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ANSI/CAN/UL 8400

JOINT CANADA-UNITED STATES
NATIONAL STANDARD

STANDARD FOR SAFETY

Virtual Reality, Augmented Reality and Mixed Reality Technology Equipment

Approved American National Standard
ANSI
ANSI/UL 8400-2023

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SCC FOREWORD

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UL Standard for Safety for Virtual Reality, Augmented Reality and Mixed Reality Technology Equipment, ANSI/CAN/UL 8400

First Edition, Dated April 28, 2023

Summary of Topics

This is the First Edition of ANSI/UL 8400, Standard for Virtual Reality, Augmented Reality and Mixed Reality Technology Equipment dated April 28, 2023.

The requirements are substantially in accordance with Proposal(s) on this subject dated June 3, 2022 and January 20, 2023.

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ANSI/UL 8400-2023

APRIL 28, 2023

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ANSI/CAN/UL 8400

Standard for Virtual Reality, Augmented Reality and Mixed Reality Technology Equipment

First Edition

April 28, 2023

This ANSI/UL Standard for Safety consists of the First Edition.

The most recent designation of ANSI/UL 8400 as an American National Standard (ANSI) occurred on April 28, 2023. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

This standard has been designated as a National Standard of Canada (NSC) on date April 28, 2023.

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Preface

This is the First Edition of ANSI/CAN/UL 8400, Standard for Virtual Reality, Augmented Reality and Mixed Reality Technology Equipment.

UL is accredited by the American National Standards Institute (ANSI) and the Standards Council of Canada (SCC) as a Standards Development Organization (SDO).

This Standard has been developed in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization.

This ANSI/CAN/UL 8400 Standard is under continuous maintenance, whereby each revision is approved in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization. In the event that no revisions are issued for a period of four years from the date of publication, action to revise, reaffirm, or withdraw the standard shall be initiated.

Annexes A and B are identified as Normative, as such, form mandatory parts of this Standard.

Annexes C, D, E, F, G and I, identified as Informative, are for information purposes only.

Annex H is identified as Normative for Canada and Informative for the US. Informative text is for informational purposes only, and Normative text is considered to be mandatory.

In Canada, there are two official languages, English and French. All safety warnings must be in French and English. Attention is drawn to the possibility that some Canadian authorities may require additional markings and/or installation instructions to be in both official languages.

Comments or proposals for revisions on any part of the Standard may be submitted at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

This Edition of the Standard has been formally approved by the Technical Committee (TC) on Virtual Reality, Augmented Reality And Mixed Reality Technology Equipment, TC 8400.

This list represents the TC 8400 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

TC 8400 Membership

Name	Representing	Interest Category	Region
Aldous, Scott	Google Inc	Producer	USA
Blackwell, John	Diamond AGE Technology	General Interest	USA
Brady, Thomas	College Of Dupage	General Interest	USA
Callahan, Haley	UL Standards & Engagement	Project Manager – Non-voting	USA

TC 8400 Membership Continued on Next Page

TC 8400 Membership Continued

Name	Representing	Interest Category	Region
Chiang, Chi Hsia	UL Solutions	Testing and Standards Organization	Chinese Taipei
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Eckert, Ted	Microsoft Corp	Producer	USA
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He, Penglin	China Electronics Standardization Institute	International Delegate	China
Hernandez, Sergio	Facebook INC (META)	Producer	USA
Hyman, Elizabeth	XR Association	General Interest	USA
Juliano, Tom	Panasonic	Supply Chain	USA
Kinateder, Max	National Research Council of Canada	Government	Canada
Ledgerwood, Scott	National Institute Of Standards & Technology	Government	USA
Marks, Ted	Standards Individuals	General Interest	USA
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Reeves, Jonathan	Magic Leap INC	Producer	USA
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Sun, He	Haier	Commercial/Industrial Users	China
Thomas, Treye	U.S. Consumer Product Safety Commission	Non-voting member	USA
Wang, Ellen	Stanford University Medical Center	Commercial/Industrial Users	USA
Wang, Rui	Zhejiang University	General Interest	China
Weech, Seamas	Serious Labs Inc.	Commercial/Industrial Users	Canada
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Xie, Jun	LENOVO (BEIJING) LTD	Producer	China

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This Standard is intended to be used for conformity assessment.

The intended primary application of this standard is stated in its scope. It is important to note that it remains the responsibility of the user of the standard to judge its suitability for this particular application.

CETTE NORME NATIONALE DU CANADA EST DISPONIBLE EN VERSIONS FRANÇAISE ET ANGLAISE

1 Scope

This Standard addresses the safety of electrical and electronic equipment within the field of virtual reality, augmented reality and mixed reality technologies with a rated voltage not exceeding 600 V.

EXAMPLE VR/AR/MR head-mounted displays, holographic displays, AR/MR smart glasses, hand-held VR/AR/MR devices and interactive virtual simulators.

Particular aspects addressed by this Standard include the means to reduce, as far as practicable, the effects of visually induced motion sickness, visual opacity, flicker, skin sensitization, heat exposure to the eye, biomechanical stress and optical occlusion to some extent.

This Standard does not address the following:

– psychological effects, such as modification of phobias and enhancement or repression of emotions,

– neurological effects on the visual systems, such as modification of stereoscopic vision, and visual acuity, and

– vestibular disturbances, such as nausea and vomiting.

This Standard is intended to supplement the requirements addressing risk of electrical shock, fire, thermal burn, and other general product safety aspects that are already covered by the CAN/CSA-C22.2 No. 62368-1/UL 62368-1 requirements for wearable equipment. Annex D summarizes these aspects.

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 and in alphabetical order. For dated references, only the edition cited apply. Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition to that code or standard.

ANSI/ISEA Z87.1, *Occupational and educational personal eye and face protection devices*

ANSI Z535.4: 2007, *Product Safety Signs and Labels*

ASTM Method D1415-88, *Standard Test Method for Rubber Property – International Hardness*

CAN/CSA C22.2 E60730-1, *Automatic electrical controls – Part 1: General requirements*

CAN/CSA C22.2 No. 0.8, *Safety functions incorporating electronic technology*

CAN/CSA C22.2 No. 62368-1, *Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements*

CSA Z94.3, *Eye and Face Protectors*

EN 960, *Headforms for use in the testing of protective helmets*

IEC 31010, *Risk management – Risk assessment techniques*

IEC 60812, *Failure modes and effects analysis (FMEA and FMECA)*

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 61025, *Fault tree analysis (FTA)*

IEC 61508-1, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 1: General requirements*

IEC GUIDE 116, *Guidelines for safety related risk assessment and risk reduction for low voltage equipment*

IEEE 1789, *IEEE Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers*

ISO 3864-1: 2011, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety sighs and safety markings*

ISO 10993-10, *Biological evaluation of medical devices – Part 10: Tests for irritation and skin sensitization*

ISO 11664-1, *Colorimetry, Part 1 CIE standard colorimetric observers*

ISO 11664-1, *Colorimetry, Part 2 CIE standard illuminants*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement* (GUM:1995)

UL 991, *Tests for safety-related controls employing solid-state devices*

UL 1998, *Software in programmable components*

UL 5500, *Remote software updates*

UL 60730-1, *Automatic electrical controls – Part 1: General requirements*

UL 62368-1, *Audio/video, information and communication technology equipment – Part 1: Safety requirements*

49 CFR Part 572, *Anthropomorphic test devices (ATD), Subpart B – 50th percentile male* (§§ 572.5 – 572.11)

Regulation (EC) No 1272/2008, *Classification, labelling and packaging of substances and mixtures*

3 Terms, definitions and abbreviations

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

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

– IEC Electropedia (also known as IEV): available at http://www.electropedia.org/

– ISO Online Browsing Platform: available at http://www.iso.org/obp

3.1 Abbreviations

Abbreviations are summarized alphabetically in Table 1.

Table 1
Abbreviations

AEL	acceptable exposure level
AR	augmented reality
arcmin	arcminute
BD	blur duration
CCD	charge-coupled device
CEL	consumer exposure level
CRT	cathode ray tube
dB	decibel
DUT	device under test
FOV	field of view
FPS	frame per second
HMD	head-mounted display
IAD	interaxial distance
IPD	interpupillary distance
IR	infrared
LCD	liquid crystal display
LMD	light measuring device
MB	megabytes
MESP	moving-edge spatial profile
METP	moving edge temporal profile
min	minute
mm	millimeter
MR	mixed reality
ms	millisecond
MtP	motion-to-photon
nm	nanometer
NOEL	no observable effect level
NST	non-see-through
OST	optical see-through
PSC	prolonged skin contact
RE	real environment
RGB	red, green, and blue
VAC	vergence-accommodation conflict

Table 1 Continued on Next Page

Table 1 Continued

VE	virtual environment
VIMS	visually induced motion sickness
VR	virtual reality
VST	video see-through

3.2 General product safety terms

3.2.1
harm
injury or damage to the health of people, or damage to property.

[SOURCE: ISO/IEC Guide 51, modified]

3.2.2
hazard
potential source of harm.

NOTE The term "hazard" can be qualified in order to define the origin of the hazard or the nature of the expected harm (e.g., "electric shock hazard", "crushing hazard", "cutting hazard", "fire hazard").

[SOURCE: ISO/IEC Guide 51]

3.2.3
hazardous event
event that can cause harm.

NOTE A hazardous event can occur over a short period of time or over an extended period of time.

[SOURCE: IEC Guide 51]

3.2.4
hazardous situation
circumstance in which people, property or the environment is/are exposed to one or more hazards.

NOTE The exposure can immediately or over a period of time result in harm.

[SOURCE: ISO/IEC Guide 51]

3.3 Modes of operation

3.3.1
intended use
use in accordance with information provided with a product or system, or, in the absence of such information, by generally understood patterns of usage.

