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Road vehicles — Ergonomic aspects of transport information and control systems — Specifications and compliance procedures for in-vehicle visual presentation

Véhicules routiers — Aspects ergonomiques des systèmes de commande et d'information du transport — Spécifications et modes opératoires de conformité pour la présentation visuelle à bord du véhicule

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15008 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 13, *Ergonomics applicable to road vehicles*.

Introduction

Driver and vehicle form an integrated system that includes the environment, the primary vehicle controls, the instrumentation and the transport information and control systems (TICS). The driving task, as well as human capabilities and limitations, are other important factors in the performance of this system.

TICS are intended to support the driver in his or her primary task, and it is therefore expected that the overall workload of the driver will not be negatively influenced by their use, while performance and comfort are increased.

The visual characteristics of display systems are only one set of factors influencing this process. They therefore have to be considered, along with human capabilities, in relation to the other elements of the driving environment.

Visual specifications fall within a wide range of environmental conditions, and constitute only a necessary condition for adequate performance, comfort and workload. Thus they refer to the relevant range of illumination conditions and to the location of the display with respect to the driver.

Road vehicles — Ergonomic aspects of transport information and control systems — Specifications and compliance procedures for in-vehicle visual presentation

1 Scope

This International Standard gives minimum specifications for the image quality and legibility of displays containing dynamic (changeable) visual information presented to the driver of a road vehicle by on-board transport information and control systems (TICS) used while the vehicle is in motion. These specifications are intended to be independent of display technologies, while test methods and measurements for assessing compliance with them have been included where necessary.

This International Standard is applicable to mainly perceptual, and some basic cognitive, components of the visual information: these include character legibility and colour recognition. It is not applicable to other factors affecting performance and comfort such as coding, format and dialogue characteristics, or to displays using

— superimposed information on the external field (e.g. head-up displays),

— pictorial images (e.g. closed-circuit TV for reversing),

— maps and topographic representations (e.g. those for setting navigation systems), or

— static information (e.g. control labels, telltales).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2575, *Road vehicles — Symbols for controls, indicators and tell-tales*

ISO 4513, *Road vehicles — Visibility — Method for establishment of eyellipses for driver's eye location*

ISO 9241-3:1992, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 3: Visual display requirements*

CIE[1] 15.2, *Colorimetry*

CIE 17.4, *International Lighting Vocabulary*

CIE 85-1989, *Solar spectral irradiance*

1) Commission Internationale de l'Eclairage/International Commission on Illumination.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. For terms and definitions relations to photometric quantities, including illuminance, luminance, luminance contrast, luminance modulation, saturation, chromatic aberration and CIELUV, see CIE 17.4.

3.1
adaptation
adjustment of the eye's sensitivity to the brightness of the observed visual field

NOTE Dark adaptation occurs at a slower rate than does light adaptation.

3.2
blink
intended periodic variation of the luminance of a light or visual information, normally from "OFF" to a given value, typically used for attracting attention

3.3
brightness
subjective attribute of light sensation by which a stimulus appears to be more or less intense or to emit more or less light

3.4
critical specular line
CSL
line from the centre of the display to the centre of the eyellipse

3.5
critical specular light direction
CSLD
line symmetrical to the CSL in respect of the normal direction to the centre of the display

3.6
critical specular light cone
specular light cone with apex angle $\varepsilon + \beta$ (10°) all around

3.7
chromatic
having hue or being coloured: appearing different in quality from a neutral grey having the same brightness

NOTE Related to the colour properties of a visual stimulus.

3.8
contrast ratio
C_R
ratio between the luminance L_{high} of an area in its "bright" state (e.g. the strokes of a character in the case of negative polarity) and the luminance L_{low} of the same area in its "dark" state

3.9
fill factor
⟨matrix display⟩ ratio between the area occupied by the physical pixel area and the active pixel area

3.10
flicker
unintended perceived temporal variation of the brightness of a visual stimulus, usually generated by refresh displays such as cathode ray tube devices

3.11
glare
⟨disability⟩ dazzling (disabling) effect produced by a bright light: retinal effect, primarily caused by light scatter in the eye, which produces a luminous veil over the retinal image, and thus reduces contrast

3.12
glare
⟨discomfort⟩ distracting or disrupting effect of bright point sources in the field of view: perceptual effect, interfering with visual attention and selection

3.13
jitter
unintended periodic movement of an image or parts of it

3.14
legibility
visual properties of a character or graphics representation that determine the ease with which it can be recognized

3.15
map
representation on plane surface of the features of a connected part of the earth surface (especially of the road and traffic environment), shown in their representative forms, sizes and relationship according to some convention of representation

3.16
pixel
⟨general⟩ smallest selectively addressable area of a display

NOTE It is an abbreviation for “picture element.”

3.17
pixel
⟨multicolour display⟩ smallest selectively addressable area of the display capable of producing the full colour range

3.18
polarity
relationship in a display between the brightness of a symbol and background

NOTE It is negative if symbols are lighter than the background, positive if symbols are darker than the background.

3.19
raster
ensemble of the adjacent lines in a display composed by sequentially addressable points

3.20
resolution
ability of display to represent fine detail

NOTE It can be expressed quantitatively in terms of the number of distinguishable lines per unit length or subtended angle.

3.21
segment
pixel with definite geometric form to give a basic entity of a character or symbol

EXAMPLE Stroke.

3.22
specular light cone
cone symmetrical to the viewing cone in respect of the normal direction to the centre of the display

3.23
transparent diffuser
material that allows the light to pass through it while scattering the light evenly in all directions

EXAMPLE Sanded white glass, white Mylar[2)].

