: It is not a mathematical roatation cone. See [Figure 1](#) for clarification.

3.12 CRITICAL SPECULAR LIGHT SOURCE CONE (CSLSC)

Defined in this document as the cone symmetrical to the driver's viewing cone (observer's viewing cone) in respect to the normal direction to the center of the display. See [Figures 1A](#) and [1B](#) for details.

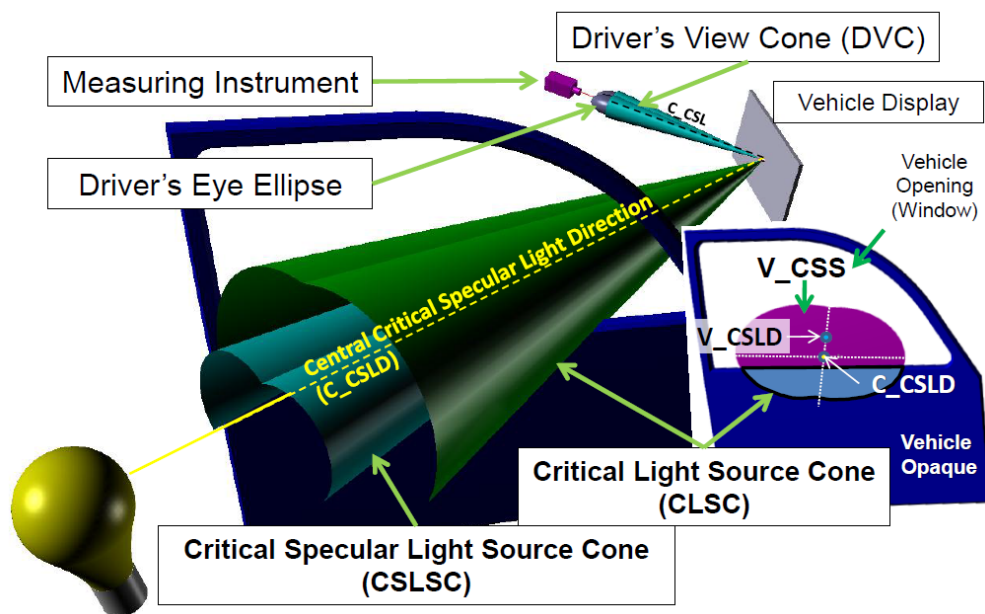


Figure 1A - Critical light illumination: central critical specular line (C_CSL), central critical specular light direction (C_CSLED), critical specular light source cone (CSLSC), critical light source cone (CLSC), vehicle critical specular surface (V_CSS), and vehicle critical specular light direction (V_CSLED)

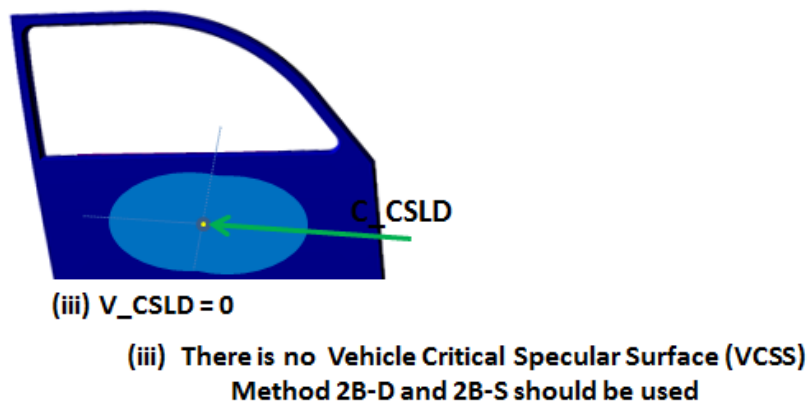
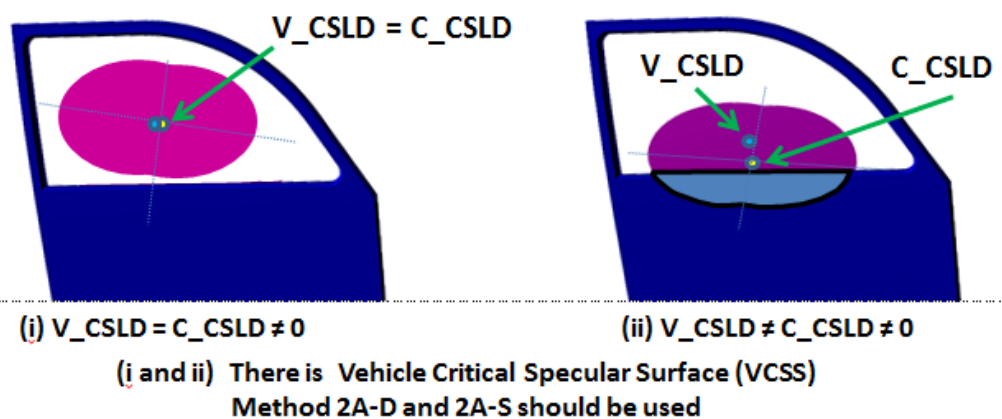


