SURFACE VEHICLE STANDARD

J1757-1	MAY2015
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(R) Standard Metrology for Vehicular Displays

RATIONALE

A new method was added to calculate the contrast in high ambient illumination based on scalable illumination data, it may be applicable to in vehicle white shirt / skirt reflections.

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.

SAE J1757-1 Optical Performance

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.

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 Publication

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

2.1.2 ISO Publication

Available from American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, Tel: 212-642-4900, www.ansi.org.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
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SAE values your input. To provide feedback on this Technical Report, please visit http://www.sae.org/technical/standards/J1757/1_201505

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 Publication

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

SAE ARP1782 Aerospace Recommended Practice: Photometric and Colorimetric Measurement Procedures for Airborne Direct View CRT Displays

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, Central Bureau of the CIE Vienna, 1976

CIE 17.4 Recommendations - CIE International Lighting Vocabulary, (Joint IEC/CIE – 1987)

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

2.2.3 MIL Publication

Available from U.S. Government, DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-2179, http://assist.daps.mil or http://stinet.dtic.mil.

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

2.2.4 ISO Publication

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

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

2.2.5 ICDM Publication

IDMS1 - Information Display Measurements Standard (Version 1.03, June 1, 2012)

Available from SID organization at: SID – 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)

SAE J941 Eye Ellipse

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 (Silviu Palalau /Pala and Masasumi Sone, Vehicular Display Forum – Ypsilanti-1995)

SID-DE 1998 Optical Specification for Automotive FPD (Silviu Palalau /Pala and Phil LeMay, 5th Annual Symposium on Vehicular Displays – Ypsilanti-1998)

SID-DE 1999 An Analysis of Direct View FPD for Automotive Multi-Media (Mark Vincen, 6th Annual Symposium on Vehicular Displays – Ypsilanti-1999)

SID-DE 1999 Haze Complications in FPD Reflection Performance Measurements (Silviu Pala and Ed Kelley, 6th Annual Symposium on Vehicular Displays – Ypsilanti-1999)

SID-DE 2013 White Shirt Reflections and Ambient Illumination Challenges in Determining Automotive Display Legibility Performance; Luc Hildebrand, Dr. Vyacheslav Birman (Continental) and Silviu Pala (DENSO)

SID-DE 2014 **Experimental characterization of measuring automotive display performance based on *white shirt reflection method* and *light transmission method Xiaona Li, Dr. Vyacheslav Birman (Continental) and Silviu Pala (Denso)***

IMPORTANT _NOTATION clarifications

For this document we will use below notation:

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

$L_{[amb-d,w]}$ =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]

If both specular (glare) and diffuse illumination is 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:

1) “diffuse” (light) source such as skylight, integrated sphere = property of the illumination (source) ⇔ E_{amb}

2) “diffuse” reflections of surface = property of the display surface ⇔ L_{amb}

In this standard we are measuring L_{amb} to determine E_{amb} value (such as 1,592 cd/m2 measured off a 0.99 standard diffuser equivalent to 5k lux illumination environment)

3. DEFINITIONS

3.1 ACTIVE AREA

Of the display is the area covered by pixels.

3.2 ADDRESSABILITY

See Display Addressability.

3.3 ASPECT RATIO (W:H)

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

3.4 CANDELA (cd)

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

3.5 CONTRAST RATIO (CR)

It is the ratio between the information luminance and background luminance:

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

Contrast Ratio in High Ambient Light Illumination is defined as CR_d for diffuse (skylight) illumination and CR_h for direct sun light illumination. See Table 1 in 4.1 for more information.

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

* NOTE: "light color" maybe white or higher luminance color for some displays and "dark color" maybe 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 (day light with and without direct sunlight and night).

3.6 CONTRAST (C)

Is defined as:

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

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

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

3.7 CENTRAL CRITICAL SPECULAR LINE (Central CSL)

It is defined, in the vehicle, as a line from the center of the display to the center of the driver's cyclopean eye-ellipse (see 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)

3.8 CENTRAL CRITICAL SPECULAR LIGHT DIRECTION (Central CSLD)

Is 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.

3.9 CRITICAL LIGHT SOURCE CONE (CSLC)

It is 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).

3.10 CRITICAL SPECULAR LIGHT SOURCE CONE (CSLSC)

Is 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 Figure 1A and 1B for details.

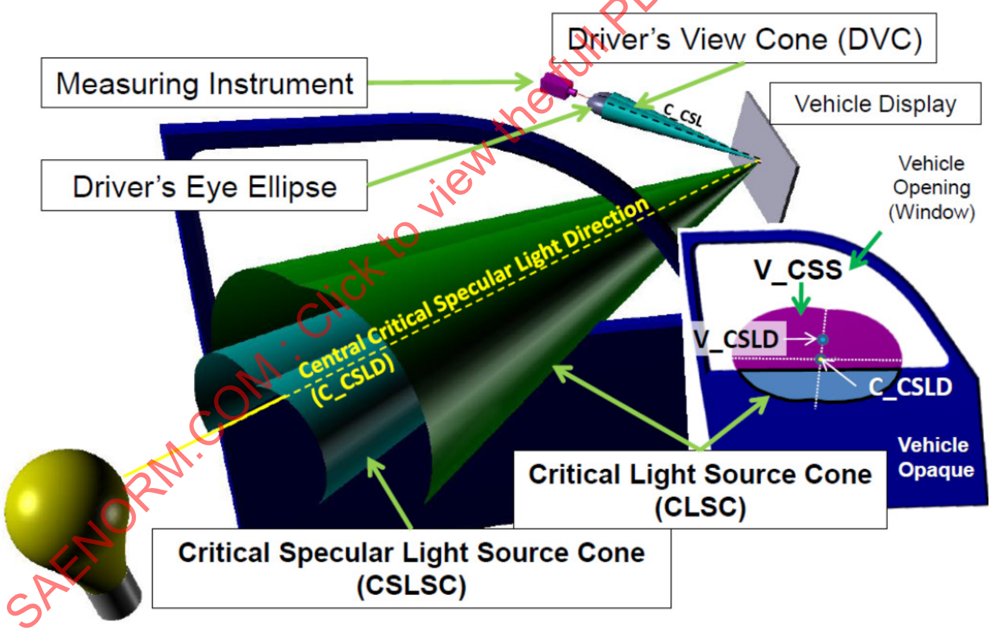


Figure 1A - Critical light illumination: central critical specular line (C_CSL), central critical specular light direction (C_ CSLD), critical specular light source cone (CSLSC) critical light source cone (CLSC) vehicle critical specular surface (V_CSS) and vehicle critical specular light direction (V_CSLD)