3.24
viewing cone
cone with opening angle, ε, formed by lines from the centre of the display tangential to the eyellipse surface

3.25
night
condition under which the adaptation level of the driver is mainly influenced by

— the portion of the road ahead covered by the vehicle's own headlights and surrounding street lights, and

— display and instrument brightness

See 4.2.2.

3.26
day
condition under which the adaptation level of the driver is mainly influenced by the external environment of a cloudy sky

See 4.2.2.

3.27
sunlight
condition under which the viewing conditions are mainly influenced by direct light from the sun on the display surface

See 4.2.2.

4 Specifications and measurement methods

4.1 General

The following minimum specifications have been chosen to help ensure that visual displays used in TICS are legible. The specifications are accompanied by standard measurement conditions in terms of ambient illuminance and observer positions.

4.2 Design viewing position and illumination range

4.2.1 Design viewing position

These specifications are applicable to displays in their installed vehicle locations as seen from any point in the 95th percentile driver eyellipse according to ISO 4513 (for passenger vehicles only). Four viewing angles shall be defined, in accordance with Figure 1, from the display centre to the opposite sides of the top and side view eyellipses, and referred to the display perpendicular direction. The 95th percentile eyellipses shall be used.

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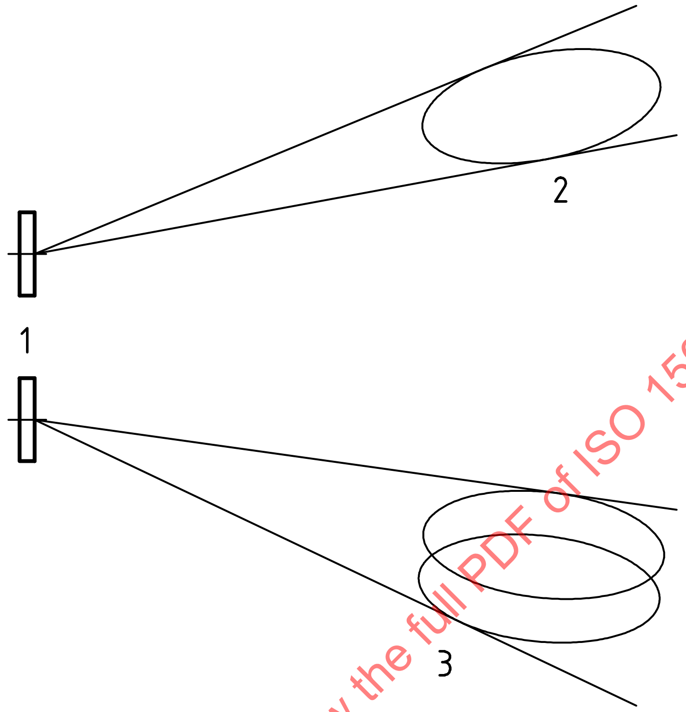
2) Mylar is the trade name of a product supplied by DuPont. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

If the display is fixed to the vehicle, the relevant specifications shall be complied with for each of the four angles. If the angle and position of the display are adjustable, the display may be adjusted for each viewing angle in order that a position can be found in which all the relevant specifications are complied with simultaneously.



Key

1 display
2 side view
3 top view

Figure 1 — Design viewing angles (display at right-hand side of driver)

4.2.2 Illumination range

The design illumination range establishes the three conditions of *night*, *day* and *sunlight*.

— Night condition is replicated in a dark environment such that the maximum illuminance on the object to be measured shall not exceed 2 lx.

— Day condition is replicated with ambient light omni-directional to the point of measurement. The ambient light measured on the surface of the display (on the standard diffuse reflector) shall be 3 klx. See Annex A for suggested methodologies.

— Sunlight condition is replicated with a standard measurement condition. The light intensity at the point of measurement shall measure $\geqslant$ 45 klx. See Annex B for details.

For day and sunlight conditions, an artificial illumination system with light type close to that of CIE 85:1989, Table 4 ($\pm$ 20 %) shall be used. Light sources with large spikes in the spectrum (such as fluorescent lamps) should be avoided. The colour temperature is secondary to this issue.

Due to the very wide range of ambient illuminations that determine the adaptation level of the driver, a brightness control which allows adjustment over a suitable range should be provided.

4.3 Luminance contrast

4.3.1 Minimum contrast

The minimum contrast ratio (higher to lower luminance) between symbol and background shall be

— 5:1 for night conditions,

— 3:1 for day conditions, and

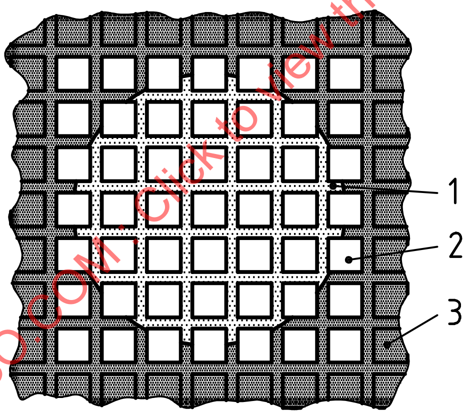
— 2:1 for sunlight conditions.

This is especially important if characters are close to the minimum specifications for the dimensions (see 4.5). Lower contrast should be avoided unless dimensions are properly increased or the reading task is simple or when both these apply.

The contrast ratio shall be calculated from two measurements in the centre of the display. For matrix display, the measurements shall be taken with a luminance meter having a field of view (FOV) of 10′ to 20′ over an area covering at least 5 × 5 pixels (see Figure 2).

For segment displays, the measurement shall be taken within a single segment using a luminance meter having a FOV angle of 10′ to 20′. The diameter of the collection area shall be less than 80 % of the relevant dimension of the segment to be measured, for all measurement directions.

The measurements shall be taken at four angles, derived in accordance with 4.2.1, in night and day conditions.



