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Road vehicles — Visibility — Specifications and test procedures for head-up displays (HUD)

Véhicules routiers — Visibilité — Spécifications et procédures d'essai pour les affichages tête haute (HUD)

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Foreword

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This document was prepared by Technical Committee ISO/TC 22, *Road Vehicles*, Subcommittee SC 35, *Lighting and visibility*.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document outlines ergonomic specifications, evaluations and test methods for the design and laboratory assessment measurement of head-up display (HUD) displayed image qualities like virtual image distance (X), aspect ratio (Y and Z), luminance, contrast and image height adjustment ranges. This document also outlines procedures for measuring HUD images for the purpose of laboratory assessments, as measured from observation areas defined by an eyebox, and provides the definition of the eyebox from the locating the driver's eyellipse (see ISO 4513).

This document also provides a standard measurement practice of HUD virtual images for HUD bench testing, static and dynamic laboratory test, as well as methods for documenting HUD virtual image attributes such as size, luminance, contrast, field of view, image location adjustment ranges and HUD eyebox attributes using image readability standards from SAE J1757-1, SAE J1757-2, ISO 15008 or other applicable standards where required.

Road vehicles — Visibility — Specifications and test procedures for head-up displays (HUD)

1 Scope

This document provides a common framework of definitions and measurement methods for the design, and ergonomics testing of automotive head-up displays (HUDs) independent of technologies except where noted. Applications in both passenger cars (including sport utility vehicles and light trucks) and commercial vehicles (including heavy trucks and buses) are covered. This document does not include helmet-mounted HUDs or other head carried gear such as glasses.

Areas covered in this document include:

— guidance on how to establish reference points and representative viewing conditions based on vehicle coordinates and ranges of driver's/passenger's eye points;

— descriptions of the HUD image geometry and optical properties measurements;

— definitions of the HUD virtual image and driver vision measurements;

— static and dynamic laboratory tests, and dynamic field operational assessments that include suggested vehicle setup procedures in order to measure HUD image attributes.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 4130, *Road vehicles — Three-dimensional reference system and fiducial marks — Definitions*

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

ISO 16750-2:—[1], *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 2: Electrical loads*

ISO 16750-3:—[2], *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 3: Mechanical loads*

ISO 16750-4:—[3], *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 4: Climatic loads*

ISO 16750-5:—[4], *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 5: Chemical loads*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

1) Fifth edition under preparation. Stage at the time of publication: ISO/FDIS 16750-2:2023.

2) Fourth edition under preparation. Stage at the time of publication: ISO/FDIS 16750-3:2023.

3) Fourth edition under preparation. Stage at the time of publication: ISO/FDIS 16750-4:2023.

4) Third edition under preparation. Stage at the time of publication: ISO/FDIS 16750-5:2023.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms related to vehicules

3.1.1
vehicular coordinate system
three-dimensional reference coordinate system showing the supporting surface of the vehicle as the zero Z plane (horizontal zero plane), the zero Y plane (vertical longitudinal zero plane), and the zero X plane (vertical transverse zero plane) at non-operational conditions

Note 1 to entry: It is defined on a right-handed coordinate system having the x-axis positive pointing opposite of the forward movement direction, z-axis positive being orthogonal to the ground plane and pointing upwards, and the y-axis positive pointing to the right seen in forward movement direction. (See also 3.1.2 for reference grid under operational condition.)

3.1.2
three-dimensional reference grid
longitudinal plane X-Z, a horizontal plane X-Y and a vertical transverse plane Y-Z which are used to determine the dimensional relationships between the positions of design points on drawings and their positions on the actual vehicle when the vehicle coordinates is in operational condition

Note 1 to entry: There can be national regulation applicable which specifies the vehicle operation condition affecting the three-dimensional reference grid which is used in the evaluation procedure of this document. For example, in countries adopting the UN Regulation No. 125, the operation condition determining the three-dimension reference grid is given in the UN Regulation No. 125, 2.3 (See also 3.1.1).