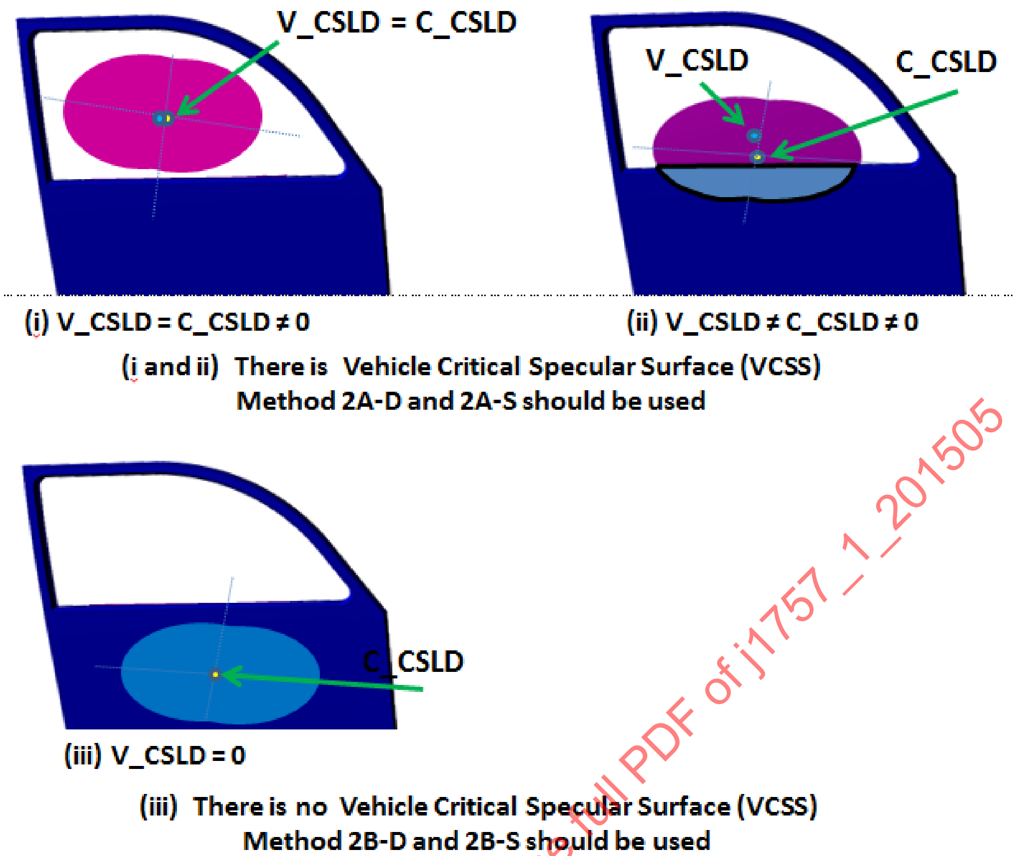


Figure 1B - Critical light illumination examples

3.11 DIFFUSE-LAMBERTIAN REFLECTION (D_L)

Is 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 $I = I_0 cosq$, 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.

3.12 DIFFUSE-LIGHT SOURCE (Skylight or ambient light)

It is 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).

3.13 DIFFUSE-HAZE REFLECTION (D_H)

Is 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 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 factor.

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

3.15 DISPLAY ADDRESSABILITY

It is expressed in P_h x P_v (number of horizontal pixels x number of vertical pixels), such as VGA (640 x 480) or SVGA (800 x 600).

3.16 DISPLAY'S DESIGN VIEW DIRECTION

See Central Critical Specular Line (Central CSL)

3.17 DRIVER'S VIEW CONE OR OBSERVER'S CONE

It is generated by a line from the center of the display tangent to the eye-ellipse borderline. Note Central Critical Specular Line (Central CSL) is included in this cone.

3.18 FPD = Flat Panel Display = Display under test.

3.19 ILLUMINANCE (E)

It is 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 fc = 10.76 lx]

3.20 JND is the abbreviation for Just Noticeable Differences

It is a unit to measure differences between two stimuli (such as color of two near-by 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.

3.21 LUMINOUS FLUX

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

Where:

- S (λ) spectral radiant flux (in W/nm)
- V (λ) 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)

3.22 LUMINANCE (L)

Is 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 fL = 3.4263 cd/m^2].

$L_{[dark,w]}$ = Luminance for the FPD white icon (information) measured in the dark ambient ligh (Ambient Light is OFF)t.

$L_{[dark,k]}$ = 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:

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

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

3.23 LUMINANCE REFLECTANCE FACTORS (β and ζ)

In-Vehicle Displays are used under some type of ambient illumination (see Luminance as effect of Illuminance) . 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 $\beta_{source/detector}$ that provides an indication under which lighting/detector conditions the measurement was made, e.g., $\beta_{d/\theta}$ 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): $\beta_{d/\theta} = \rho_{\theta/d}$ (see diffuse reflectance and IDMS for more information).

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

- β_k is display driven black with backlight off (if any) and
- 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, and we will use the following notations

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

3.24 LUMINANCE AS A RESULT OF ILLUMINATING

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

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

where L_{amb-s} is the Luminance due to Specular property of the surface enhanced by Specular Ambient light sources (such as sun or white shirt / skirt) and L_{amb-d} is Luminance due to Diffuse property of the surface enhanced by Diffuse Ambient illumination (such as skylight or ambient daytime illumination). The L_{amb-d} may have a Lamberian-like component $L_{amb-d-l}$ and a Haze-like component $L_{amb-d—h}$ noticeable when closer to specular direction. If the surface is a perfect Lambertian diffuser (such as a matt/flat paint) $L_{amb-d-l}$ value is independent of viewing angle; $L_{amb-d-h}$ value depends upon the angle. See Diffuse Light Source definition and Appendix B for more information.

Conversion between Illumination value in lux and luminance value in cd/**m²** **can be done only for specific geometries** of the measurement setup and illuminating source surface size. See Appendix B, D and E for more information.

3.25 LUMINANCE UNIFORMITY or NON-UNIFORMITY (NU)

Is 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:

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

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 see IDMS and VESA FPDM #306.

3.26 Normal (Direction)

Direction perpendicular to the surface (synonym: orthogonal).

3.27 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.

3.28 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.]

3.29 PERCEIVED BRIGHTNESS

Is 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.

3.30 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 and Specular definitions and Appendix B for more information.

3.31 RESOLUTION

How far apart and distinguishable are the pixels and often **measured in pixels/inch**. It is often improper use for addressability (640 x 480). See also pixel fusion and display addressability.

3.32 SPECULAR REFLECTION (S)

Is 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.

3.33 TRANSMISSIVE DIFFUSER

Is 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.

3.34 USER VIEWING CONE (UVC)

It is the irregular cone that includes the driver’s viewing cone and passengers’ viewing cone. Its Vertical and Horizontal apex angle define it.

3.35 VEHICLE CRITICAL SPECULAR LINE (V_CSL)

It is 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 Vew Direction).

3.36 VEHICLE CRITICAL SPECULAR LIGHT DIRECTION (V_CSLD)

It is the line from the “center of mass” of the Vehicle Critical Specular Surface to the center of the display (see Figure 1)

3.37 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

4.1 High Ambient Illumination Contrast Ratio Measurement

The challenge for the high ambient illumination set-up 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 sky light and a combination of collimated and diffuse source for the sun-light.

It is recommended to perform measurements in three ambient illumination conditions: **night time** (at 10 lx illumination), **day-time** (5 Klx diffuse illumination due to the sky light) and **direct sunlight** exposure (45 Klx due to direct sunlight and sky-light). It is to be noted the real values for illumination may be significantly higher (see Appendix A - ambient light illumination).

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 warning notes 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 High Ambient Light Simulation Set-up” should be performed to determine Vehicle Critical Specular Surface and Vehicle Critical Specular Light Direction. Based on this test, the measurement set-up 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 the 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 shell 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 set-up geometry.

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

Ambient Illumination	Ambient Illumination Range lx	Ambient Illumination Recommended lx (cd/m²)[(1)]	Method	Note	Notation
Night	0-50	10 (3.2)[(1)]	Industry standard	Not the purpose of this standard (Method 2 set-up 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 (1,592)[(1)]	1-Sample Sphere		CR_d
			2A-diffuse	Critical Specular Light Direction known	
			2B-diffuse	Critical Specular Light Direction not known	
			3 A or B	Calculate any contrast value in any configuration (specular + diffuse source and specular + difuse reflections)	
Day-Sun	10k-100k	45k (14,324)[(1)]	2A-sun-gun	Critical Specular Light Direction known	CR_{ha}
			2B-sun-gun	Critical Specular Light Direction not known	
			3 A or B	Calculate any contrast in any configuration	

	Ambient Illumination Level		
	Sky (5klx diffuse source / diffuser)	Sun (45klx collimated source /sun-gun)	Scalable
Set-up A Geometry Known (real in vehicle situation known and V_CSS ≠ 0)	2A-D (diffuse) (CR_d)	2A-S (sun-gun) (CR_{ha})	3A (CR_d), (CR_{ha}),(CR_s)
Setup B – Default = Geometry Not Known OR there is no VCSS	2B-D (diffuse) (CR_d)	2B-S (sun-gun) (CR_{ha})	3B (CR_d), (CR_s), (CR_s)
			CR_s is CR for specular /glare reflections

Figure 1B - Critical light illumination examples

NOTES:

(1) The L equivalent values in cd/m² are provided for practical reasons. The E (lux) values to equivalent L values are measured with a spectrophotometer off the White Reflective Lambertian Standard Surface. The estimated error for “conversion” is up to 8%. The lx to cd/m² was done for the standard specific test geometry and assuming the white standard diffuser reflectivity is 99%.

(2) Only if the car setting is “Night Time” for twilight illumination.