Key

1 collection area

2 pixel “bright”

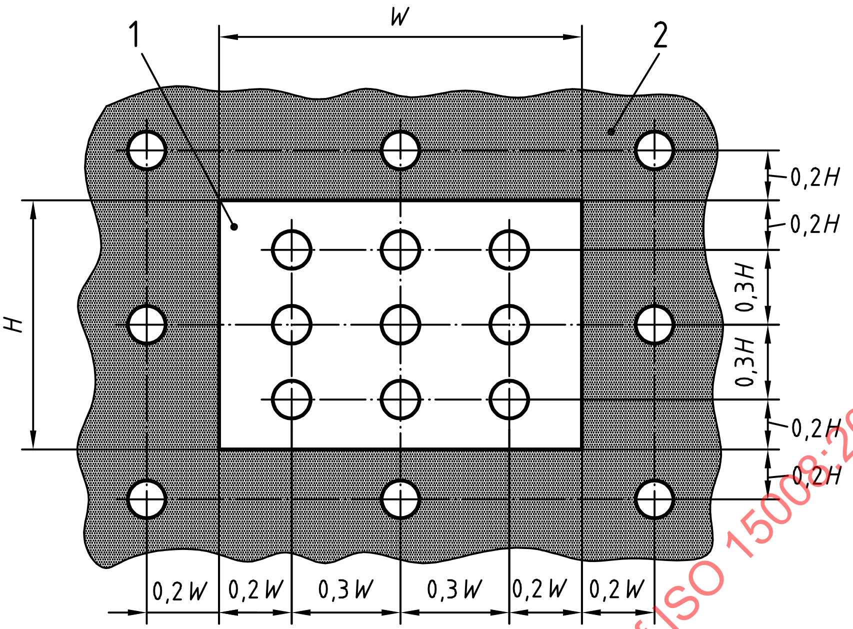
3 pixel “dark”

Figure 2 — Measurement on matrix displays

4.3.2 Luminance balance

The ratio of area average luminance of the display and of the surrounding (luminance balance) should not exceed 10:1 (higher to lower luminance). Higher ratios are often acceptable. However, a ratio of 100:1 (higher to lower luminance) would be expected to produce a small but significant drop in performance.

Luminance balance is measured as the ratio between the average luminance of the display over nine points in its active area with all pixels in bright state and the average luminance over eight points of the immediate surrounding as shown in Figure 3. The measurements shall be taken in daylight. The measurement direction shall be determined by a line passing through the centre of the display and the centre of the eyellipses as shown in Figure 4. The other points shall be reached by rotating the measuring instrument.

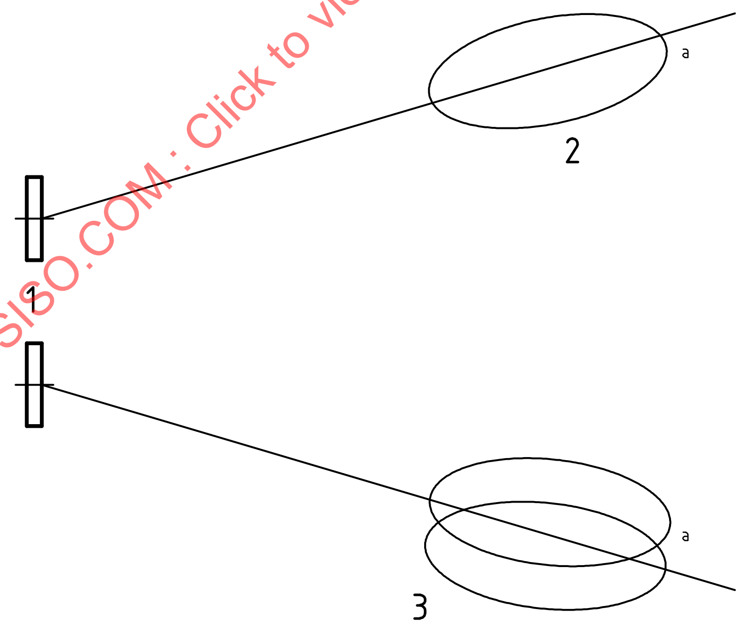


Key

1 display

2 surrounding

Figure 3 — Luminance balance measurement



Key

1 display

2 side view

3 top view

[a] Mean value of eyellipse.

Figure 4 — Measurement angles for luminance balance (display at right hand side of the driver)

4.3.3 Polarity

Display luminance is intended as the symbol luminance if the display is driven in negative polarity (i.e. light symbols on a dark background), or as the background luminance if the display is in positive polarity (i.e. dark symbols on a light background).

Either polarity is known to give satisfactory performance. The choice is determined by the area average luminance of those areas frequently viewed in sequence. Therefore, negative polarity should be used under the *night* condition. In *day* condition both are acceptable, while taking into account the often dark immediate surroundings of displays in vehicles (i.e. the dashboard). For non-sheltered displays, positive polarity can be preferable for reducing the visibility of reflections.

4.4 Colour

4.4.1 Colour combinations

When a symbol and its background are of different colours, minimum luminance contrast (see 4.3.1) shall be provided. For physiological and psychological reasons, not all symbol/background colour combinations are acceptable. Because of this, when selecting colours in full multicolour displays, symbol/background colour combinations should be chosen in accordance with Table 1.

Table 1 — Symbol/background colour combinations

Background colour	Symbol colour						
	White	Yellow	Orange	Red[a], Purple	Green, Cyan	Blue[a], Violet	Black
White		–	o	+	+	++	++
Yellow	–		–	o	o	+	++
Orange	o	–		–	–	o	+
Red[a], Purple	+	o	–		–	–	+
Green, Cyan	+	o	–	–		–	+
Blue[a], Violet	++	+	o	–	–		–
Black	++	++	+	+	+	–	

++ Preferred

\+ Recommended

o Acceptable with high saturation differences

– Not recommended

[a] Pure red and blue should be avoided because the eyes may have trouble focusing on these colours because of eye chromatic aberration.