[SOURCE: ISO/IEC Guide 51]

3.3.2
reasonably foreseeable misuse
use of a product or system in a way not intended by the manufacturer, but which can result from readily predictable human behaviour.

NOTE 1 Readily predictable human behaviour includes the behaviour of all types of users, e.g., the elderly, children and persons with disabilities. For more information, see ISO 10377.

NOTE 2 In the context of consumer safety, the term “reasonably foreseeable use” is increasingly used as a synonym for both “intended use” and “reasonably foreseeable misuse.”

[SOURCE: ISO/IEC Guide 51]

3.3.3
operating condition
characteristic which may affect performance of a component, device or equipment.

[SOURCE: IEV 151-16-01]

3.3.4
normal operating condition
mode of operating condition that represents as closely as possible the range of intended use that can reasonably be expected.

[SOURCE: CAN/CSA-C22.2 No. 62368-1/UL 62368-1, modified – replaced “normal” with “intended”]

3.3.5
single fault condition
condition in which there is a fault of a single protection (but not a reinforced protection) or of a single component or a device.

NOTE If a single fault condition results in one or more other fault conditions, all are considered as one single fault condition.

[SOURCE: IEV 903-01-15]

3.3.6
abnormal operating condition
temporary operating condition that is not a normal operating condition and is not a single fault condition of the equipment itself.

[SOURCE: CAN/CSA-C22.2 No. 62368-1/UL 62368-1]

3.3.7
mobile
capable of operating while being moved.

[SOURCE: IEV 151-16-46]

3.4 Immersive technology terms

3.4.1
head-mounted display
HMD
a visual display covering the eyes that is rigidly attached to the head.

3.4.2
virtual environment
VE
an instance of a virtual world presented in an interactive medium such as virtual reality.

NOTE Usually VE and VR are used synonymously, but some authors reserve VE for an artificial environment that the user interacts with.

3.4.3
virtual reality
VR
simulation of the physical presence of the user in a VE that typically occludes the real world and is produced by computer simulation, enabling the human to interact with a three-dimensional, computer generated environment.

NOTE The produced environment can replicate a RE or create an imaginary world.

[SOURCE: IEV 171-09-13, modified]

3.4.4
augmented reality
AR
form of reality in which the virtual content is added on top of non-occluded optical field of view of the real environment.

NOTE Such virtual content may include augmentations.

3.4.5
mixed reality
MR
the merging of real and virtual worlds in which cameras capture the real environment and then those images are modified with virtual information.

3.4.6
cross reality
extended reality
XR
an umbrella term encompassing AR, VR, MR, as well as mixing or blending and everything in between.

3.4.7
optical occlusion
an act of instance of obstructing vision.

NOTE For the purpose of this standard, immersive technologies are classified into three classes by the amount of optical occlusion: NST (non-see-through) VST (video see-through), and OST (optical see-through).

3.4.8
non-see-through
NST
a system that is subject to full optical occlusion.

NOTE For the purpose of this standard, NST is assumed that the visual stimulus is substituted by that created by computer simulation, in other words, the user is fully immersed in the VE while the real world is blocked out.

3.4.9
video see-through
VST
a system like NST but capable of streaming the “passthrough” camera feeds on the display which allows the user to get a glimpse of the surroundings.

NOTE For the purpose of this standard, the spatial and temporal resolution of the VST camera feeds is assumed to be inferior than that of vision.

3.4.10
optical see-through
OST
a system where the image is displayed on the see-through optics through reflection or waveguide that enables optical superposition of digital information onto the direct view of the physical world and optically maintains see-through vision to the real world.

NOTE For the purpose of this standard, OST is assumed that the direct view of the real world is mostly preserved at all times although the FOV may be limited, and the beam of light is neither converged nor diverged (and thus no intended focal power).

3.5 Miscellaneous

3.5.1
visually induced motion sickness
VIMS
a subcategory of motion sickness that specifically relates to nausea, oculomotor strain, and disorientation from the perception of motion while remaining still and can lead to malaise, postural instability, dysmetria, and visual disturbances.

NOTE VIMS is also known as cybersickness and may occur without vestibular stimuli.

3.5.2
latency
a time interval between the stimulation and response.

NOTE Latency is, from a more general point of view, a time delay between the cause and the effect of some physical change in the system being observed.

3.5.3
otion-to-photon latency
MtP latency
an end-to-end delay between the motion (e.g., head rotation) and the photon (e.g., at some point the photons are emitted from the image reflecting that movement).

NOTE In the context of VR, an undue amount of MtP latency may cause visual-vestibular conflict and subsequently lead to motion sickness, while in the context of AR/MR, the virtual content may be misregistered into or misaligned with real life features.

3.5.4
refresh rate
the number of times a display screen is redrawn or refreshed each second, in hertz (Hz).

NOTE In contrast with the refresh rate, the frame rate (in FPS) is the number of consecutive full-screen images that are fed to the display each second.

3.5.5
field of view
FOV
an angle in degrees of the visual field.

NOTE For the purpose of this standard, the extent of vision through the mounted lens in the as-worn position measured with reference to the entrance pupil of the stationary eye when placed on the appropriate headform.

[SOURCE: ISO 4007, 3.5.2.6]

3.5.6
luminance
a photometric measure of the luminous intensity per unit area of light travelling in a given direction, in candela per square meter (cd/m^2) or nit.

[SOURCE: IEV 845-01-35]

3.5.7
entrance pupil
the full diameter of the light gathering aperture of an instrument (e.g., the diameter of a lens).

3.5.8
eye point
the location at which the eye should be positioned for optimal viewing with respect to the corresponding displayed image.

3.5.9
360 spherical panoramic picture
a picture has a horizontal FOV of 360 degrees and a vertical FOV of 180 degrees.

3.5.10
interpupillary distance
IPD
distance between the centres of the pupils when the eyes are fixating an object at an infinite distance in the straight ahead position.

[SOURCE: ISO 13666]

3.5.11
interaxial distance
IAD
the length between the centres of the lenses.

3.5.12
optical axis
straight line joining the centres of curvature of both surfaces of a lens.

NOTE This line is normal to both optical surfaces so light can pass along it undeviated.

[SOURCE: ISO 13666]

3.5.13
smooth pursuit
a basic type of eye movements in which the eyes closely track a moving stimulus on the fovea.

NOTE Any depart of the moving object from this smooth motion trajectory is immediately perceived as image blur.

3.5.14
motion-induced blur
a type of motion artifacts due to a smooth pursuit of moving objects at discrete positions in space for an extended period of time, thus violating the assumption of smooth motion trajectory and leading to perceived blur.

NOTE In contrast with CRT phosphors that flash briefly, pixels on an LCD remain lit until the next refresh occurs, in other words, the moving objects will appear stepwise.

3.5.15
moving-edge spatial profile
MESP
a one-dimensional waveform describing the relative luminance (a linear function of luminance) as a function of horizontal position in pixels.

3.5.16
moving edge temporal profile
METP
a convolution of the luminance (gray level) transition with a pulse of duration equal to the hold time (typically one frame).

3.5.17
blur duration
BD
the time between the highest and the lowest relative luminance during gray-to-gray transitions, in ms, as a metric of perceived blur.

3.5.18
rest frame
a frame of reference that remains at rest or moves with constant velocity with respect to others.

3.5.19
jitter
a set of short-term non-cumulative variations in the significant instants of a digital signal from their ideal positions in time.

NOTE By contrast, judder is more of a result of mismatch between the frame rate and the refresh rate.

3.5.20
transmittance
quotient of transmitted radiant flux and incident radiant flux.

NOTE Transmittance can be expressed as a percentage. In this document, it is expressed as a value with a maximum of 1.0.

[SOURCE: IEV 845-24-065]

3.5.21
luminous transmittance
ratio of the luminous flux transmitted to the incident luminous flux for a specified illuminant and photopic vision.

[SOURCE: ISO 4007]

3.5.22
spectral transmittance
ratio of the spectral radiant flux transmitted by the material to the incident spectral radiant flux at any specified wavelength, for a specified angle of incidence.

[SOURCE: ISO 4007]

3.5.23
relative visual attenuation quotient
quotient of the luminous transmittance of a lens for the spectral radiant power distribution of the light emitted by a traffic signal to the luminous transmittance of the same lens for CIE standard illuminant D65.

[SOURCE: ISO 4007, modified]

3.5.24
reference point
points on the lens specified by the manufacturer as the design reference points and at the specified orientation relative to the test instrument's optical axis.

[SOURCE: ISO 4007]

3.5.25
boxed centre
intersection of the horizontal centreline and the vertical centreline of the rectangular box that circumscribes the lens shape in its intended orientation.

[SOURCE: ISO 4007]

3.5.26
flicker
perception of visual unsteadiness induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a static observer in a static environment.

NOTE Flicker is one of detrimental and undesired temporal light artifacts.

[SOURCE: CIE TN 006]

3.5.27
photosensitive seizures
a form of epilepsy in which seizures are triggered by visual stimuli that form patterns in time or space, such as flashing lights; bold, regular patterns; or regular moving patterns.

3.5.28
irradiance
the radiant power incident on an element of a surface divided by the area of that element.

[SOURCE: IEV 731-01-25]

3.5.29
skin sensitization
allergic contact dermatitis
immunologically mediated cutaneous reaction to a substance.

NOTE In the human, the responses can be characterized by pruritis, erythema, oedema, papules, vesicles, bullae or a combination of these. In other species the reactions can differ and only erythema and oedema can be seen.

[SOURCE: ISO 10993-10]

3.5.30
sensitizer
allergen
substance or material that is capable of inducing a specific hypersensitivity reaction upon repeated contact with that substance or material.