(3) Method 3 should be used for combined specular and diffuse reflections to calculate CR in different ambient lighting illumination by scaling the results at a given light source to other equivalent light illuminations, it covers the “white shirt” glare reflection situation.

4.1.1 METHOD 1

Diffuse Ambient Light Measurements, using the Sample Sphere Method (Skylight only illumination simulation)

This method is recommended to assess the CR value in diffuse ambient light (day light from the sky, no direct exposure to the sun). The illumination range is from 500 lx to 10 klx, with the recommended value of 5 klx for this test.

The advantage of the sample sphere method is that it may be performed on the isolated display (detached from the car) and with some restrictions (see warning note) on the display integrated in the car.

Figure 2 shows a 100 mm diameter sampling sphere that can be placed upon the surface of the FPD. If this sphere is properly baffled, it will provide reproducible results comparable with the large integrating sphere measurements where the display is placed entirely within a large integrating sphere. The sampling sphere is placed upon the center of a FPD. A hole through which the luminance is measured—the measurement port—is provided in the sampling sphere at approximately an angle $\theta = 8 \pm 2$ degrees with respect to the normal of the screen and sampling port area. The measurement port and sampling port must be large enough to make a good luminance measurement.

The minimum diameter of the sample port should be approximately 20% larger than the measurement area diameter of the luminance meter. The measurement port must be of a sufficient diameter so that the measurement port in the luminance-meter optics produces no vignette. All the rays from the measured spot on the display surface must reach all parts of the lens of the luminance meter without being obstructed by either the measurement port or the baffle.

Glare can be introduced into the measurement if the luminance meter is not placed far enough away from the Sample Port to exclude the area surrounding the Sample Port (a black tube may be used to prevent light leaks). A baffle is provided between the sampling port and the lamp source so that no direct rays from the source hit the FPD surface.

The photopic photodiode monitor views the interior surface away from the lamp source. If the illumination provided by the lamp source is greater than 100 times the illumination of the FPD, the photopic photodiode is not needed to monitor the illumination (if the illuminance is sufficiently bright, there will be only a small change in J). A baffle may have to be placed between the photodiode monitor and the source as well as between the photodiode and the sample port so that no direct rays from either the lamp source or the FPD hit the photopic photodiode. (The need for such baffles will depend upon the construction of the photodiode monitor).

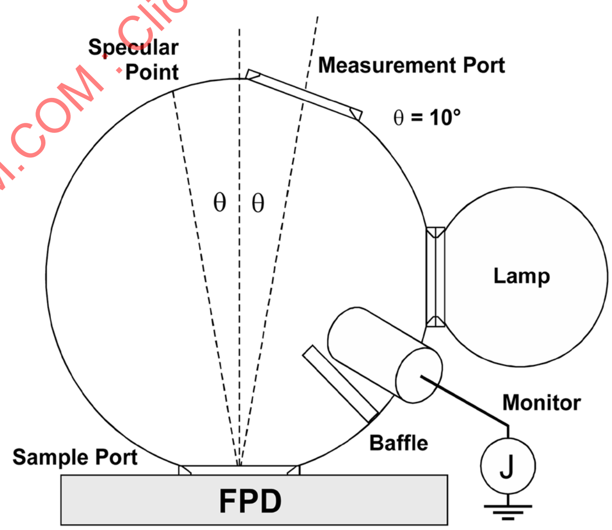


Figure 2 - Partial cross-section drawing of illuminated sampling sphere with photopic photodiode monitor

It may be possible to substitute a box, polyhedron, or geodesic sphere for an integrating sphere with various degrees of success depending upon the construction techniques employed. Any improvisation along these lines should be carefully tested and compared with the results using an integrating sphere before they can be trusted. In all cases, attention must be paid to proper baffling of the sample port and the photodiode monitor.

If the walls of the material used have a substantial thickness (thicker than 5% of the sampling port diameter) then attention must be given to properly beveling the hole. The beveled ring around the sampling port should be well illuminated by the interior (see cross-section of beveled port rings in Figure 2).

4.1.1.1 Warnings Notes

a. Some FPDs may exhibit a change in performance with even a slight pressure applied to their surfaces. It may be necessary to carefully arrange for the sampling port not to push the FPD surface (place the sphere within a millimeter or so from the FPD surface).

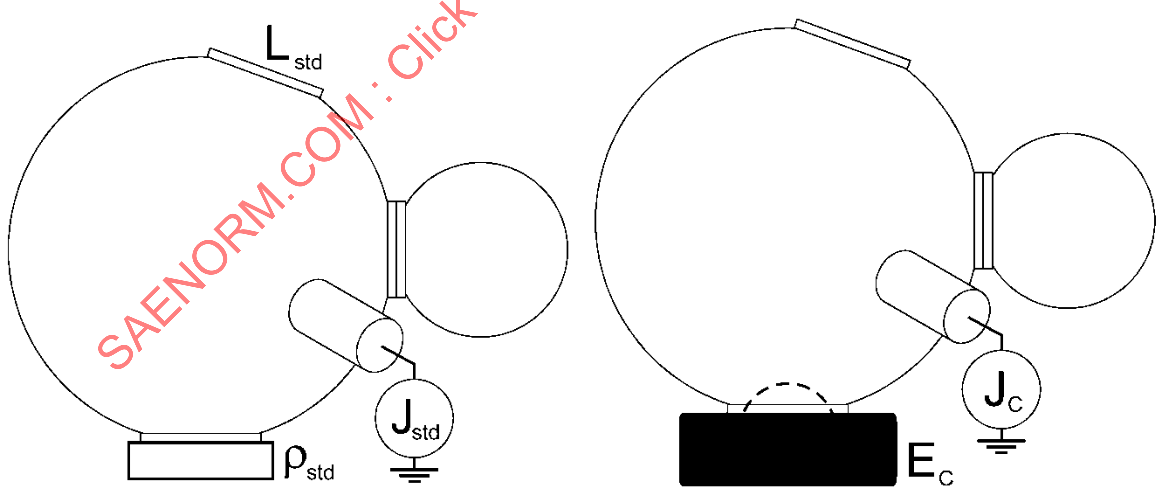
b. Some FPDs, particularly those that are measured in situ, may have glass or plastic covering plates to protect the display. In such cases the pixel surface of the FPD may be so far away from the front surface upon which the sampling sphere is place that this sampling sphere method will not produce reliable results. In such cases Method 2 should be employed.

c. Glare can be introduced into the measurement if the luminance meter is not placed far enough away from the Sample Port to exclude the area surrounding the Sample Port (a black tube may be used to prevent light leakage).

4.1.1.2 Procedure

STEP 1: Measure L_W and L_{BK} (Luminance for the information/white color and background/black color) in dark ambient light (maximum 10 lux)

STEP 2: Calibration of Photopic Photodiode Monitor (see Figure 3).
The photodiode monitor current J must be calibrated to reflect the illuminance at the sampling port. Such a calibration can be performed two ways.



3a – reflectance standard 3b – illuminance meter

Figure 3 - Calibration of photopic photodiode monitor used with the sampling sphere is based upon either a known white reflectance standard (3a) or an illuminance meter (3b) or both

a. Using white reflectance standard: The sampling port is placed upon a white reflectance standard of known reflectance ρ_{std} (because of reciprocity, the reflectance factor $\rho_{\theta/d} = \rho_{std}$ [for small θ] is the same as the luminance factor $\beta_{d/\theta}$) and the luminance L_{std} and photodiode current J_{std} are recorded. The illuminance E_{std} is related to the luminance via

$$E_{std} = \pi\left(L_{std} / \rho_{std}\right) \quad \text{(Eq. 11)}$$

The calibration constant c is given by

$$c = E_{std} / J_{std} \quad \text{(Eq. 12)}$$

The illuminance E for any other configuration can be obtained by measuring the photodiode current *J* via:

$$E = cJ \quad \text{(Eq. 13)}$$

b. Using an illuminance meter: The sampling port is placed upon an illuminance meter and the photodiode current J_c is recorded along with the illuminance E_c. The calibration constant is given by

$$c = E_c / J_c \quad \text{(Eq. 14)}$$

NOTE 1: It is recommended to use a light source able to provide illumination at least 10 times greater than the maximum (white) generated by the FPD. In this case the calibration can be performed with the photometer only (no photo-diode use).