4.4.2 Colour discriminability

For minimum colour discriminability, there shall be a minimum colour difference of $\Delta E_{UV} = 20$, in accordance with the ΔE_{UV} colour difference metric defined in the CIE 1976 colour space model CIELUV (See CIE 15.2:1986). Reference white is the white produced by the display. The measurement shall be taken using a colour meter with a FOV of 20′ with the same geometry used for the luminance contrast measurement, and shall be performed for all colours intended to be used for colour coding, both in night and day conditions. All relevant pairs of colours shall be evaluated using this ΔE_{UV} colour difference metric. Reference white is the white produced by the display in each condition.

4.4.3 Colour contrast

For legibility, the relevant metric (standard of measurement) is luminance contrast (see 4.3.1).

4.5 Alphanumerical character dimensions (see Annex C)

4.5.1 Height

For alphanumeric characters, height — measured as the subtended angle from the farthest design view point — shall be in accordance with Table 2.

4.5.2 Width-to-height ratio

The alphanumeric character width-to-height ratio should be between 0,6 and 0,8. A wider range of from 0,5 to 1 is acceptable, especially if factors such as line length or proportional spacing are important.

4.5.3 Stroke width-to-height ratio

The alphanumeric characters' stroke width-to-character height ratio shall be between 0,08 and 0,16.

Table 2 — Character heights

arcminutes	radians[a]	**Suitability level**
24	$6,98 \times 10^{-3}$	Recommended
20	$5,82 \times 10^{-3}$	Acceptable if colour is a coding dimension
18	$5,24 \times 10^{-3}$	Acceptable if colour is not a coding dimension
15	$4,36 \times 10^{-3}$	Conditional[b]

[a] If multiplied by the viewing distance, it gives (in the same units) the actual character height.

[b] When requirements for accuracy and speed of reading are modest, or when readability is incidental to the task (e.g. subscripts).

4.5.4 Spacing

For character fonts without serifs, the between-character spacing shall be a minimum of one stroke width. If characters have serifs, the between-character spacing shall be one stroke width between the serifs of adjacent characters.

A minimum of one character width ("N" for proportional spacing) shall be used between words.

A minimum of one stroke width shall be used for spacing between lines of text. This area may not contain parts of characters or diacritics.

For displays with discrete pixel matrices the character dimensions shall be measured using a measuring microscope of at least 20 × magnification.

For displays with pixels having continuous luminance distributions microphotometric techniques shall be used in accordance with Annex C (see also ISO 9241-3:1992, 6.6).

4.6 Pixel matrix character format

4.6.1 Upper and lower case

A 5 × 7 (width-to-height) character matrix shall be the minimum used for alphanumeric characters. If lower-case letters are used, or the legibility of individual alphanumeric characters is important for the task, a 7 × 9 (width-to-height) character matrix should be the minimum.

4.6.2 Diacritics

The alphanumeric character matrix shall be increased upwards by at least two pixels if diacritics (e.g. Ö, Ñ, Å, È) are used. If lower-case letters are used, the character matrix shall be increased downwards by at least two pixels, to accommodate the descenders.

4.6.3 Subscripts or superscripts

A 4 × 5 (width-to-height) alphanumeric character matrix shall be the minimum for

— subscripts and superscripts,

— numerators and denominators of fractions displayed in a single-character position, and

— information unrelated to the task [e.g. the copyright symbol (©)].

4.6.4 Automotive symbols

For automotive symbols in accordance with ISO 2575, or similar, a 32 × 32 matrix should be the minimum.

NOTE See Annex D for additional recommendations on pixel characteristics for CRT and non-CRT matrix displays.

The number of pixels shall be determined by counting them on a suitable set of characters and symbols. If necessary, a magnifying device or magnified images may be used.

4.7 Reflections and glare

Reflections and glare visible by the driver should be minimized. Additional reflection- and glare-reduction or contrast-enhancement techniques, if used, shall not cause the display to deviate from the requirements of this International Standard.

4.8 Characteristics of presentation

4.8.1 Image stability

The image should be free from temporal instability (*flicker*) and spatial instability. One factor of spatial instability is peak-to-peak variation in the geometric location of the image within the display (*jitter*): it shall not exceed 0,000 2 of the shortest viewing distance.

NOTE Additional factors contributing to spatial image stability, such as display vibrations generated by the vehicle, are not considered in this International Standard.

For displays with pixels having continuous luminance distributions only, jitter may be measured using a measuring microscope of at least 20 × magnification. The movement is determined by visual alignment of the microscope cursor or comparator reticle with the extreme positions of the centroid or the edge of a character or test object during the observation period.

For any display type, a special display-measuring device may be used. This device shall be used to determine, on a scan-by-scan basis, the relative location of a character or test object. If the device used determines movement along the horizontal and vertical axes separately, the extent of the jitter shall be defined as the square root of the sum of the squares of the maximum horizontal and vertical differences.

Observations shall extend for periods of at least 4 s of continuous observation (see also ISO 9241-3:1992, 6.6.14).

4.8.2 Image blinking

Image blinking should be used only to attract attention and inform about critical conditions requiring immediate action. For attracting attention, a single blink frequency of 2 Hz to 4 Hz with a duty cycle of 50 % should be used. If legibility of the displayed information content is required, a single blink rate of 1/3 Hz to 1 Hz with a duty cycle of 70 % is recommended.