[SOURCE: ISO 10993-10]

3.5.31
corneal apex
when in the position of the eye relative to the head looking straight ahead at a distant object at eye level, the most anterior part of the eye.

NOTE This is approximately the centre of the cornea.

[SOURCE: ISO 4007 and ISO 13666, modified]

3.5.32
vergence-accommodation conflict
VAC
conflicting signals in which the eyes' convergence demand differs from the eyes' focal demand.

NOTE Vergence refers to the simultaneous movement of both eyes in opposite directions to obtain or maintain single binocular vision, while accommodation refers to the ability of the eye to change its focus from distant to near objects (and vice versa).

3.5.33
visual-vestibular conflict
sensory conflict between the vestibular cues (oftentimes stationary) from the real-world and visual cues (oftentimes moving) from the virtual world.

4 General requirements

Equipment shall be constructed so that in its intended use, under normal operating conditions as well as abnormal operating conditions due to carelessness, it functions safely so as to cause no harm, even in the event of any single fault condition that is likely to occur in the equipment or reasonably foreseeable misuse that may occur.

4.1 Acceptance of available data

Where compliance is demonstrated by the evaluation of the available data, such compliance may be by review of published, peer-reviewed data or previous test results.

4.2 Basic safety requirements

This standard does not repeat requirements that are already covered by CAN/CSA-C22.2 No. 62368-1/UL 62368-1 and are normative for VR, AR and MR technology equipment. Annex C summarizes these requirements.

4.3 Supplementary safety requirements

Besides these general product safety aspects, this standard supplements requirements for greater relevance to the domains of VR, AR and MR technologies as specified in Clauses 5 – 13.

– See-through visual functions (Clause 5),

– Flicker (Clause 6),

– Skin compatibility (Clause 7),

– Exposure of eyes to thermal energy (Clause 8),

– Biomechanical stress (Clause 9),

– Mechanical robustness (Clause 10),

– Enhancing spatial perception (Clause 11),

– Safety and warning instructions (Clause 12), and

– Functional Safety (Clause 13).

4.4 Application of requirements

Requirements are specified in the relevant clauses and, where referenced in those clauses, in the relevant annexes.

For the purpose of this standard, immersive technologies are classified into three classes by the amount of optical occlusion:

– NST (non-see-through) which suffers from total optical occlusion,

– VST (video see-through) which is opaque but has video pass-through cameras, and

– OST (optical see-through) in which vision is mostly preserved.

Requirements applicable to each classification are summarized in Table 2.

Table 2
Applicability of requirements with respect to the amount of optical occlusion

Clause No.	Headings	NST	VST	OST
5	See-through visual functions			X
6	Flicker	X	X	
7	Skin compatibility	X	X	X
8	Exposure of eyes to thermal energy	X	X	X
9	Biomechanical stress	X	X	X

Table 2 Continued on Next Page

Table 2 Continued

Clause No.	Headings	NST	VST	OST
10.1	Static load test			X
10.2	Ball impact test			X
10.3	Loaded head impact	X	X	
11	Enhancing spatial perception	X	X	X
12	Safety and warning instructions	X	X	X
12.3	Vulnerable age groups	X	X	
12.5	Warning against Vergence-Accommodation Conflicts (VAC)	X	X	X

4.5 General environmental test conditions

Unless otherwise specified in other clauses of the standard, the general environmental test conditions are as follows:

– temperature: 22 °C (71.6 °F) to 28 °C (82.4 °F),

– relative humidity: 25 % to 85 %, and

– atmospheric pressure: 86 kPa (12.5 psi) to 106 kPa (15.4 psi).

5 See-through visual functions

The risk assessment required to be conducted in Clause 12 of this standard shall include consideration of potential hazards related to luminous transmittance, spectral transmittance, and relative visual attenuation quotient of the device for an OST HMD. The lens and filter of the device shall be designed, and suitable warnings employed, to prevent normal or foreseeable misuse harm to the user, as judged acceptable by the risk assessment. Any warnings or cautions that come from the risk assessment process shall be applied as labelling to the device or within the user instructions., The warning or caution statement may be a physical marking or as part of the device's electronic display, or specified in the instructions for use as required.

NOTE It is not the intent of the Clause above to specify a specific location for warnings or caution. Location is to be determined as part of the risk assessment process.

5.1 Risk assessment

The risk assessment shall include but not be limited to consideration of the following points for OST HMD:

– Ambient light levels intended or required to be present during use.

– Guidance from standards judged to be applicable to the use case.

– Examples of standards that may be considered:

  – ISO 12312-1 – Eye and face protection

  – ANSI Z87.1 – Safety glasses

  – CSA Z94.3-2020 – Eye and face protectors

– ANSI Z80.3 – Non-prescription sunglass and fashion eyewear requirements

– Use cases where poor visibility could lead to an unsafe condition, for example in industrial applications where the user is working near machinery or where warnings or other information must be reliably seen to avoid a hazard.

– Intended and reasonably foreseeable use cases.

– The effect of lens filters on visibility.

– Hazards associated with mobile use cases.

– Legibility and accessibility of warnings provided to the user, ex. through the device display, on device, safety guide, etc.

5.2 Measurements

An OST HMD or a sample representative of the as-worn configurations (e.g., a lens together with a visor) shall be tested to determine the spectrophotometric properties specified in 5.2.1, 5.2.2, and 5.2.3.

Properties shall be measured at the reference point specified by the manufacturer. The geometric centre (of each eye) or boxed centre takes the place of the reference point if this is not known.

The direction of measurement shall be normal to the surface of the OST HMD. Unless the effects of beam displacement are addressed, the angle of incidence shall be maintained to within ±2°. Other test methods may be used if proven to be equivalent.

All assessments should be measured and calculated in accordance with Annex A.

5.2.1 Measurement of luminous transmittance

The visibility of the OST HMD is assessed by measurement of the luminous transmittance.

5.2.2 Measurement of Spectral Transmittance

The visuality of primary colors (e.g., RGB) of the OST HMD is assessed by measurement of the spectral transmittance in the wavelength range of 475 nm to 650 nm.

5.2.3 Measurement of relative visual attenuation quotient

The visibility of signs and signals of the OST HMD is assessed by measurement of the relative visual attenuation quotient for visibility of signs and signals.

5.3 Limits

Spectrophotometric properties measured according to 5.2.1, 5.2.2, and 5.2.3 shall conform to limits specified in standards identified by the risk assessment as applicable, refer to 5.1. Where no such relevant limits are identified, the risk assessment shall determine applicability of the instructional safeguards specified in 5.4.

5.4 Instructional safeguards

The instructional safeguards for Luminous Transmittance, Spectral Transmittance, and Relative Visual Attenuation Quotient shall be considered during the risk assessment, see Annex F.

6 Flicker

The potential for biological effects induced by inherent strobing artifacts due to features such as backlights or dimmers should be minimized.

NOTE 1 Visible flicker at frequencies within the range of ~3 to ~70 Hz may provoke photosensitive seizures.

NOTE 2 Flicker may be induced or mitigated by various applications installed on the NST or VST HMD and may not be a product of the device itself. This test is intended to measure only the operation of the HMD and not software that may be operated on the device.

An NST or VST HMD shall be subjected to the flicker assessment in 6.1. The modulation (%) shall be less than 10^(w/20-1.7) when the flicker frequency is above 20 Hz. W = frequency (Hz). A display that complies with the low-risk region or NOEL in accordance with IEEE 1789 shall be considered meeting and exceeding the requirements in this standard.

6.1 Flicker assessment

Prior to the test, the DUT is running a test pattern of constant full screen white at the maximum luminance. A warm-up time of up to 20 min shall be allowed. The irradiance as a function of time is measured by the LMD specified in Annex D, Clause D.2.3 and is transformed into the function of frequency using the FFT (Fast Fourier Transform).

The risk of flicker is assessed by flicker frequency and modulation (%) which is defined as the difference between maximum and minimum luminance divided by the sum of maximum and minimum luminance, and multiplied by 100.

NOTE Modulation (%) is also known as percent flicker, peak-to-peak contrast, Michelson contrast, or modulation depth.

7 Skin compatibility

Materials used in the equipment that are intended to be worn or held and come in contact with the skin shall be evaluated for compatibility with the skin.

EXAMPLE HMD and controllers.

Risk assessment for skin compatibility is recommended for materials used in the equipment that are in prolonged contact with skin. The risk assessment shall consider the complete product design including potential impact to skin compatibility during manufacturing and manufacturer recommended cleaning procedures. The analysis and/or risk assessment may be performed by a qualified person with training in biocompatibility within or outside of the company.

Compliance is checked via documentation and shall consider the following:

– description of the device

– qualified person

– identification of materials in prolonged skin contact (PSC)

– *risk assessment*

Documentation is not required to be included in final safety report but shall be available by the manufacturer upon request.

For guidance, refer to Annex E.

8 Exposure of eyes to thermal energy

The risk of optical damage to the eye due to excessive heat exposure shall be minimized.

The HMD shall be subject to ocular surface temperature test in 8.1.

NOTE Research has shown that the thermal threshold of local cornea and retina heating in terms of the CEM43 °C [cumulative equivalent minutes at 43 °C (109.4 °F)] thermal dose isoeffect model is that acute and minor damage occurs between 21 and 40 min whilst acute and significant damage occurs when the exposure is longer than 41 min.

The temperature measured at the corneal apex shall not exceed 43 °C (109.4 °F).

Exception: This Clause does not apply to HMD with a means to allow airflow (e.g., vents).

8.1 Ocular surface temperature test

8.1.1 Test with dummy headform

The DUT is tightly put on a dummy headform as if it is worn on the head, covered with a layer of material simulating epidermis having a value of thermal conductivity of 0.209 W/mk (0.121 BTU/hr-ft-°F) or less, and a thickness of 50 µm (1.97E-03 in) or more.