Figure 1B - Critical light illumination examples

3.13 DIFFUSE—HAZE REFLECTION (D_H)

A diffuse reflection (scattered reflection) manifested around the specular direction (see [Appendix B](#)). It is not specular (mirror like) because of the spread angle (no distinct virtual image of the source is produced) and is not diffuse-Lambertian because of its strong luminance variation as a function of angle near specular direction.

3.14 DIFFUSE—LAMBERTIAN REFLECTION (D_L)

A diffuse reflection (a scattering of light out from the specular direction) whereby the observed luminance is independent of observation direction and only depends upon the illuminance falling upon the surface. The luminous intensity from a Lambertian surface is given by $I = I_0 \cos \theta$, where I_0 is the luminous intensity in the normal direction. A flat (matte) paint, or barium sulfate (BaSO_4) reflection coating, pressed polytetrafluoroethylene, or bariums sulfate powders are typical Lambertian-like diffusing surfaces.

3.15 DIFFUSE—LIGHT SOURCE (SKYLIGHT OR AMBIENT LIGHT)

Real-life ambient light illuminating the display from all angles. At any time in-vehicle display is subjected to multiple sources of illumination (vehicle interior surfaces, road objects, skylight). Each light source creates its own “luminance due to illumination” (see definition). For the purpose of this standard, we sum-up the effect of the multiple light sources as a cone of light with apex in the point of measurement. The complex optical structures and coatings of the display surface reflects this multidirectional light based on specular and diffuse reflective properties of the display (see luminance reflectance factors, [3.25](#)).

3.16 DIFFUSE REFLECTANCE (ρ , or REFLECTANCE)

The ratio of the (entire $\Omega = 2\pi$) reflected luminous flux to the incident luminous flux. If one uses a white standard, it is often this reflectance that is quoted to characterize the reflection of the material. See also luminance reflectance factor ([3.25](#)).

$$\rho = \pi L/E \quad (\text{Eq. 4})$$

3.17 DISPLAY ADDRESSABILITY

Expressed in $P_h \times P_v$ (number of horizontal pixels x number of vertical pixels), such as VGA (640 x 480) or SVGA (800 x 600).

3.18 DISPLAY'S DESIGN VIEW DIRECTION

See central critical specular line (central CSL) ([3.9](#)).

3.19 DRIVER'S VIEW CONE OR OBSERVER'S CONE

Generated by all lines from the center of the display tangent to the eye-ellipse borderline. Note central critical specular line (central CSL) is included in this cone.

3.20 FLAT PANEL DISPLAY (FPD)

FPD = Flat panel display = Display under test.

3.21 ILLUMINANCE (E)

Defined as the luminous flux (Φ) incident on a surface per unit area. The SI unit is lux (lm/m^2 , lx), the English unit is footcandle (fc) ($1 \text{ fc} = 10.76 \text{ lx}$).

3.22 JUST NOTICEABLE DIFFERENCES (JND)

A unit to measure differences between two stimuli (such as color of two nearby areas). It is defined when an observer can discriminate between two stimuli with 75% accuracy, making a 1JND unit. The 1JND has a very low perceptual impact, 3JND is considered observable (but not strong), and 10JND is clearly observable.

3.23 LUMINOUS FLUX

$$\Phi = k \int S(\lambda) V(\lambda) d\lambda \quad (\text{Eq. 5})$$

where:

$S(\lambda)$ = spectral radiant flux (in W/nm)

$V(\lambda)$ = luminous efficiency for photopic vision (1931CIE human model)

K = conversion factor from watt to lumen (683 lm/W)

λ = wavelength of light radiation (in nm)

3.24 LUMINANCE (L)

Defined as the luminous flux (Φ) emitted or reflected from a surface per unit solid angle per unit area in a given direction. The SI unit is candela per square meter (cd/m^2), the English unit is footlambert (fL) ($1 \text{ fL} = 3.4263 \text{ cd/m}^2$).