The blinking rate shall be measured using a luminance meter aimed at the blinking picture element (i.e. a pixel or segment) located in the display centre. The meter shall be capable of delivering the time varying luminance values with a low-pass cut-off frequency of at least ten times the highest frequency to be measured. The signal shall be processed with an oscilloscope or similar instrument with adequate bandpass in order to obtain the “ON” and “OFF” duration as the duration at the average between minimum and maximum luminance. From the duration in seconds, the equivalent frequency in hertz shall be obtained. For pulse width modulated backlight, the effect of the backlight variation shall be considered (e.g. triggering of oscilloscope); alternatively, a continuous stable backlight should be used for these measurements.

Annex A
(informative)

Daylight contrast measurement method

A.1 General

A variety of methods can be used. The measured illuminance on the surface of the display (on the standard diffuse reflector) shall be ⩾ 3 klx.

A.2 Method 1

Place the entire display in an integrating sphere so that the display is tilted at an angle, θ, with respect to the measurement axis. The integrating sphere will have one port to view the display, one port for the light source and one port for the photometer. The photometer is perpendicular to the display for this measurement.

A.3 Method 2

IMPORTANT — Some displays can exhibit a change in performance when even slight pressure is applied to their surfaces. It could be necessary to carefully arrange that the sampling port does not push the display surface (place the sphere within approximately 1 mm of the display surface).

Some displays, particularly those measured *in-situ*, can have glass or plastic covering plates as protection. In such cases, the pixel surface of the display can be so far away from the front surface upon which the sampling sphere is placed that this sampling sphere method will not produce reliable results. In such cases, Method 3 should be employed.

A.3.1 General

The advantage of this, the *sampling sphere* method, is that it may be performed on the isolated display (detached from the car) and, with certain restrictions, on the display integrated in the vehicle.

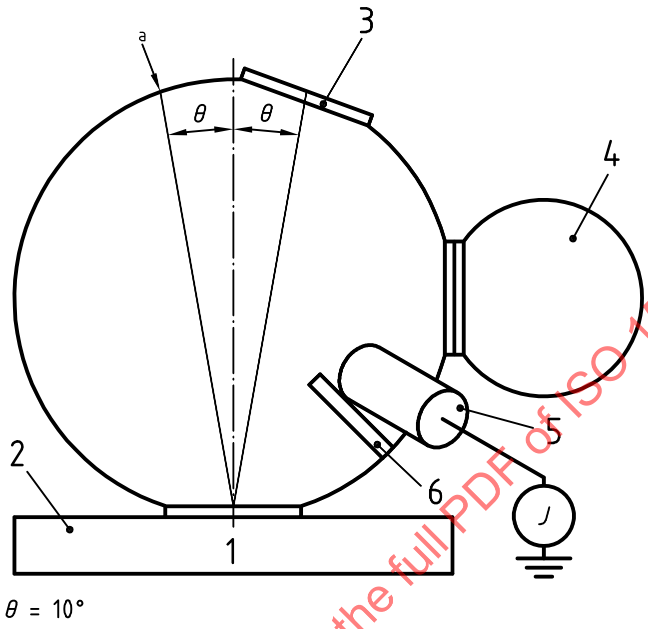
Figure A.1 shows a 100 mm diameter sampling sphere that can be placed upon the surface of the display. If such a sphere is properly baffled, it can provide reproducible results comparable with the large integrating sphere measurements.

Place the sampling sphere upon the centre of a display. Provide a hole through which the luminance shall be measured (the measurement port) in the sampling sphere at an angle of approximately $\theta = 10°$ with respect to the screen and sampling port area. The measurement port and sampling port shall be large enough to allow a good luminance measurement.

The minimum diameter should be approximately 20 % larger than the measurement area diameter of the luminance meter. The measurement port must be of sufficient diameter such that no vignette is produced by the measurement port in the luminance meter optics. All rays from the measured spot shall reach all parts of the lens of the luminance meter without being obstructed by the measurement port.

The luminance meter should be placed far enough back so that its reading is not influenced by the bright internal area surrounding the sample port, which can introduce glare into the measurement; a black tube may be used to prevent light leaks. A baffle shall be provided between the sample port and the lamp source so that no direct rays can hit the display 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 display, the photopic photodiode is not needed for monitoring the illumination. A baffle might 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 display hit the photopic photodiode. (The need for such a baffle will depend upon the construction of the photodiode monitor.)



Key

1 display

2 sample port

3 measurement port

4 lamp

5 monitor

6 baffle

[a] Specular point.

Figure A.1 — Partial cross-section of illuminated sampling sphere with photopic photodiode monitor — Method 1

It might 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 using an integrating sphere and compared with the results before being accepted. In all cases, attention shall 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 shall be given to proper bevelling of the hole. The bevelled ring around the sampling port should be well illuminated by the interior (see cross-section of bevelled port rings in Figure A.1).

A.3.2 Procedure

A.3.2.1 Step 1

Measure the luminance for the information/white colour, L_W, and for the background/black colour, L_{BK}, in dark ambient light (10 lx max.)

A.3.2.2 Step 2 — Calibration of photopic photodiode monitor (see Figure A.2).