The DUT is operated normally, set such that it produces the worst-case temperature likely to be present at the eyes. The ocular surface temperatures shall be constantly measured using thermocouples at the location as if it is at the corneal apex. The test is continued until the temperatures do not deviate from 3 °C (5.4 °F) in any consecutive session of 30 min.

Alternately, the test may be performed with the DUT fitted to a skin-imitating thermal manikin/fixture.

8.1.2 Test without dummy headform

Alternatively, the test may be made without a dummy headform. In this case, the open side of the DUT shall be airtightly covered with a layer of material same as above. The ocular surface temperature shall be measured at 20 – 25 mm ahead of the HMD lens. The ambient temperature at which the test is performed shall be maintained between 35 °C (95 °F) and 37 °C (98.6 °F).

NOTE For HMD that is intended to be used in a higher ambient temperature environment (e.g., industrial applications), a higher ambient temperature condition may be declared by the manufacturer.

9 Biomechanical stress

9.1 General

The HMD and its accessories that are intended to be worn on the head shall be so designed that undue biomechanical stress is not imposed on the upper cervical spine. The effort arm is twice of the resistance arm.

NOTE The torques from the HMD and the head combine to create a flexion moment that is larger than that due to the head alone and has to be balanced to maintain an upright posture, or will lead to neck strain or tension.

9.2 Requirements

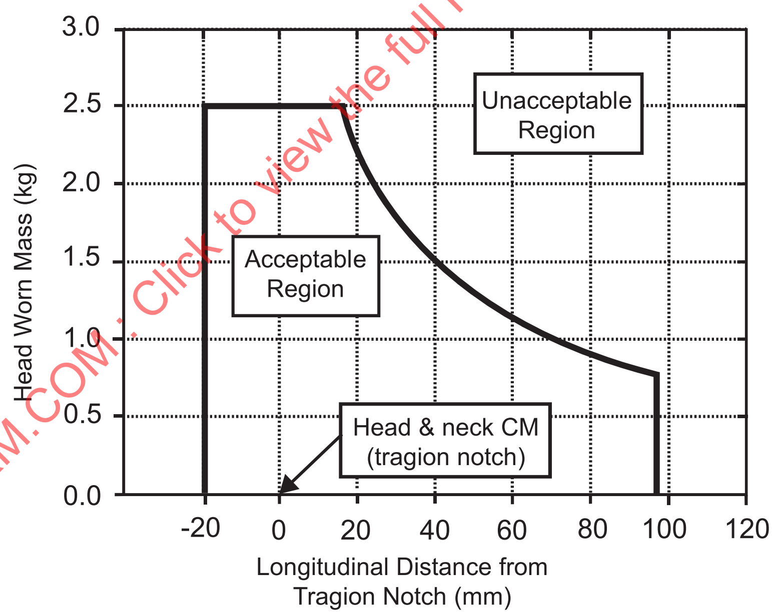
The HMD and its accessories shall be subjected to the HMD weight and anthropometric distance parameters outlined in 9.3 in order to reduce cervical strain and allow for adjustability of the HMD. When calculating anthropometric distance parameters, the use of the use of USAARL (United States Army Aeromedical Research Laboratory), FOCUS (Facial and Ocular Countermeasure Safety) or other equivalent head forms shall be permitted.

9.3 Compliance

The HMD shall be in compliance with the following:

– A longitudinal distance from the Tragion Notch shall fall within the "Accepted Injury Risk" region from Figure 1.

NOTE Ensure that the measurements are taken from the Tragion Notch to Centre of Gravity of the Device (see Figure 2).



su4560

Figure 1

Accepted injury risk, longitudinal distance

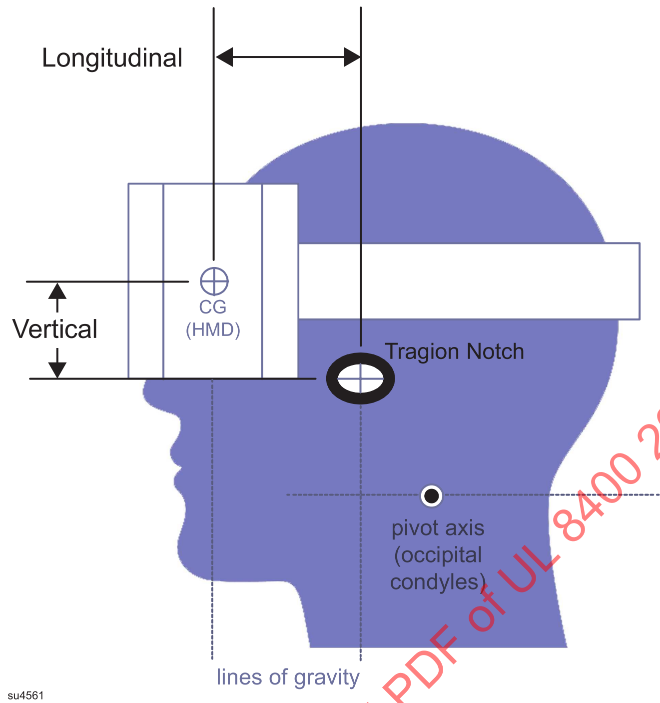


Figure 2

Tragion notch

10 Mechanical robustness

The likelihood of ocular injuries caused by shattered glass or sharp shards subsequent to broken parts shall be minimized. HMD shall be constructed to withstand such rough handling reasonably foreseeable in normal use and shall demonstrate adequate mechanical robustness by the following:

– for OST HMD, the static load (10.1) and ball impact tests (10.2),

– for NST or VST HMD, the loaded head impact test (10.3)

The DUT shall be an HMD or a sample representative of the as-worn configurations. Only exterior surfaces are subject to test.

NOTE For HMD intended for occupational and educational personal eye and face protection, other standards such as ANSI/ISEA Z87.1 or CSA Z94.3 should be consulted.

10.1 Static load test

This test applies only to OST HMD.

Prior to the test, the DUT is placed on a rigid support has an area larger than the DUT. The central vertical axis of the load device shall be aligned with that of the support. A static load of 100 ±2 N (22.48 ±0.4 lbf) is placed onto the exterior surface of the DUT within a 16 mm (0.04 inch) diameter circle centred at the reference point or the boxed centre whichever is expected to produce the most unfavorable result. The static load is maintained for 10 ±2 s and then removed.

The loading device shall be a rigid body in the form of a cylinder with a hemispherical end. The total weight of the device shall be of 100 ±2 N (444.82 ±8.9 lbf) and the diameter of the cylinder is 40 mm (1.6 in). As an alternative, the static load may be exerted by a force gauge has a hemispherical end with a diameter of 40 mm (1.6 in). In this case, the force is exerted at a speed not faster than 400 mm/min (15.76 in/min).

Observe and record whether the DUT has fractured.

During and after the test, the DUT shall not break or crack, unless the DUT has a construction such that particles do not fall off or separate from each other (e.g., laminated).

10.2 Ball impact test

This applies only to OST HMD.

A steel test ball of nominal diameter 15.875 mm (5/8 in) and mass not less than 15.876 g (0.56 oz) is dropped through a height of 1.27 m (50 in) upon the horizontal upper surface of the lens. The ball shall strike within a 15.875 mm (5/8 in) diameter circle located at the geometric centre of the lens where the most unfavorable result may be expected. The ball may be guided but not restricted in its fall by being dropped through a tube extending to within approximately 4 in of the lens.

The test shall be conducted with the lens supported by a tube with a 25.4 mm (1 in) inside diameter, 31.75 mm (1 1/4 in) outside diameter, and approximately 25.4 mm (1 in) high affixed to a rigid iron or steel base plate. The total weight of the base plate and its rigidly attached fixtures shall be not less than 12.247 kg (27 lbs). For lenses of small minimum diameter, a support tube having an outside diameter of less than 31.75 mm (1 1/4 in) may be used. The support tube shall be made of rigid acrylic plastic, steel, or other suitable substance and shall have securely bonded on the top edge a 3.175 mm by 3.175 mm (1/8 in x 1/8 in) neoprene gasket having a hardness of 40 ±5, as determined by ASTM Method D1415-88.

Observe and record whether the DUT has fractured.

During and after the test, the DUT shall not break or crack, unless the DUT has a construction such that particles do not fall off or separate from each other (e.g., laminated).

10.3 Loaded head impact

This applies only to NST or VST HMD which suffers optical occlusion.

Exception: NST or VST HMD used exclusively for restricted use area or stationary applications (e.g., VR amusement park rides).

The HMD shall have a means to safeguard against the likelihood of ocular injury from accidental falls or head hitting against the hard walls. Furthermore, the HMD shall withstand accidental head collisions without compromising lithium-ion battery safeguards.

Prior to the test, a fully charged DUT is is to be fitted per manufacturer’s recommendation, dimensioned and weighted in conformity with the EN 960 head form No. 605, with a weight of 5600 ±160 g as if it is worn on the head. Another fully charged DUT remains undropped (as the reference). Alternatively, other equivalent dummy headforms with detailed facial features such as FOCUS and NOCSAE (National Operating Committee on Standards for Athletic Equipment) headforms having the same weight shall also be permitted.

NOTE The EN 960 head form No. 605 represents the head size and weight of 95th percentile male.

A combination of the DUT and headform is subject to one free-fall vertical drop from a height of 1800 ±10 mm (70.9 ±0.4 in) onto a horizontal support consisting of hardwood at least 13 mm (1/2 in) thick, mounted on two layers of plywood each 18 ±2 mm thick, all supported on a concrete or equivalent non-resilient floor.

During the drop, the DUT shall not rotate unless the impact is precisely made at the most unfavorable location. The drop may be guided.