3.1.3
V point
vision point positions in the passenger compartment determined as a function of vertical longitudinal planes passing through the centres of the outermost designated seating positions on the front seat and in relation to the "R" point and the design angle of the seat-back, and are used for verifying compliance with driver's fields of view requirements

3.1.4
H point
pivot centre of the torso and thigh of the 3-D H machine installed in the vehicle seat, and located in the centre of the centre line of the device which is between the 'H' point sight buttons on either side of the 3-D H machine

Note 1 to entry: The H point is detailed in ISO 6549 and it is used to determine the location of the *eyellipse* (3.2.1). The "H point" corresponds theoretically to the "R" point.

3.1.5
SgRP
seating reference point
R point
design point defined by the vehicle manufacturer for each seating position and established with respect to the three-dimensional reference system

Note 1 to entry: The R point is detailed in ISO 6549 and it is used to determine the location of the *eyellipse* (3.2.1).

3.1.6
windscreen datum point
point situated at the intersection with the *windscreen* (3.3.13) of lines radiating forward from the *V points* (3.1.3) to the outer surface of the windscreen

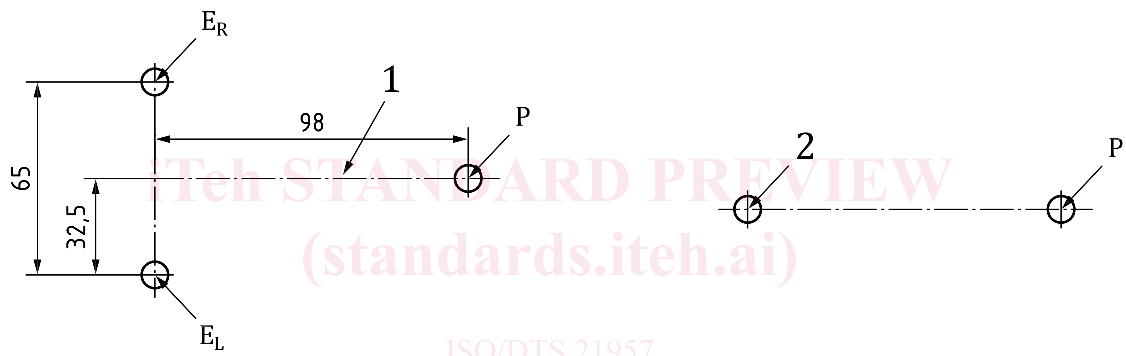
3.1.7
P point
point about which the driver's head rotates when driver views objects on a horizontal plane at eye level

Note 1 to entry: *Head-up display* (*HUD*) (3.3.1) images are presented to the driver intended to be observed with the head oriented in a forward direction (for P3 and P4, see Figure 7). Nevertheless, small head rotation may occur while accessing device for indirect vision with some minor residual head turn around this point (for P1 and P2, see Figure 7).

3.1.8
E point
point representing the centre of the driver's eyes and used to assess the extent to which "A" pillars obscure the field of vision

Note 1 to entry: The E points' definition is adopted from UN Regulation 125 when observing the direction of "A" pillar while the driver's ocular reference point (ORP) defined in 3.3.17 is the centre at forward-facing driver head orientation. See Figure 1 for the correlation of E point to with *P point* (3.1.7).

Dimensions in millimetres



a) Plan view **b) Side view**

Key

E_L left eye

E_R right eye

P neck pivot point

1 driver head centre line

2 line, viewed end on, between E_L and E_R

Figure 1 — Neck pivot point and associated eye points

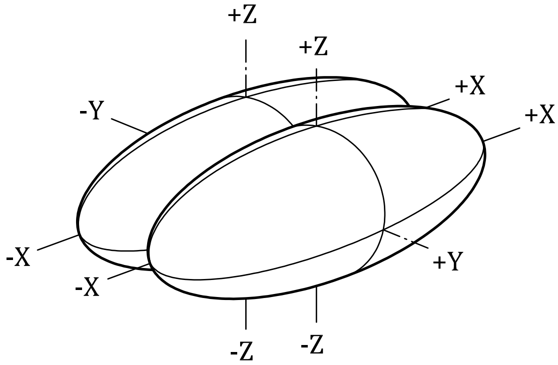
3.1.9
seat-back angle
angle measured between a vertical line through the *H point* (3.1.4) and the torso line using the back-angle quadrant on the 3-D H machine