Calibrate the photodiode monitor current, J, to reflect the illuminance at the sampling port. Such a calibration can be performed in the following two ways.

a) **Using a white reflectance standard**

Place the sampling port upon a white reflectance standard of known diffuse reflectance, ρ_{std}, and record the luminance, L_{std}, and photodiode current, J_{std}. The illuminance, E_{std}, is related to the luminance by

$$E_{std} = \frac{\pi L_{std}}{\rho_{std}} \quad (A.1)$$

The calibration constant, c, is given by

$$c = \frac{E_{std}}{J_{std}} \quad (A.2)$$

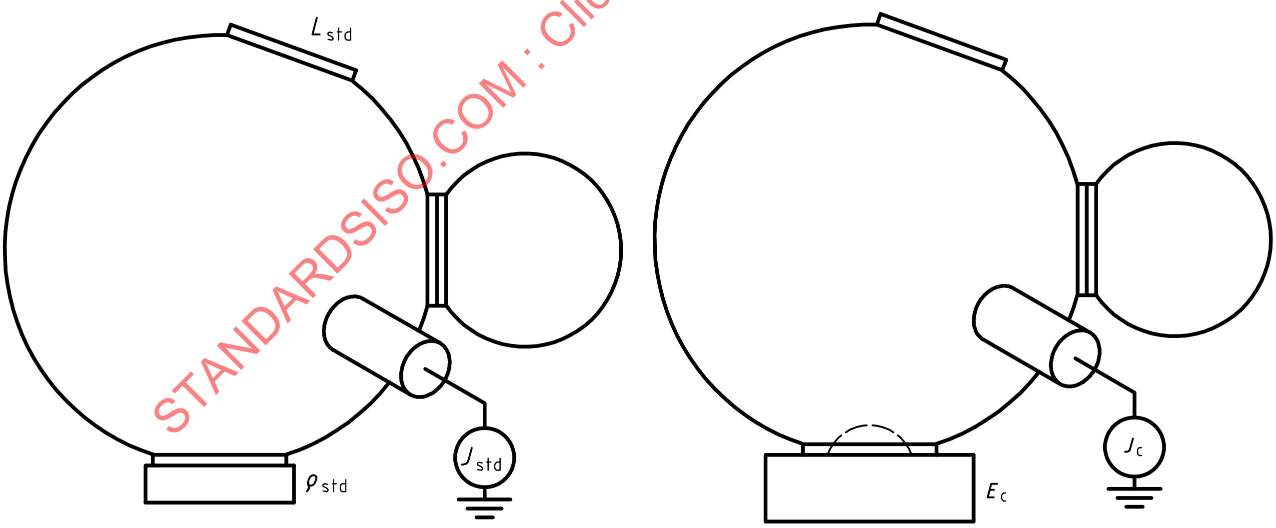
The illuminance, E, for any other configuration can be obtained by measuring the photodiode current, J, with

$$E = cJ \quad (A.3)$$

b) **Using an illuminance meter**

Place the sampling port upon an illuminance meter and record the photodiode current, J_c, along with the illuminance E_c. The calibration constant is given by

$$c = \frac{E_c}{J_c} \quad (A.4)$$



a) Using white reflectance standard **b) Using illuminance meter**

Figure A.2 — Calibration of photopic photodiode monitor by sampling sphere — Method 2

A light source able to provide illumination at least 10 times greater than the maximum (white) generated by the display should be used.

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.

A.3.2.3 Step 3

Place the sphere sample port on top of the display under test. Display a white icon in the point of measurement (may be full-screen white).

Measure the photocurrent, J_h, from the photodiode monitor and the resulting luminance, L_{hW}, of the white icon (see Figure A.2)

A.3.2.4 Step 4

Calculate the diffuse reflectance, ρ_W, for full-screen white mode:

$$\rho_W = \frac{\pi\left(L_{hW} - L_W\right)}{cJ_{hW}} \tag{A.5}$$

A.3.2.5 Step 5

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

A.3.2.6 Step 6

Calculate the diffuse reflectance, ρ_{BK}, for full-screen black mode:

$$\rho_{BK} = \frac{\pi\left(L_{hB} - L_K\right)}{cJ_{hB}} \tag{A.6}$$

A.3.2.7 Step 7

Scale the results for a diffuse illuminance of E_d = 3 klx and calculate the ambient contrast C_d using

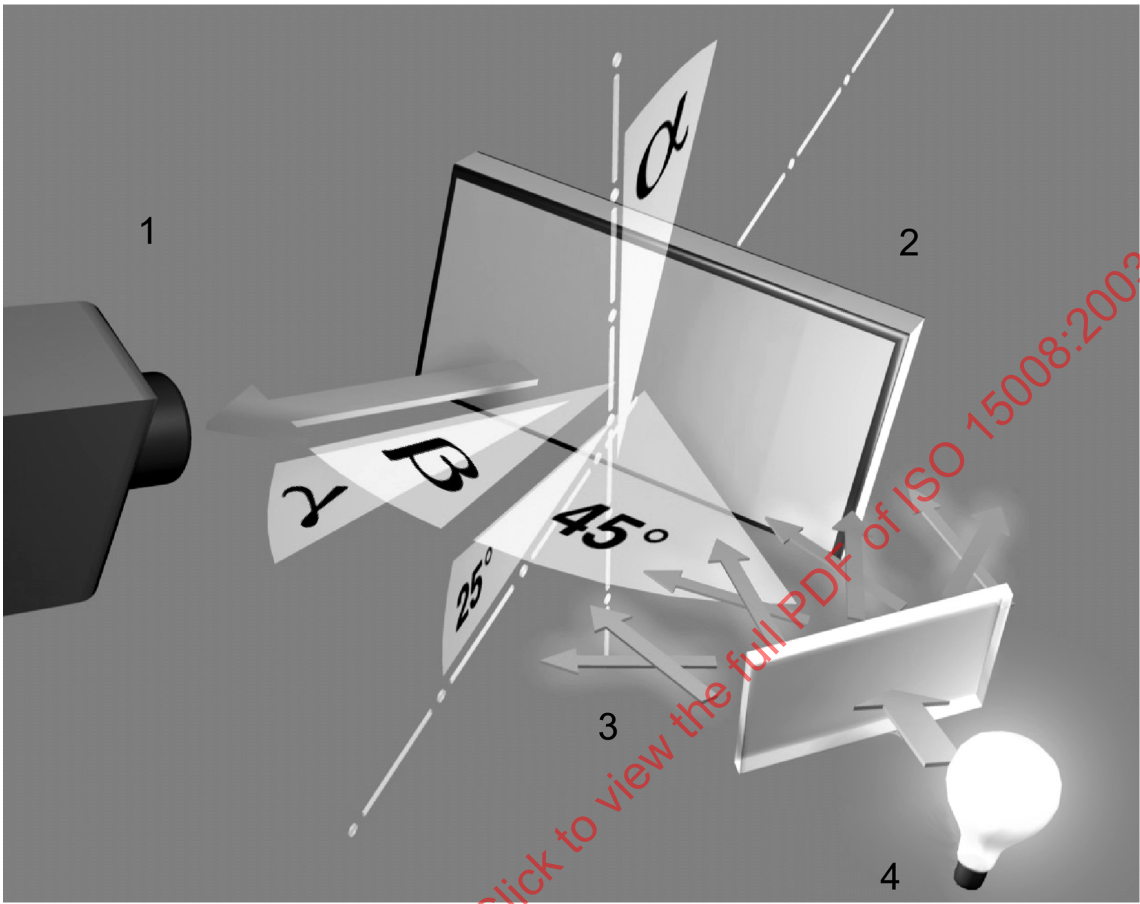
$$C_d = \frac{L_{hW}}{L_{hB}} = \frac{\left(\frac{\rho_W E_d}{\pi} + L_W\right)}{\left(\frac{\rho_{BK} E_d}{\pi} + L_{BK}\right)} \tag{A.7}$$