After the drop, neither access to hazardous parts nor loose shattered particles, that can cause injury to the user’s eye, shall be present inside the HMD.

If the battery is still operable after the drop, the lithium-ion cell shall be removed from the HMD and subject to three additional sequences of discharge-charge operations. The open-circuit voltages of the dropped and the reference (undropped) cells are periodically monitored during the following 24 hours. Other equivalent methods to monitor the cell voltages without removal of the cells shall be permitted. The relative change in voltage difference (defined as follows) shall not exceed 5%.

$$\frac{(U_{d(t=0)} - U_{d(t=24h)}) - (U_{u(t=0)} - U_{u(t=24h)})}{U_{u(t=24h)}} \times 100\ \%$$

where

$U_{d(t=0)}$ is the open-circuit voltage of the dropped cell measured immediately after additional cycles

$U_{d(t=24h)}$ is the open-circuit voltage of the dropped cell measured at the following 24 h

$U_{u(t=0)}$ is the open-circuit voltage of the undropped (reference) cell measured immediately after additional cycles

$U_{u(t=24h)}$ is the open-circuit voltage of the dropped cell measured at the following 24 h

The result shall be deemed compliant if the battery becomes inoperable after the drop, provided that neither hazards nor hazardous events are created (i.e., fail-safe).

11 Enhancing spatial perception

Collision hazards due to limited spatial perception are associated with optical occlusion from HMD. The requirements in this Clause are organized by the amount of optical occlusion by the HMD, and further categorized by whether the application is mobile, with a restricted versus unrestricted use area, or stationary.

In addition to the safety and warning instructions specified in 12.2, the manufacturer shall provide the user mechanisms by which to reduce the likelihood of collisions or falls associated with optical occlusion by physical and digital elements of immersive technology equipment.

Compliance is demonstrated by all of the following, as appropriate:

– an analysis of potential hazards including FMEA (failure mode and effect analysis) or equivalent method,

– a risk assessment shall be conducted to determine that events that could lead to hazardous situations related to spatial awareness have been addressed through design or other means. In this context, Annex C provides normative guidelines for such assessment, and

– employing the collision mitigation measures with respect to the amount of optical occlusion:

– for NST HMD, as specified in 11.1,

– for VST HMD, as specified in 11.2, or

– for OST HMD, as specified in 11.3.

11.1 NST HMD

NST HMD for mobile applications with restricted use area shall have a means to enhance spatial perception and shall include identification by the HMD of the boundaries of the safe use area prior to the user reaching the boundaries the user is facing or within the user's peripheral vision. Boundaries are not required in the horizontal plane above the user's head.

Compliance is demonstrated by verification that the HMD provides indication that the user is approaching the boundary at least 305 mm (1 ft) before the HMD is a distance no closer than 1.18 m (46.5 in) from a boundary.

HMD in compliance with this requirement shall employ at least one of the following collision mitigation measures, clearly notable to the user wearing the NST HMD:

a) virtual boundaries that are continuously visible,

b) visible or audible notification, including virtual boundaries that are only visible when the user approaches them,

c) interruption of the software, or

d) disabling the display.

NOTE The requirements in this Clause do not consider hazards associated with movement beyond a limited, prepared space. Requirements associated with such additional hazards are under consideration.

11.2 VST HMD

11.2.1 Use in mobile applications with restricted use area

When video see-through is not active, the requirements above for collision mitigation measures in 11.1 are applicable. When video see-through is active, the following shall instead be applied:

The risk assessment for VST HMD shall:

– indicate which of the collision mitigation measures specified in 11.1 are applicable, and these requirements shall be implemented, and

– further include the considerations given in Annex B, Clause B.3.

11.2.2 Use in mobile applications with unrestricted use area

VST HMD for mobile applications with unrestricted use area shall have constant video see-through, as well as meet the requirements specified in 11.2.1 for the risk assessment.

11.2.3 Use in stationary applications

VST HMD for stationary applications require no measures for spatial perception beyond the risk assessment specified in 12.3.1, and safety and warning instructions in 12.2.

11.3 OST HMD

11.3.1 Use in mobile applications

OST HMD for mobile applications whether restricted or unrestricted use area, the risk assessment shall further include the considerations given in Annex B, Clause B.4.

11.3.2 Use in stationary applications

OST HMD for stationary applications require no measures for spatial perception beyond the risk assessment specified in 11.1, and safety and warning instructions in 12.2.

12 Safety and warning instructions

The applicable safety and warning instructions specified in this Clause shall be provided to address adequately the known and foreseeable risks of injury associated with use of the product. If it is necessary to take special precautions to avoid the introduction of any hazardous event when installing, operating, servicing, transporting or storing equipment, such safety and warning instructions shall be provided. In addition to the requirements specified in this Clause, the required safety and warning instructions are determined by completing a risk assessment, which considers the most onerous, reasonably foreseeable uses of the product, including duration of use, physical exertion, and use environment, among other factors. The risk assessment shall consider the items in Annex G.

12.1 Warning design

Warnings provided shall conform to ISO 3864 or ANSI Z535, as applicable, including but not limited to requirements pertaining to graphic symbols, signal words, and minimum type sizes.

Exception: For warnings presented digitally, minimum type size requirements are not applicable. Such warnings shall be clearly legible without the aid of magnification.

Warnings provided shall be conspicuous. Warnings provided shall be easy to read and understand. Any abbreviations, such as “IPD,” shall be written out when first presented.

Any marking or labeling provided in addition to those required by Clause 12 shall neither contradict nor confuse the meaning of the required information or be otherwise misleading to the user.

12.2 Warning statements

The warning information or equivalent specified in 12.2.1 – 12.2.5, shall be included and not preclude other necessary information appropriate for the technologies employed.

NOTE The product should be designed such that the hazards are prevented. When this is not feasible, safeguards should be used with warnings to limit the user’s access to the hazards.

12.2.1 Basic health and safety information

Identification of known and reasonably foreseeable hazards associated with use of the product and means to mitigate risks associated with the hazards.

Explanations of graphical symbols and system alerts and features related to safe use of the product, such as pertaining to product overheating.

12.2.2 Preparation of safe use equipment

All instructions necessary for selecting and preparing the appropriate location(s) for safe operation of the product, including consideration for collision and fall hazards.

12.2.3 Preparation of product and accessories for safe use

– All installation and preparation instructions necessary for safe operation of the product and included or bundled accessories, including the following if applicable to the product (if the product affords the following): appropriate sizing, securing accessories and attachments, IPD adjustment, importance of IPD matching, calibration, collision mitigation measures, and parental controls.

12.2.4 Proper maintenance and storage of product

– All information necessary for safe maintenance and storage of the product.

– Validated cleaning requirements, including considerations for sweat, bacterial growth, and degradation and leeching of harmful chemicals.

12.2.5 Safe use of product

– All information necessary for safe operation of the product, including explanation of reasonably foreseeable uses that may result in death or injury to the user or bystanders, and taking into consideration the user's mobility during use, duration of use, the use environment, and the limitations of the product (e.g., latency and impaired depth perception of camera-provided views, if applicable), among other factors.

– Conditions under which they need to immediately discontinue use of the product (such as dizziness, vertigo, increased salivation, blurred vision, neck strain or difficulty focusing in applicable), and conditions under which they need to seek medical treatment immediately (such as serious allergic reactions and severe changes in overall clarity of sight, unsteadiness, or impaired coordination, if applicable, for which cessation of use may not be sufficient to alleviate symptoms).

12.3 Vulnerable age groups

The requirements specified in this standard are based on anthropometric and biomechanical measurements, among other factors, specific to average adults. Therefore, a risk assessment considering user age shall be conducted, and safety and warning instructions pertaining to user age shall be provided.

NOTE Immersive technologies continue to evolve, and as such, the lack of adequate data about the short- and long-term risks to human health and safety for different age groups is acknowledged. The design requirements in this standard may not adequately address the developing and/or diminishing systems of vulnerable age groups, particularly children under 12 years of age. See Annex G for more information.

12.3.1 Risk Assessment

The risk assessment shall consider reasonably foreseeable use of the product by vulnerable age groups to determine adequate safety and warning instructions pertaining to these populations. The risk assessment shall consider the end user population(s) to whom the product appeals and for whom it is designed, marketed, and intended.

EXAMPLE Neck injuries associated with size and weight of HMD, unstable binocular vision, and susceptibility to seizures.

12.3.2 Information and labels pertaining to user age

12.3.2.1 Age label for HMDs

The product shall be marked with an age label specifying the minimum user age for safe use of the product. Refer to 12.4. The word "WARNING" and the following or the equivalent: "This product was not designed for users under the age of [_____] and may not be safe for use by these ages." Where "[_____]" is to be filled in with "12 years" or a higher age, as appropriate.

12.4 Mediums for conveying safety and warning instructions

The safety and warning instructions shall be presented using the mediums identified in 12.4.1 to 12.4.5, unless otherwise stated. The safety and warning instructions specified in 12.4.1 to 12.4.5 shall be provided. The risk assessment shall determine the specific language required and additional safety and warning instructions.

NOTE Selection of warning statements to be presented through each medium should consider the following, among others: space limitations for displaying safety and warning instructions, selection of the product for appropriate users at purchase, initial use of the product, secondary users of the product, hazard prioritization, and likelihood and frequency of interaction with the safety and warning instructions.

12.4.1 Retail packaging

The consumer retail packaging for the product shall be marked with the minimum age for safe use of the product.

12.4.2 Instruction manual

An instruction manual shall be provided with the product. The instruction manual shall include all applicable safety and warning instructions described in 12.2 to 12.3, including explanations of the hazards and how to avoid the hazards. The instruction manual shall be accessible prior to use of the product.