3.1.10
A pillar
roof support forward of the vertical transverse plane located 68 mm in front of the *V points* (3.1.3) and includes non-transparent items such as *windscreen* (3.3.13) mouldings and door frames, attached or contiguous to such a support

3.2 Terms related to the eyellipse and eyebox

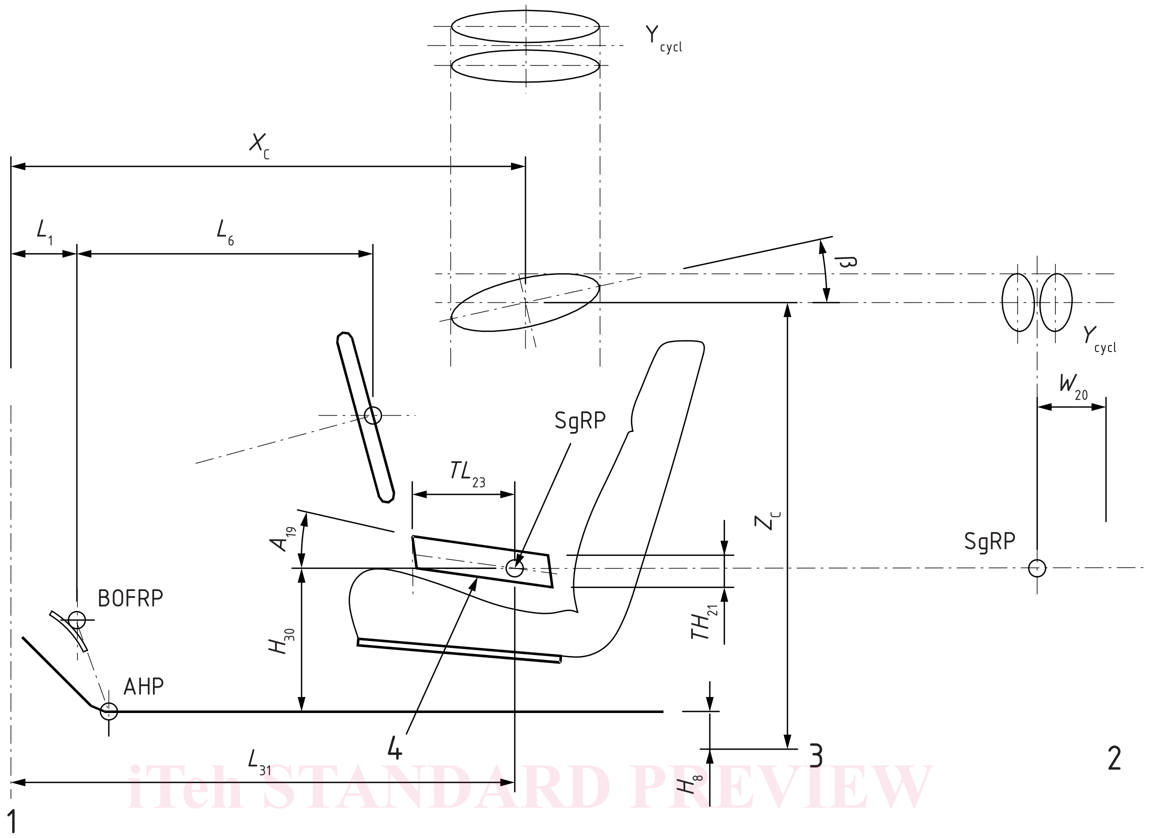
3.2.1
eyellipse
statistical distribution of eye locations in three-dimensional space located relative to defined vehicle interior reference points

Note 1 to entry: Eyellipse is a term derived as a contraction of the words "eye" and "ellipse" and it is defined in ISO 4513. Unless otherwise specified, the eyellipse space in this document refers to the specific eyellipse representing the distribution of the 95 % percentile of driver population as seated in the drive seat. Figure 2 shows an eyellipse model which would be located as shown in Figure 3.