$L_{[\text{dark},w]}$ = Luminance for the FPD white icon (information) measured in the dark ambient light (ambient light is OFF).

$L_{[\text{dark},k]}$ = Luminance for the FPD black screen (background) in dark ambient light (ambient light is OFF).

Total display luminance measured in ambient illumination by a photometer positioned in a specific direction toward the point of measurement is:

$$L_{\text{amb-x},w} = L_w + L_{\text{amb-x}} \quad (\text{Eq. 6})$$

Where L_w is the display luminance measured in the dark and $L_{\text{amb-x}}$ is the display luminance due to ambient illumination. If the geometry is known, the $L_{\text{amb-x}}$ could be $L_{\text{amb-d}}$ or $L_{\text{amb-s}}$. Sometime the $L_{\text{amb-x}}$ is notated as L_{ha} (high ambient).

3.25 LUMINANCE REFLECTANCE FACTORS (β and ζ)

In-vehicle displays are used under some type of ambient illumination (see luminance as a result of illuminating, [3.26](#)). Quantifying the amount of ambient light that is reflected from the display to the eye depends on the source-detector geometry, the illumination type (such as diffuse/hemispherical and/or specular) and the reflection properties of the display who are dependent of the angular directions of illumination and measurement. For the purpose of this standard, we will use the IDMS nomenclature and definitions and use luminance factor (β) for diffuse illumination and specular reflectance (factor (ζ))*for specular illumination.

Luminance factor (β) is defined as the ratio of the luminance of the object to that of the luminance of a perfect reflecting diffuser (perfectly white Lambertian material) for identical illumination conditions.

$$\beta = \pi L/E \quad (\text{Eq. 7})$$

where L is the luminance of the surface and E is the illuminance upon the surface. Generally, there is a subscript $\beta_{\text{source/detector}}$ that provides an indication under which lighting/detector conditions the measurement was made, e.g., $\beta_{\text{d}/\theta}$ would refer to diffuse lighting conditions where the luminance measurement was made at an angle of θ from the normal. In this document, we will not be using the subscript notation and the conditions under which the luminance factor is measured will be indicated in the context. Generally, we specify diffuse illumination and a detector angle of approximately 10 degrees. There is a fortuitous reciprocity between the luminance factor and the reflectance (diffuse reflectance): $\beta_{\text{d}/\theta} = \rho_{\theta/\text{d}}$ (see diffuse reflectance and IDMS for more information).

For some display technologies, the luminance factor depends on the energized state of the display panel; we will use the following notations:

- β_k is display driven black with backlight off (if any).
- β_w is display driven white with backlight off (if any).

Specular reflectance (ζ) is defined as the ratio of the net reflected luminance L to the source luminance L_s in the specular direction.

$$\zeta = L/L_s \quad (\text{Eq. 8})$$

For some display technologies, the specular reflectance depends on the energized state of the display panel; we will use the following notations:

- ζ_{off} is display driven black with backlight off (if any).
- ζ_{on} is display driven white with backlight off (if any).

3.26 LUMINANCE AS A RESULT OF ILLUMINATING

The display surface luminance as a result of ambient illumination E_{amb} is in general:

$$L_h = L_{\text{amb-x}} = L_{\text{amb-s}} + L_{\text{amb-d}} \quad (\text{Eq. 9})$$

where $L_{\text{amb-s}}$ is the luminance due to specular property of the surface induced by specular ambient light sources (such as sun or white shirt/skirt) and $L_{\text{amb-d}}$ is luminance due to diffuse property of the surface induced by diffuse ambient illumination (such as skylight or ambient daytime illumination). The $L_{\text{amb-d}}$ may have a Lambertian-like component $L_{\text{amb-d-l}}$ and a haze-like component $L_{\text{amb-d-h}}$ noticeable when closer to specular direction. If the surface is a perfect Lambertian diffuser (such as a matt/flat paint), $L_{\text{amb-d-l}}$ value is independent of viewing angle; $L_{\text{amb-d-h}}$ value depends upon the angle. See diffuse light source definitions (3.13, 3.14, and 3.15) and [Appendix B](#) for more information.

Conversion between Illumination value in lux and luminance value in cd/m^2 can be done only for specific geometries of the measurement setup and illuminating source surface size. See [Appendices B](#), [D](#), and [E](#) for more information.