12.4.3 First-use tutorial

NST and VST HMDs shall include a digital first-use tutorial upon first activation of each user of the product which shall provide information on the safe use of the product, which includes the information as determined applicable by the risk assessment. The tutorial shall be accessible to the user after completion. This requirement may be satisfied by displaying the tutorial through the product's display, and/or presenting the tutorial in a companion application for products that require a companion application for use of the product. Tutorials shall provide guidance to the user to review full safety manual. First-Use tutorials are recommended for OST HMDs.

NOTE It is expected that the warning information provided in a first-use tutorial may be a limited subset of the full information required in the product manual. The risk assessment should balance criticality of specific warnings against total length of warnings included in the tutorial to reduce warning fatigue.

12.4.4 Digital forced acknowledgment prompt

HMDs shall include as a default setting a recurring digital forced acknowledgement prompt. The prompt shall be shown to the user upon powering on the product. The default setting requires a recurring forced acknowledgement.

NOTE 1 The software may allow users to disable the prompt.

EXAMPLE A warning message displayed until the user indicates acknowledgment, such as by selecting a clickable element labeled "Okay."

The prompt shall include the following:

– Appropriate user age

– Conditions under which the user should cease using the product

– Awareness of surroundings

– Directions to review all the safety and warning instructions provided in the instruction manual

NOTE 2 It is expected that the warning information provided in a digital forced acknowledgement prompt may be a limited subset of the full information required in the product manual. The risk assessment should balance criticality of specific warnings against total length of warnings included in the prompt to avoid warning fatigue.

12.4.5 Digital safety section in product interface

The product interface shall incorporate an option to view the applicable safety and warning instructions specified in 12.2 to 12.3.

EXAMPLE (e.g., a digital menu page called "Safety").

This requirement may be satisfied by displaying the safety section through the product's display and/or presenting the safety section in a companion application for products that require a companion application for use of the product.

NOTE For products with limited capability for displaying information through the device display, which do not have a required companion application for use of the product, it may be permissible to instead provide directions for accessing elsewhere the applicable safety and warning instructions required by 12.2 to 12.3.

12.5 Warning against vergence-accommodation conflicts (VAC)

The likelihood of falls and collisions due to the after effect of VAC shall be minimized.

NOTE Eyes can adapt to VAC if this persists, leading to temporary decoupling between vergence and accommodation, misjudging depth, consequently, poses risks of injury.

Compliance is demonstrated by the evaluation of the available data, or relevant requirements in this standard.

A user shall be warned of the risk of consequential injury prior to use if such risk exists.

Furthermore, the user shall be advised that a break not shorter than 30 min shall be taken after each session, during which the user shall not perform any sensorimotor-demanding activities such as taking the stairs, driving, riding a bike, etc.

13 Functional safety

A system safety analysis shall be conducted on the equipment to determine hazardous events and/or hazardous situations due to system faults, component faults, or operation parameter faults and to identify the measures in place to address them. Acceptable guidance documents include, but not limited to IEC 60812 and IEC 61025.

Other internationally accepted, equivalent methods that are considered to provide equivalent results shall not be precluded.

As identified in the system safety analysis, where a defined set of actions that is designed to maintain a safe state of the equipment with respect to a specific hazardous event or hazardous situation, and is implemented in the form of electronic sensors and actuators, or software, or a combination of both, its functional safety shall be assessed by relevant standards or appropriate performance classification referenced in 13.1.

NOTE For the purpose of this standard, software may also refer to embedded software or firmware.

13.1 Requirements and compliance

A function is considered to be functionally safe if any of the following is fulfilled:

– UL 991, and Software Class 1 or better, in accordance with UL 1998 (if software is used).

– Control Class B or better, in accordance with CAN/CSA C22.2 No. 0.8.

– Class B Control Function or better, as per UL 60730-1 or CAN/CSA C22.2 E60730-1.

– Safety Integrity Level (SIL) 1 or better, in accordance with IEC 61508 (all parts).

13.2 Remote patch management

Remote patches and software updates that have an influence on device safety shall be well-managed.

Any safety function that is subjected to 13.2 and is maintained through remote patches or software updates over the life cycle shall comply with UL 5500.

The required processes shall be verifiable and shall be documented.

Annex A
(normative)

Measuring spectrophotometric properties

A.1 General

Test methods shall be used which have relative uncertainties in spectral transmittance less than or equal to those given in Table A.1. The methods of evaluating the components of uncertainty are set out in ISO/IEC Guide 98-3.

Table A.1
Relative uncertainty of measured spectral transmittance

Spectral transmittance value		Uncertainty
Less than %	to %	%
100	17.8	±2 absolute
17.8	0.44	±10 relative
0.44	0.023	±15 relative
0.023	0.0012	±20 relative
0.0012	0.000023	±30 relative

Calculations shall be carried out at not more than 5 nm intervals ($\Delta\lambda \leq 5$ nm).

A.2 Calculations of luminous transmittance

The DUT and the light beam are positioned so that the incident light falls normally on the surface of the DUT at the reference point. The spectral data are measured and recorded by scanning the DUT from 380 nm to 780 nm at intervals not less than 5 nm.

Luminous transmittance is calculated as a percentage from the spectral transmittances and with reference to a standard observer and a source or illuminant. For the purposes of this standard, all calculations use the CIE 1931 Standard Colorimetric Observer function as defined in ISO/CIE 11664-1 and the CIE Standard Illuminant D65 as defined in ISO/CIE 11664-2.

NOTE The CIE 1931 Standard Colorimetric Observer function is also known as the CIE 1931 2° Standard Observer.

$$\tau_v = 100 \times \frac{\int_{380}^{780} \tau(\lambda) \cdot S_{D65}(\lambda) \cdot V(\lambda) \cdot d\lambda}{\int_{380}^{780} S_{D65}(\lambda) \cdot V(\lambda) \cdot d\lambda}$$

where

λ is the wavelength of the light in nm

$\tau(\lambda)$ is the spectral transmittance of the DUT

$V(\lambda)$ is the CIE spectral luminous efficiency function for photopic vision

$S_{D65}(\lambda)$ is the spectral energy distribution of radiation of CIE Standard Illuminant D65

For convenience sake, the values of $S_{D65}(\lambda) \cdot V(\lambda)$ are given in Table A.2.

Table A.2
Product of the energy distribution of Standard Illuminant D65 and the spectral visibility function of the average human eye for daylight vision

Wavelength λ nm	$S_{D65}(\lambda) \cdot V(\lambda)$	Wavelength λ nm	$S_{D65}(\lambda) \cdot V(\lambda)$	Wavelength λ nm	$S_{D65}(\lambda) \cdot V(\lambda)$
380	0,0001	515	3,0589	650	0,4052
385	0,0002	520	3,5203	655	0,3093
390	0,0003	525	3,9873	660	0,2315
395	0,0007	530	4,3922	665	0,1714
400	0,0016	535	4,5905	670	0,1246
405	0,0026	540	4,7128	675	0,0881
410	0,0052	545	4,8343	680	0,0630
415	0,0095	550	4,8981	685	0,0417
420	0,0177	555	4,8272	690	0,0271
425	0,0311	560	4,7078	695	0,0191
430	0,0476	565	4,5455	700	0,0139
435	0,0763	570	4,3393	705	0,0101
440	0,1141	575	4,1607	710	0,0074
445	0,1564	580	3,9431	715	0,0048
450	0,2104	585	3,5626	720	0,0031
455	0,2667	590	3,1766	725	0,0023
460	0,3345	595	2,9377	730	0,0017
465	0,4068	600	2,6873	735	0,0012
470	0,4945	605	2,4084	740	0,0009
475	0,6148	610	2,1324	745	0,0006
480	0,7625	615	1,8506	750	0,0004
485	0,9001	620	1,5810	755	0,0002
490	1,0710	625	1,2985	760	0,0001
495	1,3347	630	1,0443	765	0,0001
500	1,6713	635	0,8573	770	0,0001
505	2,0925	640	0,6931	775	0,0001
510	2,5657	645	0,5353	780	0,0000
				Sum	**100,0000**

As an alternative, the equivalent summations as follows may be used:

$$\tau_v = 100 \times \frac{\Sigma_{380}^{780} \tau(\lambda) \cdot S_{D65}(\lambda) \cdot V(\lambda) \cdot d\lambda}{\Sigma_{380}^{780} S_{D65}(\lambda) \cdot V(\lambda) \cdot d\lambda}$$

A.3 Calculations of spectral transmittance

The calculations of spectral transmittance are the same as those of luminous transmittance in Clause A.2, except for the wavelength band of 475 nm to 650 nm is used.

A.4 Calculation of relative visual attenuation quotient

The relative visual attenuation quotient Q for visibility of signs and signals Q_{signal} is defined as:

$$Q_{signal} = \frac{\tau_{signal}}{\tau_v}$$

where

$$\tau_v = 100 \times \frac{\int_{380}^{780} \tau(\lambda) \cdot S_{D65}(\lambda) \cdot V(\lambda) \cdot d\lambda}{\int_{380}^{780} S_{D65}(\lambda) \cdot V(\lambda) \cdot d\lambda}$$

and

$$\tau_{signal} = 100 \times \frac{\int_{380}^{780} \tau(\lambda) \cdot E_{signal}(\lambda) \cdot V(\lambda) \cdot d\lambda}{\int_{380}^{780} E_{signal}(\lambda) \cdot V(\lambda) \cdot d\lambda}$$

where

λ is the wavelength in nm

$\tau(\lambda)$ is the spectral transmittance

$V(\lambda)$ is the CIE spectral luminous efficiency function for photopic vision

$S_{D65}(\lambda)$ is the spectral energy distribution of radiation of CIE Standard Illuminant D65

$E_{signal}(\lambda)$ is the spectral energy distribution of the red, yellow, green and blue traffic signals

For convenience sake, the values of $S_{D65}(\lambda) \cdot V(\lambda)$ are given in Table A.2 and the values of $E_{signal}(\lambda) \cdot V(\lambda)$ for incandescent signals are given in Table A.3 and for LED signals in Table A.4.