Key
X, Y, Z ellipse axes

Figure 2 — Eyellipse



Key

A_{19}	seat track rise
AHP	accelerator heel point
BOFRP	ball of foot reference point
H_8	z-coordinate of the AHP
H_{30}	z distance of the *SgRP* (3.1.5) from the AHP
L_1	x-coordinate of the BOFRP
L_6	x distance from the steering wheel centre to BOFRP
L_{31}	x-coordinate of the SgRP
SgRP	seating reference point
TH_{21}	H-point vertical adjustment
TL_{23}	seat track travel
W_{20}	y-coordinate of the SgRP
X_c	x-coordinate of the eyellipse centroid location
Y_{cycl}	mid-eye y-coordinate
Z_c	z-coordinate of the eyellipse centroid location
β	side view angle
1	zero X grid
2	zero Y grid
3	zero Z grid
4	H-point travel path

Figure 3 — Location of the eyellipse relative to driver packaging dimensions

[SOURCE: ISO 4513:2022, 3.1, modified — Explanation on "contraction of the words “eye” and “ellipse” used to describe" has been deleted, Figure 3 was added and Note 1 to entry has been replaced.]

3.2.2
eyebox
simplified two-dimensional rectangular box model providing the representative distribution range of the driver's eye reference point for evaluation, encapsulation and having its frame line tangential to the *eyellipse* (3.2.1)

Note 1 to entry: The eyebox is an area covering the entire range of driver with different physical characteristics and a *device under test* (*DUT*) (3.3.25) may not necessarily be capable of conveying visual information within the entire eyebox range without personal adjustment. See also *adjusted viewable HUD window* (3.2.3). It is rather a rectangular vertical plane defined at the centre of the eyellipse and actually it is not a three-dimensional box.

3.2.3
adjusted viewable HUD window
observation eyebox window at adjusted condition
range designed to convey the visual information to the viewer at adjusted condition, within which the image generated by the *device under test* (*DUT*) (3.3.25) satisfies the required image quality condition

Note 1 to entry: The driver's eye position is expected to come somewhere within the *eyellipse* (3.2.1) range. A *head-up display* (*HUD*) (3.3.1) system is often composed of a reflective device transferring image from the imaging device towards the driver's eye, and its visibility is affected by the observation point. To satisfy needs of drivers with different genders or anthropometric characteristics, a system may provide adjustability to satisfy those different needs. A DUT adjusted to a specific eye position shall provide satisfactory image within an expect range of driver head movement.

Note 2 to entry: An HUD system is a system expected to be capable of providing a uniform image quality to the entire eyellipse range without deterioration of the image quality, and this implies to cover a certain acceptable range of eye movement coverage while in operation that may not cause a drastical degradation on the perceived image quality by the driver normal head movements within this specified window. The DUT shall be capable of properly conveying the visual information to at least a defined range characterized according to this constrained window once adjusted by each driver. This auxiliary observation *eyebox* (3.2.2) range is defined as complementary range for image quality evaluation.

Note 3 to entry: If the quality of the image conveyed to the viewer drastically varies within this range, it may induce discomfort. On the other hand, if the quality of the image gradually degrades with the driver head displacement going beyond this adjusted viewable HUD window position, the degradation of the image caused by the displacement of head position will motivate the driver to return his head position to within this window, therefore, to enable such design strategy which may motivate the driver to return his head position within the adjusted viewable HUD window, but it does not prevent to cause degradation when the driver may move his/her eyes beyond this range as a mean to motivate the driver to maintain their head to a certain limited range to be able to access to the visual information conveyed by the HUD. the image quality beyond this range does not necessarily need to fulfil the same image quality as required with driver eye at nominal position.