NOTE 2: The spectral distribution of the light should be close to the CIE 85 Table 4 (±20%). The light sources with large spikes in the spectrum (such as fluorescent lamps) should be avoided. The color temperature is secondary to this issue. See Appendix C.

NOTE 3: If both a white diffuse standard and an illuminance meter are available, it is instructive to compare the values of "c" obtained by both methods of calibration. The overall uncertainty in the measurement using the sampling sphere is reflected in the uncertainty in a comparison of the "c" values.

NOTE 4: Illuminance measurement can be inferred from the illuminance of the sphere wall if no light from source directly hit that area. The luminance G of that portion of the wall can be used to determine the illuminance falling upon the sample surface. By placing the white standard at the measurement port, measuring its luminance L_{std} and the wall luminance G_{std}, and forming the constant $g = L_{std}/G_{std}$; the illuminance at the measurement port can be determined from a measurement of the wall luminance via $E = \pi gG/\rho_{std}$. Alternatively, an illuminance meter can be employed instead of the white standard. With the illuminance meter in place a wall luminance G_c is measured corresponding to the measured illuminance E_c. With anything else at the measurement port, the illuminance is given in terms of the wall luminance via $E = GE_c/G_c$. In the following, the quantity cJ represents the illuminance E falling on the sample. Replacing cJ_i with E_i measured via the wall luminance in the formulation as follows will permit the use of the wall luminance instead of the photodiode current.

STEP 3: Place the Sphere Sample Port on top of the Display Under Test (see warning notes) with a white icon displayed at the point of measurement (DUT full screen white is acceptable). Measure photocurrent J_h from the photodiode monitor and resulting luminance $L_{[amb\text{-}d,w]}$ of the white icon. (See Figure 2.)

STEP 4: Calculate the luminance factor β_W for full-screen white mode:

$$\beta_W = \pi\left(\left(L_{[amb-d,w]} - L_{[dark,w]}\right)/\left(cJ_{hw}\right)\right) \quad \text{(Eq. 15)}$$

STEP 5: Measure photocurrent J_d from the photodiode and resulting luminance L_d of the screen for full-screen black.

STEP 6: Calculate the luminance factor β_K for full-screen black mode:

$$\beta_K = \pi\left(L_{[amb-d,k]} - L_{[dark,k]}\right)/\,cJ_{hb} \tag{Eq. 16}$$

STEP 7: Scale the results for a diffuse illuminance of E_d = 5000 lx and calculate the ambient contrast CR_d using Equation 11.

$$CR_d = \frac{\left(\dfrac{\beta_W E_d}{\pi} + L_{[dark,w]}\right)}{\left(\dfrac{\beta_K E_d}{\pi} + L_{[dark,k]}\right)} \tag{Eq. 17}$$

The determined CR value is the main information for legibility assessment of the FPD viewed from normal direction. If other direction of view is needed the sample sphere should have means to rotate the measurement port (half of the hemisphere containing the measurement port is rotatable). The diameter of the sphere may be larger than 100 mm. Precautions should be taken for the placement of the port not to be in the direction of the light source or the target for the photocurrent photodiode.

4.1.2 **METHOD 2: Real Life/In Car Measurements Using High Ambient Light Illumination Simulation** [there are 2 ambient environments: day-sun and day-diffuse; and 2 set-up situations: when vehicle CSLD (light source direction) and Central CSL (photometer direction) are known (-2A) and the default situation (-2B). See Table 1A and 1B for clarification.

The measurements can be performed either in car (under simulated ambient illumination) or in the lab (under the same illumination conditions). Vehicle Critical Specular Light Direction (Vehicle CSLD) should be specified for the light source illumination direction and Central CSL should be specified for the photometer measurement direction in the display XYZ coordinates. If critical light path in vehicle is not defined, the default set-up should be used (setup 2B). The test to determine measurement set-up should be performed for in car measurements or determined in CAD simulation. Based on the results of this test the measurement set-up should be either 2A or 2B. At least one method should be tested.

Equipment

Spectrophotometer / or Photometer minimum requirement: NIST traceable with a 5%*expanded uncertainty with a coverage factor of two for Luminance and ±0. 008 for color (u' v').

See detailed specification below:

Wavelength Range	380-780
Spectral Resolution (nm)	0.4
Spectral Accuracy (nm)	0.3
Spectral Bandwidth (nm)	2.5
Min. Measuring Area (mm)	0.25
Luminance Sensitivity (cd/m2)	0.1
Luminance Accuracy (%)	2 **
Luminance Repeatability (%)	0.1
Color Accuracy (x, 2856K)	0.002
Color Repeatability	0.0002
Linearity (%)	1 *

Notes:

* Only with linearity calibration

** Reference to the 2856K-calibration source

*** Color performance is for reference only and not needed for this standard.

See Appendix E for more information on traceability.

Sun-Gun Lamp: Metal Halide Day-Lamp capable of 14000Fc, 5600ºK, 245 mm diameter lens, Flicker Free (>10 000 images/second) capable of required illumination over a 245 mm spot area. (Such as ARRISUN12) or equivalent (e.g. cluster of high bright RGB-white LEDs).

Transmissive Diffuser: Any semi-transparent material (glass or plastic) able to scatter the light close to Lambertian distribution.

Standard White Diffuser (diffuse reflective white standard), preferable on metal substrate (small height, about 2-3 mm so the reflective surface is not far off display surface to require photometer re-focus)

Goniometer or any other device to measure the angles (position the photometer and light source in respect to the display)

4.1.2.1 **Determine High Ambient Light Illumination Directions** for In Car Measurements (photometer direction and light source direction toward the display)

a. Determine Vehicle Critical Specular Surface (VCSS).

Place a small round mirror on the surface of the display under test, in the center (imaginary intersection of the active area diagonals). From the driver's eye ellipses area, look toward the center of the mirror then extended your viewing direction 5 degrees all around (to compensate for potential haze properties of the display). If you see a portion of the windshield, side door window, rear window or sunroof, this is the Vehicle Critical Specular Surface (see definition). If you see a seat area where a person wearing white clothes can be directly illuminated by the sun, the area could be a Vehicle Critical Specular Surface. Vehicle CAD simulation can provide the best & accurate data. Note the Critical Light Cone is determined by increasing the apex of the Critical Specular Light Source Cone (the symmetrical of the Driver's Viewing Cone in respect to the normal direction in the center of the display) with 5º all around. See Fig. 1A and 1B. for more information.

Light from VCSS area toward the center of the display has the most influence on the CR value and consequently on the display legibility. In this case use method 2A (real life situation 2A-D and 2A-S) for the set-up of ambient light.

b. If there is a Vehicle Critical Specular Surface (VCSS), determine Vehicle CSLD (Critical Specular Light Direction). The Vehicle CSLD is determined by the center of the display and the "mass center" of the Vehicle Critical Specular Surface (see Fig. 1). The best results are from CAD determination but any approximation of the mass center is OK (such as a "center of the circle tangent to the VCSS borderline").

c. If there is no Vehicle Critical Specular Surface or the car geometry is not known use set-up 2B (default conditions 2B-D and 2B-S)

Important Note: The surface determined by intersecting the Critical Light Source Cone with the vehicle may be a potential critical one if it is a high reflective material (white surface for example). For this situation the equivalent luminance of the surface must be estimated and can replace the value from Table 1.

4.1.2.2 **Procedure for Set-Up 2A – Direct Sun-Light Exposure** (Measure CR_{ha} – Method 2A)

This set-up is recommended when the Critical Light Source Cone intersects a part of the windshield, side windows, rear window or sunroof. (There is a Vehicle Critical Specular Surface). When there is no VCSS, the measurement for direct sunlight is not necessary, default situation should be considered.

STEP 1: Position the photometer in the center of the eye-ellipse area (center of the cyclopean eye-ellipse for in vehicle measurement) toward the measuring point (Central CSL direction). CSL direction should be specified relative to the display. See Figure 4. Set-up for Method 2A-S.