Table A.3
Spectral energy distribution of radiation in signal lights weighted by the sensitivity of the human eye

Wavelength	Red	Yellow	Green	Blue
λ (nm)	$E_{Red}(\lambda) \cdot V(\lambda)$	$E_{Yellow}(\lambda) \cdot V(\lambda)$	$E_{Green}(\lambda) \cdot V(\lambda)$	$E_{Blue}(\lambda) \cdot V(\lambda)$
380	0,000	0,000	0,000	0,000
385	0,000	0,000	0,000	0,000
390	0,000	0,000	0,000	0,000
395	0,000	0,000	0,000	0,000
400	0,000	0,000	0,000	0,010
405	0,000	0,000	0,000	0,010
410	0,000	0,000	0,000	0,030
415	0,000	0,000	0,000	0,060
420	0,000	0,000	0,000	0,120
425	0,000	0,000	0,000	0,250
430	0,000	0,000	0,000	0,440
435	0,000	0,000	0,010	0,680
440	0,000	0,000	0,020	0,970
445	0,000	0,000	0,030	1,260
450	0,000	0,000	0,050	1,600
455	0,000	0,000	0,080	1,950
460	0,000	0,000	0,120	2,350
465	0,000	0,000	0,180	2,760
470	0,000	0,000	0,270	3,230
475	0,000	0,010	0,380	3,720
480	0,000	0,010	0,540	4,240
485	0,000	0,020	0,740	4,650
490	0,000	0,040	1,020	5,080
495	0,000	0,070	1,410	5,510
500	0,010	0,120	1,910	5,870
505	0,010	0,200	2,610	6,450
510	0,010	0,320	3,430	6,800
515	0,010	0,490	4,370	6,660
520	0,010	0,760	5,320	5,950
525	0,020	1,160	6,130	5,150
530	0,020	1,700	6,860	3,960
535	0,020	2,350	7,370	3,370
540	0,020	3,060	7,700	2,650
545	0,020	3,710	7,750	2,320
550	0,020	4,260	7,340	1,940
555	0,020	4,730	6,460	1,460
560	0,030	5,050	5,480	0,970
565	0,040	5,270	4,790	0,660
570	0,080	5,440	4,340	0,360
575	0,230	5,470	3,770	0,280
580	0,670	5,430	3,040	0,200

Table A.3 Continued on Next Page

Table A.3 Continued

Wavelength	Red	Yellow	Green	Blue
λ (nm)	$E_{Red}(\lambda) \cdot V(\lambda)$	$E_{Yellow}(\lambda) \cdot V(\lambda)$	$E_{Green}(\lambda) \cdot V(\lambda)$	$E_{Blue}(\lambda) \cdot V(\lambda)$
585	1,640	5,320	2,400	0,220
590	3,320	5,160	1,790	0,240
595	5,400	4,940	1,050	0,230
600	7,320	4,670	0,400	0,230
605	8,750	4,380	0,120	0,180
610	9,350	4,040	0,050	0,130
615	9,320	3,640	0,060	0,100
620	8,950	3,270	0,090	0,060
625	8,080	2,840	0,110	0,070
630	7,070	2,420	0,100	0,070
635	6,100	2,030	0,070	0,160
640	5,150	1,700	0,040	0,210
645	4,230	1,390	0,020	0,430
650	3,410	1,110	0,020	0,540
655	2,690	0,870	0,010	0,420
660	2,090	0,670	0,000	0,320
665	1,570	0,510	0,000	0,210
670	1,150	0,370	0,000	0,140
675	0,850	0,280	0,000	0,260
680	0,640	0,210	0,000	0,300
685	0,470	0,150	0,000	0,320
690	0,330	0,100	0,000	0,300
695	0,240	0,070	0,000	0,230
700	0,180	0,060	0,010	0,180
705	0,130	0,040	0,020	0,130
710	0,090	0,030	0,020	0,100
715	0,070	0,020	0,020	0,070
720	0,050	0,010	0,020	0,050
725	0,030	0,010	0,020	0,030
730	0,020	0,010	0,010	0,030
735	0,020	0,010	0,010	0,020
740	0,010	0,000	0,010	0,010
745	0,010	0,000	0,010	0,010
750	0,010	0,000	0,000	0,010
755	0,010	0,000	0,000	0,010
760	0,010	0,000	0,000	0,010
765	0,000	0,000	0,000	0,000
770	0,000	0,000	0,000	0,000
775	0,000	0,000	0,000	0,000
780	0,000	0,000	0,000	0,000
Sum	100,000	100,000	100,000	100,000

Table A.4
Spectral energy distribution of radiation in LED signal lights weighted by the sensitivity of the human eye

Wavelength	Red LED	Yellow LED	Green LED	Blue LED
λ (nm)	$E'_{Red}(\lambda) \cdot V(\lambda)$	$E'_{Yellow}(\lambda) \cdot V(\lambda)$	$E'_{Green}(\lambda) \cdot V(\lambda)$	$E'_{Blue}(\lambda) \cdot V(\lambda)$
380	0,000	0,000	0,000	0,000
385	0,000	0,000	0,000	0,000
390	0,000	0,000	0,000	0,000
395	0,000	0,000	0,000	0,000
400	0,000	0,000	0,000	0,000
405	0,000	0,000	0,000	0,000
410	0,000	0,000	0,000	0,000
415	0,000	0,000	0,000	0,000
420	0,000	0,000	0,000	0,000
425	0,000	0,000	0,000	0,010
430	0,000	0,000	0,000	0,050
435	0,000	0,000	0,000	0,170
440	0,000	0,000	0,010	0,550
445	0,000	0,000	0,010	1,650
450	0,000	0,000	0,020	4,470
455	0,000	0,000	0,040	9,600
460	0,000	0,000	0,090	14,170
465	0,000	0,000	0,190	13,990
470	0,000	0,000	0,450	11,180
475	0,000	0,000	1,010	9,070
480	0,000	0,000	2,130	7,370
485	0,000	0,000	4,000	5,470
490	0,000	0,000	6,530	4,210
495	0,000	0,000	9,380	3,380
500	0,000	0,000	11,340	2,690
505	0,000	0,000	11,820	2,160
510	0,000	0,000	11,150	1,760
515	0,000	0,000	9,840	1,410
520	0,000	0,010	8,220	1,140
525	0,000	0,010	6,550	0,900
530	0,000	0,020	4,890	0,690
535	0,000	0,030	3,570	0,570
540	0,000	0,050	2,630	0,480
545	0,000	0,120	1,870	0,410
550	0,000	0,240	1,290	0,330
555	0,010	0,500	0,930	0,270
560	0,020	1,000	0,630	0,220
565	0,040	1,850	0,430	0,220
570	0,070	3,390	0,300	0,200
575	0,110	6,080	0,210	0,170
580	0,210	11,180	0,140	0,140

Table A.4 Continued on Next Page

Table A.4 Continued

Wavelength	Red LED	Yellow LED	Green LED	Blue LED
λ (nm)	$E'_{Red}(\lambda) \cdot V(\lambda)$	$E'_{Yellow}(\lambda) \cdot V(\lambda)$	$E'_{Green}(\lambda) \cdot V(\lambda)$	$E'_{Blue}(\lambda) \cdot V(\lambda)$
585	0,400	20,100	0,090	0,110
590	0,690	26,720	0,070	0,140
595	1,110	18,530	0,050	0,120
600	1,710	6,910	0,030	0,090
605	2,520	2,200	0,020	0,070
610	3,640	0,700	0,020	0,090
615	5,350	0,230	0,010	0,050
620	7,990	0,080	0,010	0,040
625	12,220	0,030	0,010	0,030
630	17,410	0,010	0,010	0,040
635	19,030	0,010	0,010	0,040
640	14,200	0,000	0,000	0,020
645	7,800	0,000	0,000	0,020
650	3,380	0,000	0,000	0,010
655	1,320	0,000	0,000	0,010
660	0,490	0,000	0,000	0,010
665	0,180	0,000	0,000	0,010
670	0,060	0,000	0,000	0,000
675	0,030	0,000	0,000	0,000
680	0,010	0,000	0,000	0,000
685	0,000	0,000	0,000	0,000
690	0,000	0,000	0,000	0,000
695	0,000	0,000	0,000	0,000
700	0,000	0,000	0,000	0,000
705	0,000	0,000	0,000	0,000
710	0,000	0,000	0,000	0,000
715	0,000	0,000	0,000	0,000
720	0,000	0,000	0,000	0,000
725	0,000	0,000	0,000	0,000
730	0,000	0,000	0,000	0,000
735	0,000	0,000	0,000	0,000
740	0,000	0,000	0,000	0,000
745	0,000	0,000	0,000	0,000
750	0,000	0,000	0,000	0,000
755	0,000	0,000	0,000	0,000
760	0,000	0,000	0,000	0,000
765	0,000	0,000	0,000	0,000
770	0,000	0,000	0,000	0,000
775	0,000	0,000	0,000	0,000
780	0,000	0,000	0,000	0,000
Sum	100,000	100,000	100,000	100,000

Annex B
(normative)

Methods for Assessing Risks of Collison Hazards

B.1 General

Documents that may be used as guidance for the risk assessment include:

– IEC 60812

– IEC 61025

– IEC 61508

– IEC Guide 116

– ISO/IEC 31010

The risk assessment shall include considerations for collision hazards, as applicable. As a minimum, the examples given in the following shall be considered:

– Clause B.2, for NST HMD with total optical occlusion,

– Clause B.3, for VST HMD with video passthrough cameras,

– Clause B.4, for OST HMD with see-through optics.