3.2.4
eye position tracker
equipment to localize the dynamic positioning of the driver's eye

Note 1 to entry: The detected position of the eye serves to dynamically control and generate augmented reality images of intended information according to geometrical positional configuration of the driver's eye point of observation. Other adaptations or adjustments according to detected driver's eye position may apply.

3.3 Terms related to an HUD system

3.3.1
HUD
head-up display
information display system that enables the driver to access visual information within a driver's direct field of view without requiring drivers to move their gaze orientation toward the traditional information cluster panel display

Note 1 to entry: The nomenclature of head-up display (HUD) came from the use of this term to describe a type of display system used in military avionics application, where information to the pilot was provided in a form not requiring any deliberated head down movement to access the dynamic displayed information.

Note 2 to entry: The use of this term for automotive applications includes a variety of display systems that display information such that drivers do not need to look down at traditional cluster displays.

3.3.2
HUD engine
PGU
picture generation unit
assembly which composes part of a *head-up display* (*HUD*) (3.3.1) system incorporating an image generating device and optical components to guide the generated image onto the display *combiner* (3.3.3)

Note 1 to entry: The visual information generated by the HUD engine is reflected by the combiner which directs visual information to the observer.

Note 2 to entry: HUD systems may have compensation optics unit to extend the visual accommodation distance of generated images by using a combination of transmissive and reflective optical elements.

Note 3 to entry: Many aftermarket HUDs often use a simple combiner with limited capability to project the virtual image at a specified distance, which results in higher accommodation efforts when images are viewed by the observer.

3.3.3
combiner
element or subcomponent of a *head-up display* (*HUD*) (3.3.1) system in which images generated on by the *HUD engine* (3.3.2) are reflected to reach the observers eyes (retina)

Note 1 to entry: There are several types of HUD, and the use of combiners may differ according to the construction design or technology adopted to create the HUD system. HUD systems using the front *windscreen* (3.3.13) itself to act as combiner have their surface treated to properly reflect the image generated by the HUD engine.

Note 2 to entry: The HUD type using a separate transparent optical combiner to reflect the image generated by the HUD engine is differentiated from an HUD in which the windscreen itself acts as combiner. These HUDs have a separate physical combiner, so they are often called "combiner HUDs" to distinguish them from a windscreen-type HUD. A benefit of combiner HUDs is their capability to apply different optical design curvature on the combiner surface when compared the windscreen type which has its reflective surface restricted to the curvatures of the vehicle windscreen design. Separate physical combiner components in a combiner type HUD imposes bordering frames to the viewer.

Note 3 to entry: A combiner in HUD systems is a component the helps the system to combine and superimpose the generated image on top of the actual driving scene image when an observer watches a roadway scene through the combiner. A combiner does not be necessarily need to be a physically reflective element. Holographic diffractive elements are an example of an element that is not reflective but still capable to deliver images as combiner.

3.3.4
AR HUD
augmented reality head-up display
genre of *head-up display* (*HUD*) (3.3.1) where images displayed to the viewer are presented in driver normal front gaze orientation requiring minimum movement of viewer gaze orientation to access to the displayed information

Note 1 to entry: Presentation of the information in augment reality in many applications is intended to provide the presented information superimposed on image of the real-world view scene, virtually creating, and displaying symbols and signs as they might exist in the real world, but in a virtual visual manner.

3.3.5
C-HUD
combiner head-up display
genre of *head-up display* (*HUD*) (3.3.1) where image displayed to the viewer are reflected by a separate *combiner* (3.3.3) which is located in between driver's eye and the *windscreen* (3.3.13)

3.3.6
W-HUD
windscreen head-up display
windshield head-up display
genre of *head-up display* (*HUD*) (3.3.1) where images displayed to the viewer are reflected by the *windscreen* (3.3.13) itself and the windscreen acts as an integrated *combiner* (3.3.3)

3.3.7
2D HUD
two-dimensional head-up display
traditional *head-up display* (*HUD*) (3.3.1) that displays information on a flat focal plane at a virtual distance from the observer

Note 1 to entry: This term is sometimes used to differentiate the traditional 2D HUD from the genre of HUDs that have added functionality to display information with depth perceptibility (e.g. *3D HUD* (3.3.8)).