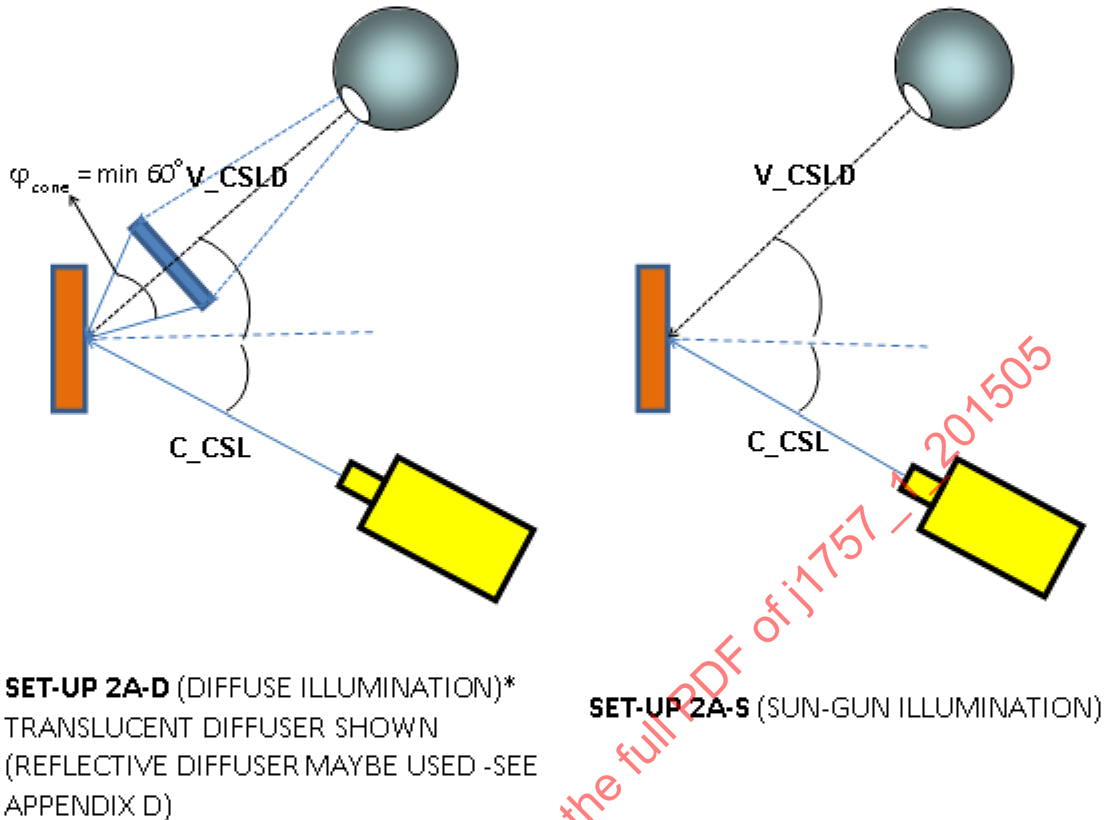


Figure 4 - Set-up for Method 2A

STEP 2: Position the light source direction parallel to Vehicle CSLD toward the center of the display.

STEP 3: Position the standard reflective diffuser on the top of the FPD in the point of the measurement.

STEP 4: Adjust the illumination and measure L_{ha} in order to get E_{ha} = 45 klx from the surface of the standard reflective diffuser. See Equation 13.

$$E_{ha} = \pi L_{ha} / \beta_{std} \quad \text{(Eq. 18)}$$

NOTE: The diffuse reflectivity standard should be calibrated for the given measurement angles or the luminance factor β_{std} should be determined for the specific angles (there is no ideal Lambertian diffuser).

STEP 5: Remove the standard diffuser. Display sufficient different colors to calculate all contrast ratios that are used in the screen design under test and measure respectively L_{hk} = $L_{[amb,k]}$ and L_{hw} = $L_{[amb,w]}$.

STEP 6: Calculate the High Ambient Illumination Contrast Ratio (CR_{ha}) using formula (1)

$$CR_{ha} = L_{[amb-d,w]} / L_{[amb-d,k]} \quad \text{(Eq. 19)}$$

4.1.2.3 **Procedure for Set-Up 2A-D – Diffuse Sky-Light Illumination** (No Direct Sun Light; Measure CR_d – Method 2A-D)

The objective of this method is to determine the CR_d in simulated diffuse illumination (such as the day-time sky-light).

Perform STEPs 1 to 3 as previous (see 4.1.2.2.)

Position the transmissive diffuser perpendicular to the Vehicle CSLD, and close to the area of measurement. The apex of the illumination cone from the transmissive diffuser should be about 60 degrees. (See Appendix D Guideline for the transmissive diffuser use).

Take precautions to avoid veiling-glare from the diffuser (and other potential bright sources) illuminating the photometer lens.

STEP 4: Adjust the illumination and measure $L_{[amb-d,k]}$ in order to get E_{da} = 5 klx from the surface of the standard reflective diffuser.

Perform the STEPs 5 and 6 as previous (see 4.1.2.2Calculate the High Diffuse Ambient Illumination Contrast Ratio CR_d. See Equation 20.

$$CR_d = L_{[amb-d,w]} / L_{[amb-d,k]} \quad \text{(Eq. 20)}$$

4.1.2.4 **Procedure for Set-Up 2B-S – Direct Sun Light Exposure** (Measure CR_h – Method 2B-S)

This set up is recommended when there is no Vehicle Critical Specular Surface. This set up can be used as a default value for geometry and ambient illumination. This situation must be tested.

If Central CSL is not defined the default value for the photometer measuring direction θ_p is 20 degrees off normal in a plane perpendicular to the FPD. The source illumination direction is θ_s= 45 degrees in the same plane. See Figure 5 for more information.

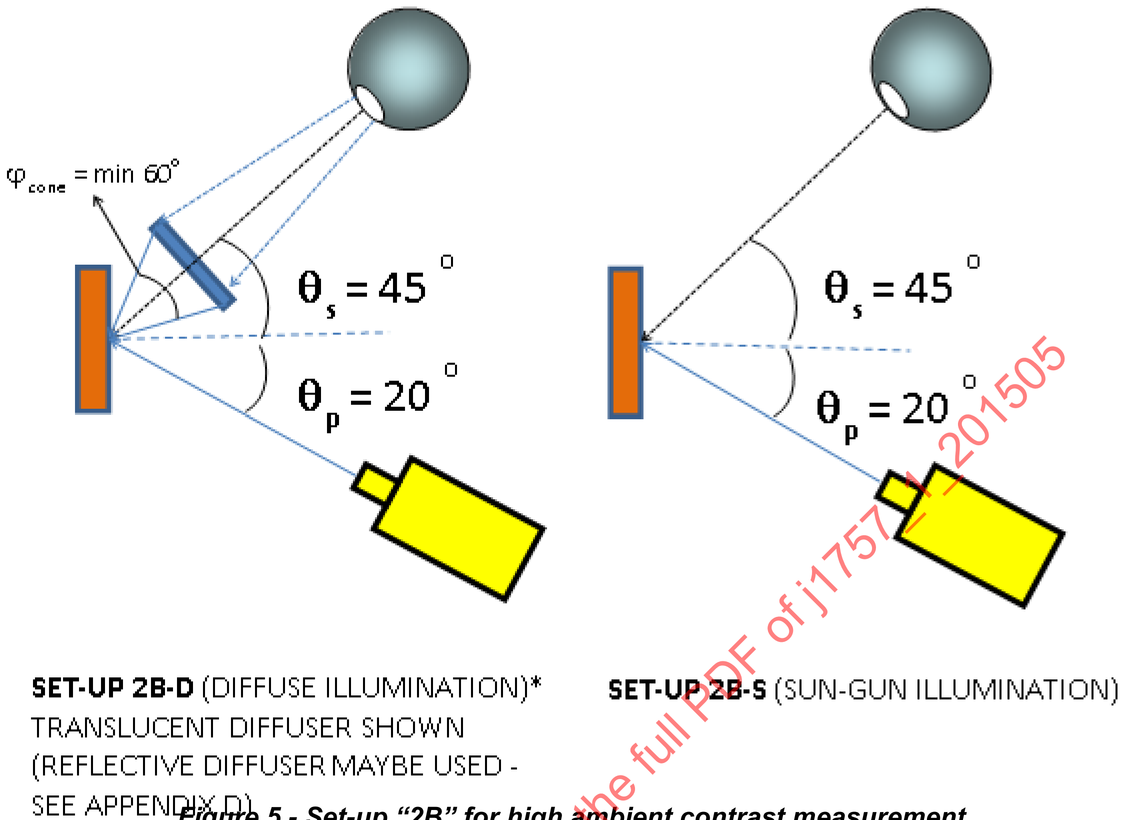


Figure 5 - Set-up "2B" for high ambient contrast measurement

This set-up (relative position of the light source and measurement direction) is in accordance with ISO TC22 SC13 WG8 ISO 15008 proposal for display legibility measurement.