3.27 LUMINANCE UNIFORMITY or NON-UNIFORMITY (NU)

A measure of how constant the luminance (for white, black, or color) is over the full display. Luminance non-uniformity may or may not be permanent. It can be independent of displayed image, due to manufacturing process or “burn-in images” (permanent). It can be temporary due to the image content and pixel addressing, including cross talk, ghosting, shadowing, or streaking.

- a. Burn-in image: Permanent unwanted image created by a static image displayed for a long time.
- b. Cross talk: Unwanted noisy coupling between nearby circuits.
- c. Ghosting or shadowing: Unwanted offset image of the intended image.
- d. Streaking: A shadow with a short spatial distribution and decayed over the distance.

Luminance non-uniformity is:

$$\text{LNU} = [(L_{\max} - L_{\min})/L_{\max}] \times 100\% \quad (\text{Eq. 10})$$

NOTE 1: Sometimes “uniformity” is improperly described as “non-uniformity”; please note 90% uniformity is equivalent with 10% non-uniformity.

NOTE 2: In general, a gradual 10 to 20% non-uniformity across the screen is not distinguishable by the human eye.

NOTE 3: A high luminance or low luminance spot that is 2% different than its immediate surroundings will be very visible. For anomalous uniformity measurements, refer to IDMS and VESA FPDM #306.

3.28 NORMAL (DIRECTION)

Direction perpendicular to the surface (synonym: orthogonal).

3.29 PIXEL (px)

Short for picture element is the smallest element of the display surface capable to reproduce the full range of luminance and colors. Often is composed of sub-pixels (R, G, B) or dots.

3.30 PIXEL FUSION DISTANCE

The minimum distance from the display where two individual pixels appear to merge. It depends upon pixel size, resolution and human eye performance. [The pixel fusion distance is about 76 cm (about 30 inches) for a pixel pitch of 31.5 pixels/cm (80 pixels/inch) for a normal eye.]

3.31 PERCEIVED BRIGHTNESS

The human eye perception (subjective) of the display luminance (L) or reflected illuminance (E). Sometimes brightness is wrongfully substitute by luminance because both provide information on “light intensity.” In order to avoid any confusion, it is recommended to use the term “perceived brightness” when non-linear response of the eye is considered. CIELUV (1976) or CIELAB (1976) are standardized color spaces considering a non-linear eye response. As a good approximation, “perceived brightness” is a cube root of luminance, except at low light levels when it is linear.

3.32 REFLECTIONS

From any (display) surface are considered to be: specular and diffuse; the diffuse can be DL (diffuse lambertian) and/or DH (diffuse haze). See diffuse ([3.15](#)) and specular ([3.33](#)) definitions and [Appendix B](#) for more information.

3.33 RESOLUTION

How far apart and distinguishable are the pixels and often measured in pixels/inch. It is often improper use for addressability (such as 640 x 480). See also pixel fusion ([3.30](#)) and display addressability ([3.17](#)).

3.34 SPECULAR REFLECTION (S)

A mirror-like reflection with the characteristic that the angle of incidence equals the angle of reflection and a distinct virtual image is visible of the source with the luminance of the image being proportional to the luminance of the source.

3.35 TRANSMISSIVE DIFFUSER

A material (such as an opal glass, sanded white glass, or white plastic) that allows the light to go through but scatters the light in all directions.

3.36 USER VIEWING CONE (UVC)

The irregular cone that includes the driver’s viewing cone and passengers’ viewing cone. Its vertical and horizontal apex angle define it.

3.37 VEHICLE CRITICAL SPECULAR LINE (V_CSL)

The line symmetrical to the vehicle CSLD (vehicle critical specular light direction) in respect to the normal direction to the center of display. (If vehicle CSLD coincides with central CSLD, then vehicle CSL coincides with central CSL or display design view direction.)

3.38 VEHICLE CRITICAL SPECULAR LIGHT DIRECTION (V_CSLD)

The line from the “center of mass” of the vehicle critical specular surface to the center of the display (see [Figure 1](#)).

3.39 VEHICLE CRITICAL SPECULAR SURFACE (V_CSS)

It is determined by the intersection of critical light source cone with a car opening (such as glass window, see [Figure 1](#)) or a high diffuse reflective surface (white seat/shirt/skirt) illuminated by the sun.