3.3.8
3D HUD
three-dimensional head-up display
genre of *head-up display* (*HUD*) (3.3.1) where images are presented to the viewer with stereoscopy aspects providing observers a sense of virtual depth

Note 1 to entry: While a classical *augmented reality head-up display* (*AR HUD*) (3.3.4) provides visual information to the viewer image at the same gaze orientation to where the information is expected to be shown in three-dimensional real-world space, the 3D HUD also provides the visual information by means of stereoscopy giving the viewer an additional sense of depth perception.

Note 2 to entry: The three-dimensional sense of perception is achieved by different means and there exist multiple techniques to achieve it. One technique is that the image viewer captures images for each eye with perspective.

3.3.9
HUD effective display area
active area in which the generated virtual image is effectively observable within the direct field of view of the driver/observer

3.3.10
HUD absolute maximum luminance level
maximum luminance functional capability to display a virtual image by the *device under test* (*DUT*) (3.3.25) regardless of ambient light condition

Note 1 to entry: The luminance level under night ambient condition may impose gaze disturbing the driver's vision. A DUT may have an embedded function to adjust the maximum brightness level up to this maximum limit, whether manually or automatically. Conditional maximum brightness level is defined in 3.3.11.

3.3.11
HUD conditional maximum brightness level
maximum luminance adjusted under detected ambient light condition in operation

Note 1 to entry: The *head-up display* (*HUD*) (3.3.1) illumination setting is typically automatically controlled according to the detected external environment condition and avoids excessive bright display in night drive environment as a use case example. Figure 4 is an example of linear gradation test image with brightest and *HUD ON darkest level* (3.3.12).

Key

1 brightest display level (100 % signal level)

2 HUD ON darkest level (0 % signal level)

Figure 4 — Example of neutral colour luminance gradation test image

3.3.12
HUD ON darkest level
darkest luminance level when the *head-up display* (*HUD*) (3.3.1) is in operation, displaying a "numerically absolute black signal" and capable to achieve when displayed as a virtual image by the *device under test* (*DUT*) (3.3.25)

Note 1 to entry: Depending on the technology used, the darkest level achieved when a "numerically black signal" does not reach an absolute zero. When pixel uses light-emitting devices, 0 level is likely to be achieved while back-lit LCD or LCOS type devices have some extent of leak light even when displaying a "numerically black signal" when the device is in operation mode.

3.3.13
windscreen
windshield
W/S
transparent structural component of a vehicle used to protect the vehicle's occupant from the wind and alien objects reaching the occupant while traveling and at the same time providing necessary direct frontal vision to the driver (in front of the driver through which the driver views the road ahead) to access the visual scene to convey a safe driving manoeuvre task

Note 1 to entry: It is a protective laminar composite component often made as an assembly of at least two laminar glass sheets with an intermediate plastic material which holds together when shattered, for improved safety.

Note 2 to entry: The windscreen has at least two reflective surfaces (outer/inner) and it is likely to have an anisotropic curved surface relative to the driver seating positioning. In a W-HUD, its surface(s) acts as *combiner* (3.3.3) element reflecting the projected image from the *HUD engine* (3.3.2) toward the driver's eye.

Note 3 to entry: Windscreen or windshield are common term largely used to refer to the safety "glazing" component or material as defined under UN Regulation No. 43 or FMVSS SS571.205

3.3.14
depth of field
axial depth of the space on both sides of the image within which the image appears acceptably sharp, while the positions (distance) of the object plane and of the objective of the camera are maintained

Note 1 to entry: In some publications, the term "depth of focus" is used to refer to object space. It is recommended that, when the distinction is important, the full terms "depth of field (in object space)" and "depth of focus (in image space)" be used.

Note 2 to entry: It is the range of observed distance of objects nearest and furthest from observer which are in focus.

[SOURCE: ISO 10934:2020, 3.1.37, modified — The term was originally "depth of field", Notes 2 and 3 to entry have been added.]