NOTE: It is somewhat similar to MIL-L-85762A, but the angles are different (-30, +30)

It is also recommended to perform the measurement with the photometer in both vertical and horizontal extremes of the User Viewing Cone.

STEP 1: Position the photometer in the center of the eye-ellipse area toward the measuring points (Central CSL direction). See Figures 1 and 5. The default value for the photometer measuring direction is 20 degrees off normal.

STEP 2: Position the light source direction θs = 45 degrees off normal toward the center of the display.

STEP 3: Same as in method 2A (see 4.1.2.2)

STEP 4: Same as in method 2A (see 4.1.2.2, E_{ha} = 45 klx)

STEP 5: Same as in method 2A (see 4.1.2.2).

STEP 6: Same as in method 2A (see 4.1.2.2).

4.1.2.5 **Procedure for Set-Up 2B-D Diffuse Sky-Light Exposure** (No Direct Sun Light; Measure CR_d – Method 2B-D)

The objective of this procedure is to determine the CR in simulated diffuse illumination (daytime sky-light condition) when the Critical Light Source Cone does not intersect a part of the windshield, windows, sunroof, vehicle opening or the vehicle geometry is not known. Perform STEP 1 to 3 as previous (see 4.1.2.4.)

Position the transmissive diffuser perpendicular to the Vehicle CSLD direction (45 deg off normal), and close to the area of measurement. The illumination cone from the transmissive diffuser should be about 60 degrees. (see Appendix D Guideline to use the Transmissive Diffuser)

Take precautions to avoid veiling-glare from diffuser (and other potential bright sources) illuminating the photometer lens.

STEP 4: Adjust the illumination and measure L_{da} in order to get E_{da} = 5 klx from the surface of the standard reflective diffuser.

Perform the STEPs 5 and 6 as previous (see 4.1.2.4.)

Calculate the High Diffuse Ambient Illumination Contrast Ration CR_d

$$CR_d = L_{[amb-d,w]} / L_{[amb-d,k]} \qquad \text{(Eq. 21)}$$

IMPORTANT NOTE: Perform all display measurements on the area previously covered by the standard reflective diffuser (same area used to determine illumination value).

4.1.3 Method 3 Scalable illumination method applicable for both diffuse, specular illumination, enable white shirt / skirt specular reflections measurements / glare in the display and combines diffuse & specular illumination. Method 3A and 3B have the same procedure, the only difference is the geometry of the setup. Below is the description for method 3B (default situation geometry)

The illumination cone with a 60 ° apex using the translucent diffuser or reflective diffuser will provide both specular (at 20°) and diffuse (at 45 °) illumination, with different values due to specific optical property of the materials and the luminance source power. For a illuminance level of 1Klux to 5Klux (sky-light) the display is subjected to both type of illumination **<u>at the same time</u>**. The method enables the measurement of the contrast performance with **skylight ambient illumination** and determines:

1. Luminance Factor (β) important for diffuse display surfaces, haze like

2. Specular Reflectance (ζ) important for mirror like display surfaces

The large "source surface" provided by the diffuser (translucent or reflective) will eliminate the CR variations due to the size of the light source (see Appendix E for more information)

Procedure for Method 3. Display is in OFF mode for steps 1-8

STEP 1: Position the photometer in the center of the eye-ellipse area toward the measuring points (Central CSL direction). See Figures 4 and 5. The default value for the photometer measuring direction is □p = 20 degrees off normal. Focus on the center of the display = point of measurement

STEP 2:Position the light source direction θ_s = 45 degrees off normal toward the center of the display.

STEP 3:Position the standard reflective diffuser on the top of the FPD in the point of the measurement.

STEP 4: Adjust the source illumination and measure Lha in order to get required Eha (TBD lx) from the surface of the standard reflective diffuser. See Equation 18.

$$E_{ha} = \pi L_{ha} / \beta_{std} \qquad \text{Same as in method 2A (see 4.1.2.2) Ec. 18}$$

STEP 5: Remove the standard diffuser, and replace it with a mirror of specular reflectance ζ_m ζ_{m}, Do not change the focus of the photometer.

STEP 6: Measure the **reflected luminance** L_m from the source. The actual luminance from the source is then

$$L_s = L_m / \zeta_m \tag{Eq22}$$

STEP 7: Remove the mirror, keep same focus for the photometer and measure a luminance L_{off} and L_{on} on the display surface

STEP 8: Calculate a **specular reflectance**,

$$\zeta_{off} = L_{off} / L_s \quad , \tag{Eq. 23}$$

$$\zeta_{on} = L_{on} / L_s$$

STEP 9: Measure display luminance for dark (background / black) and bright (white) in the darkroom L_{K}, L_{W}, We can estimate the ambient contrast ratio for any source luminance L_{A} (LA is actually Ls determined above for TBD value of ambient illumination, it can be scaled for other values using linear approximation IF we have large surface source illumination)

$$CR_{amb-s} = \frac{L_{[dark,w]} + L'_{[amb,w]}}{L_{[dark,k]} + L'_{[amb,k]}}$$

$$CR_{amb-s} = \frac{L_{[dark,w]} + \zeta_{on} L_A}{L_{[dark,k]} + \zeta_{off} L_A} \tag{Eq. 24}$$

$L'_{[amb,w]}$ =Luminance of the display at conditions: ambient light ON, white pixels ON, display backlighting OFF

$L'_{[amb,k]}$ =Luminance of the display at conditions: ambient light ON, pixels OFF, display backlighting OFF

E_0 or E_{ha} is the required value (45klux or whatever) to use to test the display. L_0 or L_{ha} of the source would need to be in order to get the desired illuminance, the ratio of the luminance to the illuminance must be the same if we don't change the geometry of the source and detector:

$$\frac{L_0}{E_0} = \frac{L_{std}}{E_{std}} \quad \frac{L_0}{E_0} = \frac{L_{std}}{E_{\mathrm{std}}} \quad \text{or} \quad L_0 = \frac{L_{std}}{E_{std}} E_0 \quad L_0 = \frac{L_{std}}{E_{\mathrm{std}}} E_0 \ . \tag{Eq.25}$$

Now the ambient contrast for specular sources can be estimated using our new required luminance L_0,

$$CR_A = \frac{L_{[dark,w]} + \zeta_{on} L_A}{L_{[dark,k]} + \zeta_{off} L_0} \tag{Eq. 26}$$

For total contrast value in combined specular and diffuse environment is

CRds = (L white @ dark +Reflected Diffuse Component + Reflected Secular Component) / (L black@dark + Reflected Diffuse Component + Reflected Secular Component)

$$CR_{amb,ds} = \frac{L_{[dark,w]} + \left(\frac{\beta_W E_d}{\pi} + \zeta_{on} L_0 \right)}{L_{[dark,k]} + \left(\frac{\beta_K E_d}{\pi} + \zeta_{off} L_0 \right)} \quad \text{(Eq. 27)}$$

NOTE:

1. This assumes that the primary reflection property of the display is specular or specular with a peaked haze component and even matrix scatter. It also assumes that the reflectance for white and black is about the same as with the display off. This assumption must be verified and may not be applicable for transflective displays
2. Both standard diffuser and mirror must be small thickness and parallel with display surface.

For most displays except transflective type it is recommended that $\beta_w = \beta_k$ and β_k is used (see #3.23), same for ζ_{on} and ζ_{off} usage of ζ_{off}.

5. LUMINANCE UNIFORMITY

5.1 Full Screen Uniformity

The measurement should be performed in a dark room.

STEP 1: Display the full screen image

a. Black (or 10% of maximum white screen luminance) for the LNU_{BK}.

b. White for white luminance non-uniformity LNU_W.
Both values should be measured.