The determined contrast value is the main information for legibility assessment of the display viewed from normal direction. If other direction of view is needed, the sample sphere should have the means to rotate the measurement port (half of the hemisphere containing the measurement port is rotatable). Precautions should be taken for the placement of the port so that it is not in the direction of the light source or the target for the photocurrent photodiode.

A.4 Method 3

A third method uses a standard light source with horizontal and vertical off-axis angles of 45° and 25° and with a Lambertian diffuser between light source and display (see Figure A.3) to produce 3 klx on the display surface. The display and photometer shall be positioned according to the design viewing angles given in 4.2.1, resulting in four sets of the angles α, β, γ.

Position the transparent diffuser perpendicular to the light source direction and close to the area of measurement. The illumination cone from the transparent diffuser should be at least 90°. Take precautions to avoid veiling glare from the diffuser (or other potential bright sources) illuminating the photometer lens.



Key

1 photometer

2 display

3 lambertian diffuser

4 light source (3 klx at display)

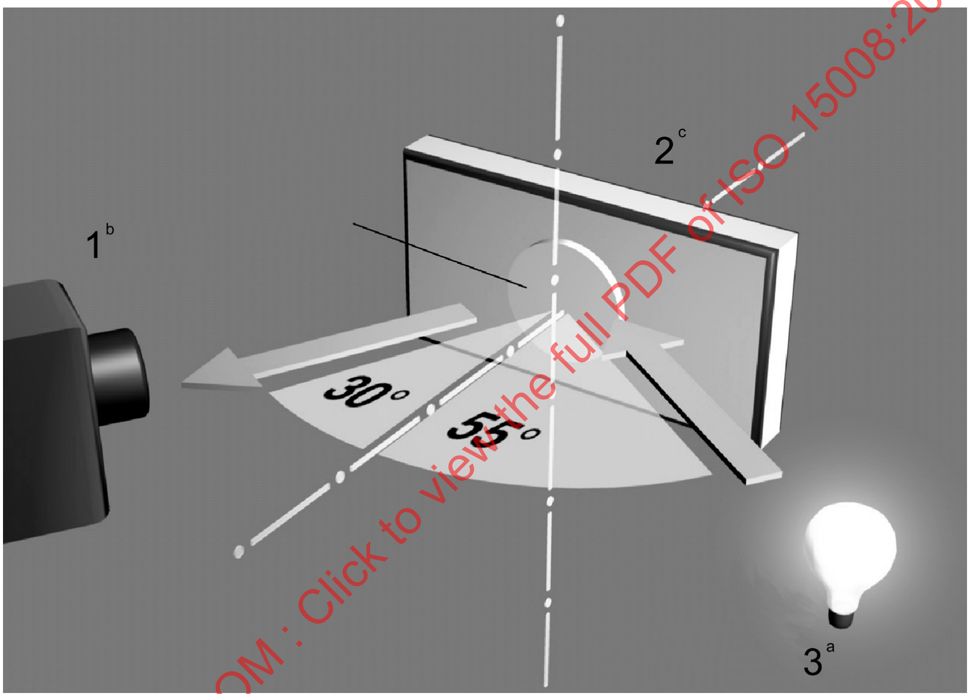
Figure A.3 — Set-up for light source and photometer relative to display position for daylight measurement — Method 3

Annex B
(informative)

Sunlight contrast measurement method

B.1 Standard measurement conditions

The standard measurement conditions are shown in Figure B.1.



Key

1 photometer

2 display

3 light source (45 klx at display)

a 55° from right horizontal.

b 30° left horizontal.

c Upright position (shift relative to upright position is possible for measurement purposes).