4. MEASUREMENTS

Important Clarifications for any measurements:

- a. Spot size for ambient measurements shall include at least 10 x 10 full pixels included within the round measuring spot (note: larger spot is better; see [Appendix E](#)).
- b. Measuring points for an observer or meter as defined in SAE J1757-2, section 3.5. For the purpose of this standard, we use only point 5 (the center point). See [Appendix G](#) for details.
- c. Do not use checkerboard measurements at dark to scale sunlight performance from $L_{[dark,w]}$ to determine the ambient light for different situations— $L_{[amb-d,k]}$, $L_{[amb-d,w]}$, $L_{[amb-s,w]}$, $L_{[amb-s,k]}$ —because:
 1. Scaling number issue (many proper bits needed for scaling to ambient, usually 10^4 to 10^5 cd/m²).
 2. Surface properties do not show at dark, so DUT must be illuminated as mentioned in [Appendices A](#), [B](#), and [C](#).
- d. Light sources to provide ambient illumination should not have light pulse when optical digital meter is not sampling the image. If light source is PWM, then you have to either synchronize the measurement with the pulse or integrate over a long period of time to include at least ten pulses.
- e. Area illuminated for daylight or sunlight must be large for proper measurement. See [Appendix E](#) for details. A minimum size of 300 mm for illuminated area is recommended.
- f. Under high illumination, a stray light elimination tube (SLET) or frustum cone should be used. The description and construction example can be found in the ICDM manual (Appendix A2).

4.1 High Ambient Illumination Contrast Ratio Measurement

The challenge for the high ambient illumination setup is to create the ambient light closer to real outdoor light. [Appendix A](#) presents the main parameters for the real ambient light: omni-directional spatial distribution, spectral distribution, and color temperature. Because the sunlight is relatively uniform scattered by the Earth atmosphere, the closest light source for illumination should be a diffuse-like source for the skylight and a combination of collimated and diffuse source for the sunlight.

It is recommended to perform measurements in three ambient illumination conditions: night time (at 10 lx illumination), daytime (5 klx diffuse illumination due to the skylight), and direct sunlight exposure (45 klx due to direct sunlight and skylight). It is to be noted the real values for illumination may be significantly higher (see [Appendix A](#)).

The committee recommends three methods for high ambient contrast ratio measurement:

- a. METHOD 1: Diffuse ambient light measurements, using the sample sphere method (recommended for the assessment of the CR value in a skylight illumination). The method is applicable for the measurements in the lab (display detached from the car) and with some restrictions in the car (see [4.1.1.1](#)).
- b. METHOD 2: Real-life in-car simulation measurements, performed on the display integrated in the car. The method is applicable for both in lab (display detached from the car—on the bench) and in-car measurements. For this part, the “test to determine ambient light simulation setup” should be performed to determine vehicle critical specular surface and vehicle critical specular light direction. Based on this test, the measurement setup will be either 2A (vehicle geometry known) or 2B (default situation when vehicle geometry is not known or there is no vehicle critical specular surface). Each Method 2A or 2B has two parts: diffuse illumination and sun illumination. The values for ambient illumination are provided in [Table 1A](#).
- c. METHOD 3: Scalable illumination measurements for any geometry; 3A when the critical specular line (CSL) and vehicle critical specular light direction (V_CSLD) are known and 3B when the geometry is not known and default situation shall be used.

The reported CR value has to mention the measurement type (Method 1 or 2). If the FPD is a perfect Lambertian type (paper-like surface), a factor of 1 can be expected between the measurements based on Method 1 versus Method 2. If it is not Lambertian (glass-like) the factor is 3. In general, because there is no “perfect” surface the correlation is not determined, and the measurement is sensitive to the setup geometry.

Table 1A - Summary of the recommended measurement methods for contrast ratio

Ambient Illumination	Ambient Illumination Range lx	Ambient Illumination Recommended lx (cd/m ²) ⁽¹⁾	Method	Note	Notation
Night	0-50	10 (3.2) ⁽¹⁾	Industry standard	Not the purpose of this standard (Method 2 setup may be used without ambient illumination, for in-car measurements)	CR
Twilight	50-500	250 (79.6) ⁽¹⁾	Any method	Car setting for night time ⁽²⁾	CR _{tw}
Day: Diffuse	500-10k	5k (1592) ⁽¹⁾	1: Sample sphere		CR _d
			2A: Diffuse	Critical specular light direction known	
			2B: Diffuse 3A or B	Critical specular light direction not known Calculate any contrast value in any configuration (specular + diffuse source and specular + diffuse reflections)	
		10k	2A-D	Combined white cloth in CLSC	
Day: Sun	10k-100k	45k (14324) ⁽¹⁾	2A: Sun-gun	Critical specular light direction known	CR _{ha}
			2B: Sun-gun 3A or B	Critical specular light direction not known Calculate any contrast in any configuration	