STEP 2: Perform the measurement:

a. Use the measurement points defined in Figure 6. The maximum spot size is the smaller of 0.2*H or 0.2*V. The minimum spot size should cover at least 10 pixels.

STEP 3: Calculate LNU based on formula (Eq.5)

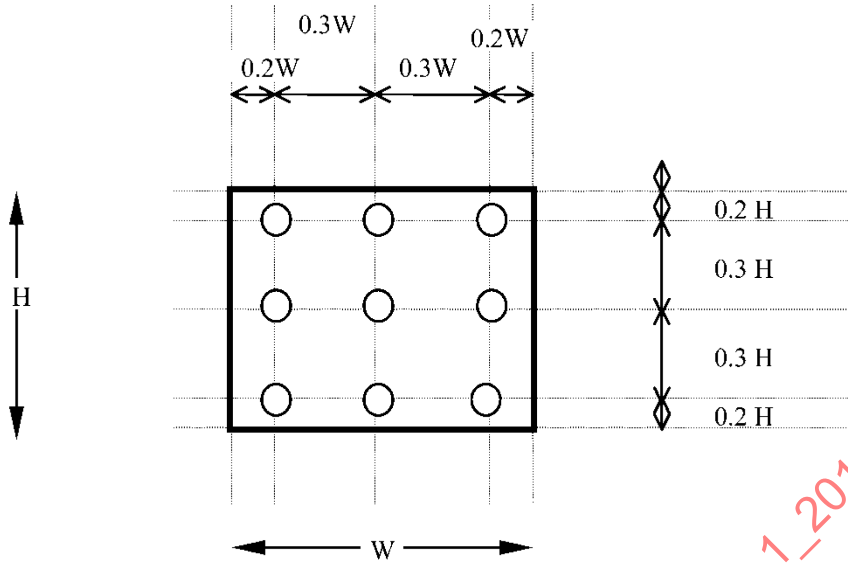


Figure 6 - Points for non-uniformity measurements

5.2 Luminance Non-Uniformity Due to Burn in Static Images (Differential Aging)

WARNING: This test may damage the display irreversibly.

STEP 1: Age a specific area of the display

a. Display the test image 1, white square in the center of the display, (see Figure 7) for $t_{burn\text{-}in}$ = 500 hours continuously, at room temperature. Then measure LNU (full screen 50% white / 50% brightness) in the points shown in Figure 7.

STEP 2: Perform the measurement

a. Use the points of measurement defined in Figure 7.

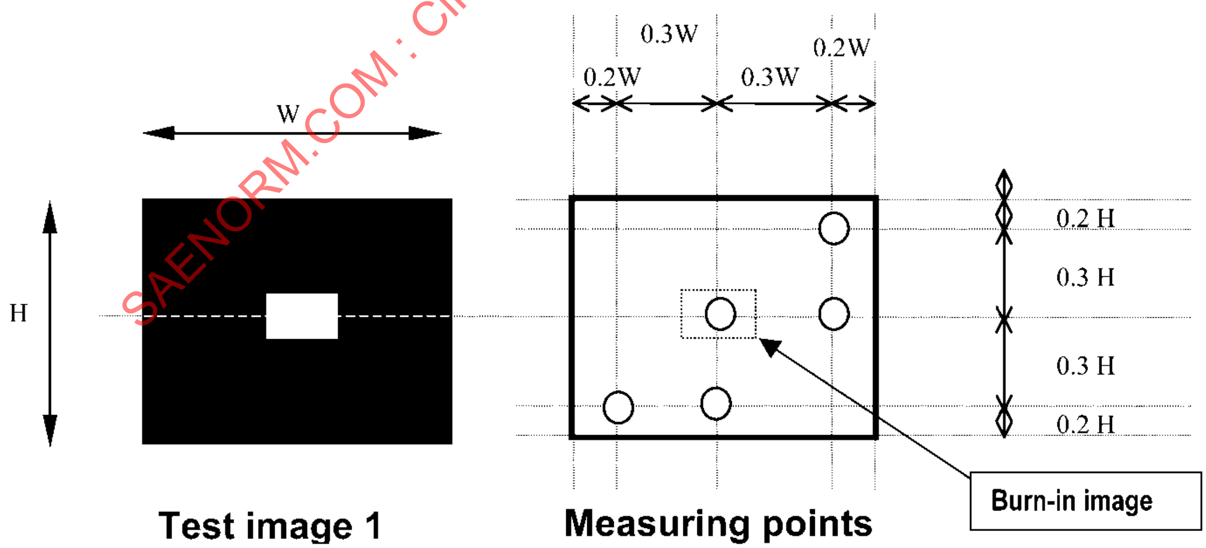


Figure 7 - Test image and measuring points for burn-in NU

5.3 Luminance Non-Uniformity Due to Image Content ("Cross Talk")

STEP 1:

a. Display the Test Image 2 (three white squares in the corner of the display on the black background, Figure 8).

STEP 2: Perform the measurement, use the points of measurement presented in the Figure 8.

STEP 3: Calculate Image LNU due to cross talk:

a. Use formula (Eq.5) for the LNU in the points of measurement specified in the Figure 8.

b. Then display the complementary of the Test Image 2 (three black squares on the white background) and follow the same procedure.

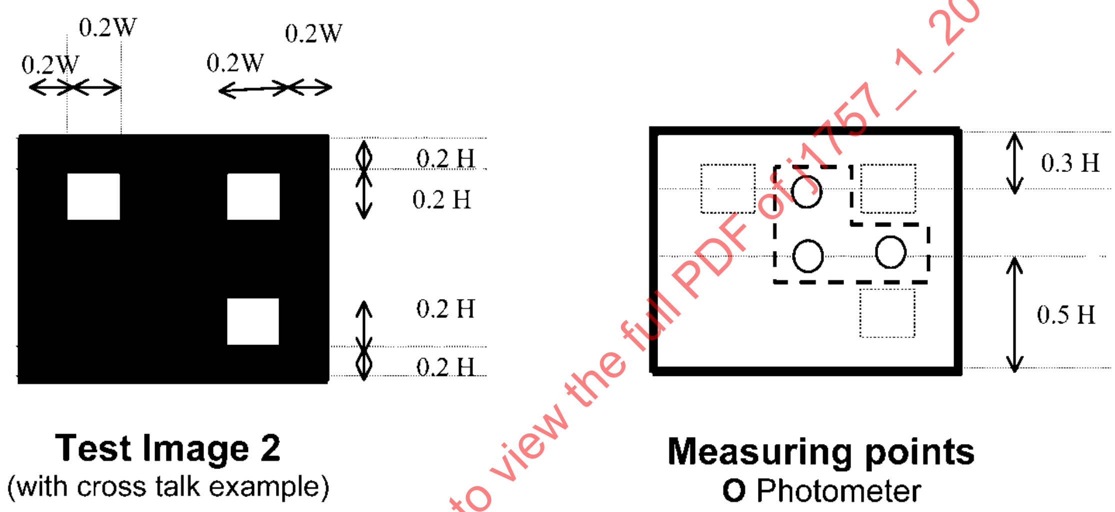


Figure 8 - Test image and measuring points for image LNU (cross talk)

5.4 Luminance Balance

Luminance balance (B_L) is measured in vehicle as the ratio between the average luminance of the display in its active area with all pixels in bright state (white or default background color) and the average luminance of the immediate surrounding as described in the Figure 9. The measurements shall be taken in both dark (night balance) and daylight (day-balance).

$$B_L = L_{avg.d} / L_{avg.b} \quad \text{(Eq. 28)}$$

where:

$L_{avg.d}$ is the average luminance of the display
$L_{avg.b}$ is average luminance of the surrounding (border area)

The daylight measurement should be performed in high ambient conditions defined in 4.1.2.4 for the light direction, and the photometer in the center of the eye-ellipses.

The light from the diffuser should cover more than 150% of the display active area (display and its border area).