Figure B.1 — Standard measurement conditions for sunlight (display at right-hand side of driver)

B.2 Procedure

B.2.1 Step 1

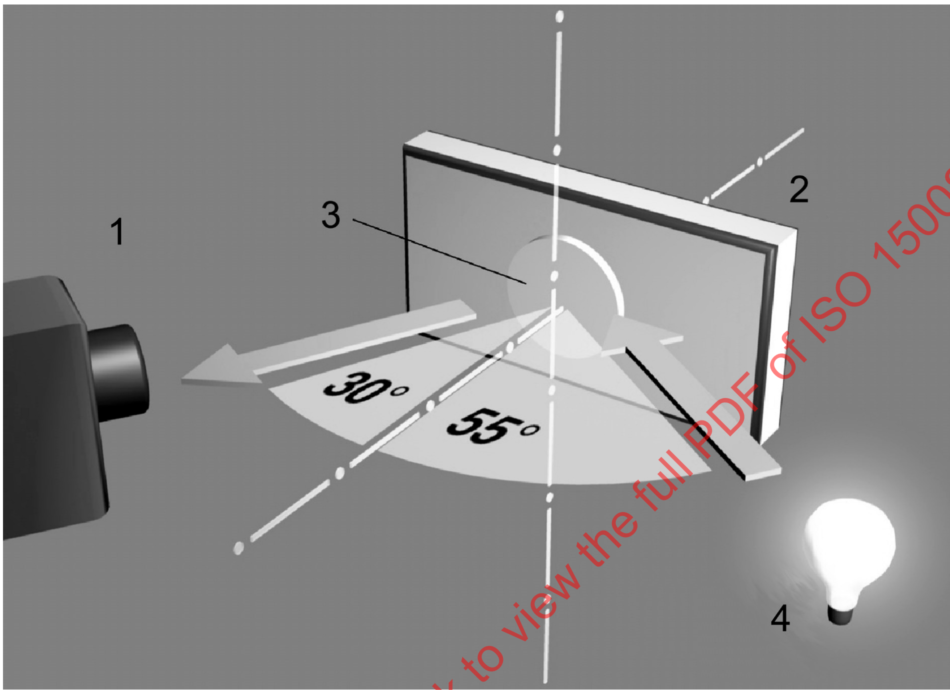
Position the photometer in the default measuring direction 30° off normal.

B.2.2 Step 2

Position the light source direction 55° off normal toward the centre of the display.

B.2.3 Step 3

Position the standard reflective diffuser on the top of the display in the point of the measurement (see Figure B.2).



Key

1 photometer

2 display

3 standard diffuse reflector

4 light source (45 klx at display)

Figure B.2 — Standard diffuse reflector on display surface — 45 klx sunlight condition on surface

B.2.4 Step 4

Adjust the illumination and measure L_{ha} in order to obtain $E_{ha} = 45$ klx from the surface of the standard reflective diffuser.

$$E_{ha} = \frac{\pi L_{ha}}{\rho_{std}} \qquad \text{(B.1)}$$

The diffuse reflectivity standard should be calibrated for the given measurement angles or the coefficient ρ_{std} should be determined for the specific angles.

B.2.5 Step 5

Remove the standard diffuser. Display a black image (background) and a white icon image (information) and measure, respectively, L_{hB} and L_{hW}.

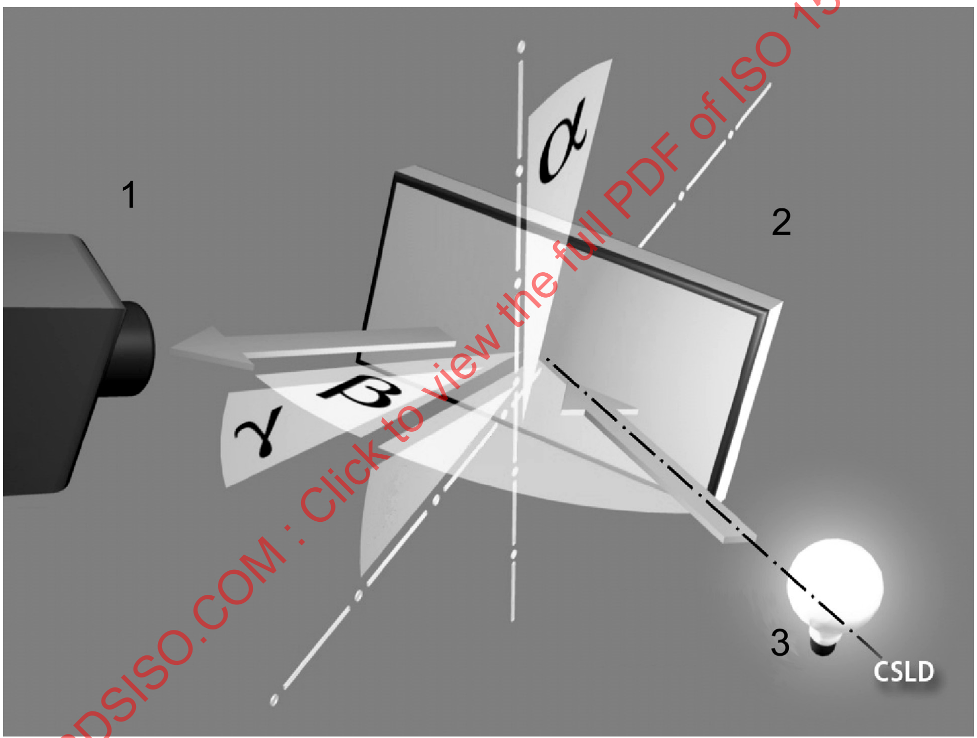
B.2.6 Step 6

Calculate the high ambient illumination contrast ratio C_h:

$$C_h = \frac{L_{hW}}{L_{hB}} \quad \text{(B.2)}$$

B.3 Vehicle-specific method

An alternative, vehicle-specific method, may be used based on the design viewing angles in accordance with 4.2.1. In this case, the angles α, β, γ as shown in Figure B.3 shall be determined according to the display position and eyellipse data specified for a specific vehicle. The direction of the light source may be moved from the standard value of 55° to the vehicle-specific critical light source direction (CSLD) produced by parts of the windshield, side-door window, rear window or sunroof.



Key

1 photometer

2 display

3 light source (45 klx at display)

Figure B.3 — Vehicle-specific measurement conditions