NOTE: The ratio B_L should not exceed 10:1 or be less than 1:10. Higher ratios are often acceptable. However a ratio of 100:1 or 1:100 would be expected to produce a drop in performance

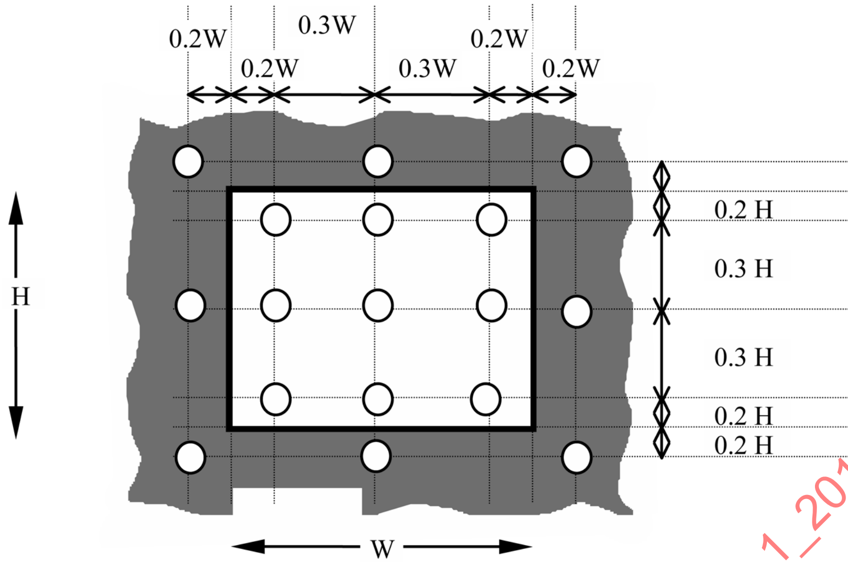


Figure 9 - Luminance balance measurement

6. COLOR UNIFORMITY

Color Uniformity is a measure of how constant is the color between any points (actually very small areas such as the measuring points defined in the Figure 6). There is a “Pixel color Non-Uniformity”, characterized by color variation within the surface of the pixel and “Display color Non–Uniformity” characterized by color variation between “averaged” areas (tens of pixels). For the purpose of this document we should consider only Display Color NU for the points defined by Figure 6.

For Color measurements Uniform Chromaticity Scale 1976-CIE (L’, u’, v’) is recommended.

The color separation (distance between two points on this scale) is given by:

$$\Delta u'v' = \left[(u_1' - u_2')^2 + (v_1' - v_2')^2\right]^{1/2} \quad \text{(Eq. 29)}$$

$$\Delta L' = L_1' - L_2' \quad \text{(Eq. 30)}$$

The human eye perception of the total color variation (ΔE or JND) is a function of the above variables (ΔL’ and Δu’v’). Because there are several options in the industry to define ΔE or JND and all have specific advantages but also all are related to the above variables (ΔL’ and Δu’v’) we recommend both parameters to be specified for color non-uniformity. For the same Luminance, a Δu’v’ = 0.04 is considered discernable (if the display areas do not touch, the value is smaller if surfaces are side by side).

7. NOTES

7.1 Marginal Indicia

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE VEHICULAR FLAT PANEL DISPLAY STANDARDS COMMITTEE

APPENDIX A - AMBIENT LIGHT ILLUMINATION ON THE EARTH SURFACE

A.1 The sun is a point source, but when light rays interact with the earth, two types of light rays are created, direct sunrays and indirect (scattering) sunrays. Direct sunrays are those that come through the earth's atmosphere scattered in phase causing little change in direction (all light is scattered). Indirect sunrays (we will call it sky light) sunrays are actually rayleigh scattering (named after lord rayleigh) and are caused by the earth's atmosphere. They are randomly scattered (no specific direction) depending on the density of the atmosphere. Figure A1 ambient light illumination on the earth surface and figures a2a and a2b ambient illumination in front of the instrument cluster meter illustrates the dual characteristic of the ambient illumination (direct and diffuse)".

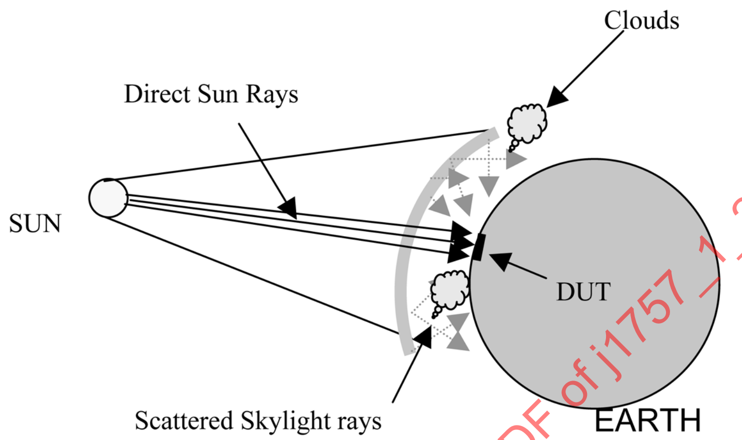


Figure A1 - Ambient light illumination on the earth surface

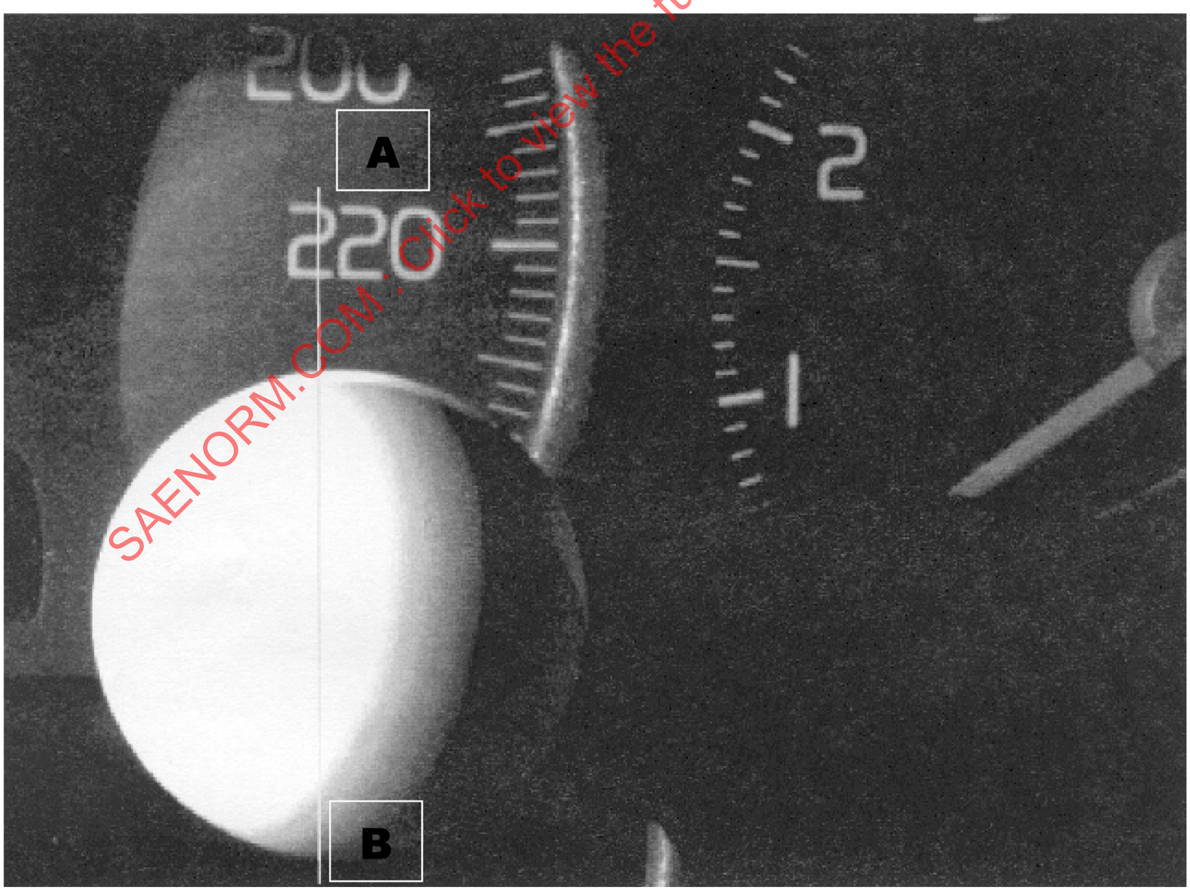


Figure A2A - Ambient light illumination of a spherical diffuser positioned in car in front of a typical instrument cluster meter - (digital image)