B.2 NST HMD with total optical occlusion

For NST HMD with total optical occlusion, the following considerations shall be included:

– intended and reasonably foreseeable applications,

– fit of the HMD where there is potential for the device to slip or move,

– user distraction by physical and/or digital elements of the HMD,

– legibility of displayed text,

– obstruction of view by physical elements of the HMD, and

– movement of the operator's extremities outside the operator's FOV.

B.3 VST HMD with video pass through cameras

For VST HMD, in addition to the considerations given in Clause B.2, the following shall be included:

– latency, freezing or interruption of video pass through,

– FOV of video pass through, and

– resolution or fidelity of video pass through.

B.4 OST HMD with see-through optics

For OST HMD, in addition to the considerations given in Clause B.2, the following shall be included:

– acceptable transmissivity, taking Clause 6 into account,

– interaction between ambient light levels and display luminosity,

– obstruction of view by display overlay elements, and

– obstruction of view by device physical elements.

Annex C
(informative)

General Safety Requirements

C.1 General

For the convenience of the general user, Table C.1 summarizes the main safety requirements covered by CAN/CSA-C22,2 No. 62368-1/UL 62368-1. The actual requirements may vary with the immersive technologies employed and the extent of their complexity, mobility, scale, user groups, etc.

Table C.1
General safety requirements covered by CAN/CSA-C22.2 No. 62368-1/UL 62368-1

Clause	Description	Summary of requirements
4.4.3	Safeguard robustness	The integrity of safeguards guarding hazardous energy sources shall not be compromised due to various mechanical strength tests.
5	Electrically-caused injury	Air and solid electrical insulation shall be adequately dimensioned for the electrical stresses arises from power transmission lines.
6	Electrically-caused fire	The amount of combustible materials shall be managed with respect to the available power (which may convert into heat) and the source of ignition (high current arc or ohmic heating).
8.4	Mechanically-caused injury	Accessible parts shall not constitute sharp edges and corners that is capable of causing pain or injury.
9	Thermal burn injury	The touch temperature at accessible parts shall not exceed the skin burn thresholds for the intended contact period.
10	Radiation	Excessive optical (visible, IR, UV) and acoustic energy sources shall be safeguarded from exposure.
Annex M	Lithium-ion batteries	The battery protection scheme shall be adequate for the electrical and thermal stresses expected throughout its service life.

Annex D
(informative)

Visually Induced Motion Sickness

D.1 General

Immersive technology equipment that is prone to optical occlusion, i.e., NST or VST, should be designed and constructed so that the likelihood of occurrence and the magnitude of consequences of accidental falls and collisions due to visually induced motion sickness (VIMS) and subsequent postural instability or unsteady gait, are reduced.

VIMS may result from:

– visual-vestibular sensory mismatch due to excessive MtP latency (Clause D.2),

– misperception in depth and subsequent false spatial judgment due to mismatch between IAD and IPD, inadequate range of adjustable IAD, misaligned mechanical and optical axes, or misaligned optical axes of binocular lenses (Clause D.3),

– impaired peripheral vision due to unwanted motion artifacts (Clause D.4), or

– unstable vertical visual reference due to poor tracking and sensor fusion (Clause D.5).

D.2 MtP latency

In order to reduce malaise, the likelihood of falls and collision due to postural instability and unsteady gait, dysmetria, visual disturbances consequent on VIMS, the end-to-end MtP latency should be minimized to reduce the extent of visual-vestibular mismatch. MtP latency is the amount of time between a user input movement (e.g., head movement, control device movement, physical body movement) and the screen being updated.

The end-to-end MtP latency (Δt, in ms) is a comparison of successive time measurements for a change in test pattern luminance and is defined as follows:

$$\Delta t = t_{VE} - t_{RE}$$

where

t_{VE} is the travel time between the start and final positions in VE

t_{RE} is the travel time between the start and final positions in RE

NOTE 1 In general, the MtP latency is the multiplier of the reciprocal of the refresh rate.

An NST or VST HMD should be subject to the MtP latency measurement, as specified in D.2.1 – D.2.5.

The measured end-to-end MtP latency, Δt, should not exceed 20 ms for a good user experience. Further, it is important to note that latency is different with different head worn display devices, different software configurations and authoring tools, and different input methods

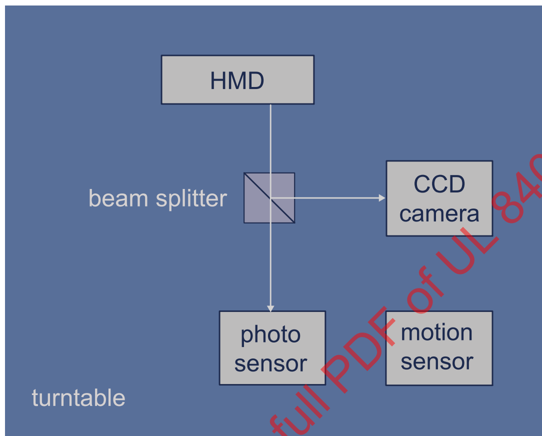
NOTE 2 MtP latency may be induced or mitigated by various software and applications installed on the NST or VST HMD and may not be a product of the device itself. This test should be run using all algorithms that will affect latency during normal usage.

D.2.1 Test Setup

The test setup should comprise of a beam splitter that directs the light emitted from the DUT to a photoelectric sensor, with a sampling rate not less than 10 kHz, and a CCD camera. A turntable driven by a stepper motor, with integer steps not less than 3,600 per revolution, supports and provides motion to the DUT. The test setup is illustrated conceptually in Figure D.1.

NOTE 1 The beam splitter may be a polarizing cube.

NOTE 2 The precise alignment between the test pattern and the beam splitter is aided by the CCD camera.



su4562

Figure D.1

Test setup diagram

D.2.2 FOV Measurement

Prior to the test, the DUT is running a test pattern of constant full screen white at the maximum luminance. A warm-up time of up to 20 min should be allowed.

The LMD, as specified in D.2.3, is adjusted to match the entrance pupil at the centre of rotation of the biaxial goniometer, and then align the measuring direction at the centre of the virtual image and measure the luminance of the centre.

The corners of the FOV is determined by iterative luminance measurement according to D.2.4 and the boundaries of effective FOV is defined as either the horizontal or vertical edges at which the luminance drops below 50 % of the luminance at the centre of the display.

NOTE In mathematics, the Euclidean algorithm is an efficient method for computing the greatest common divisor of two numbers, the largest number that divides both without leaving a remainder.

D.2.3 Light measuring device (LMD)

The optics of the LMD should be approximate to the human eye and shall be equipped with a finder. The size of the entrance pupil of the LMD shall be set, depending on the environmental illuminance and can range between 2 mm and 7 mm, and should be smaller than the output light field of the equipment. The LMD should be dark field (zero) corrected and low-pass filtered, with a cut-off frequency at 150 Hz (±3 dB), and −60 dB at the sampling frequency.

D.2.4 Luminance measurement

The display is adjusted at its maximum brightness and running a test pattern of constant full screen while at the maximum luminance. A warm-up time of up to 20 min should be allowed.

The LMD is adjusted to match the entrance pupil at the eye point of the equipment and is focused at a specified virtual image distance. The luminance at each measuring location as illustrated in Figure D.2 is measured and recorded. This is repeated for the other ocular.

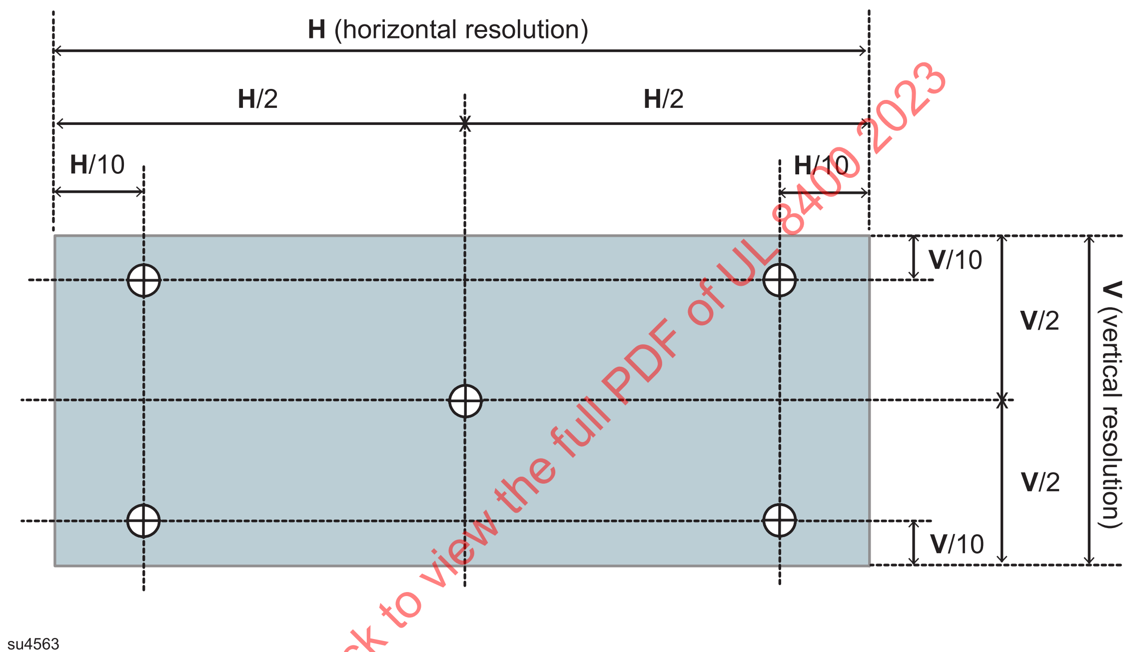


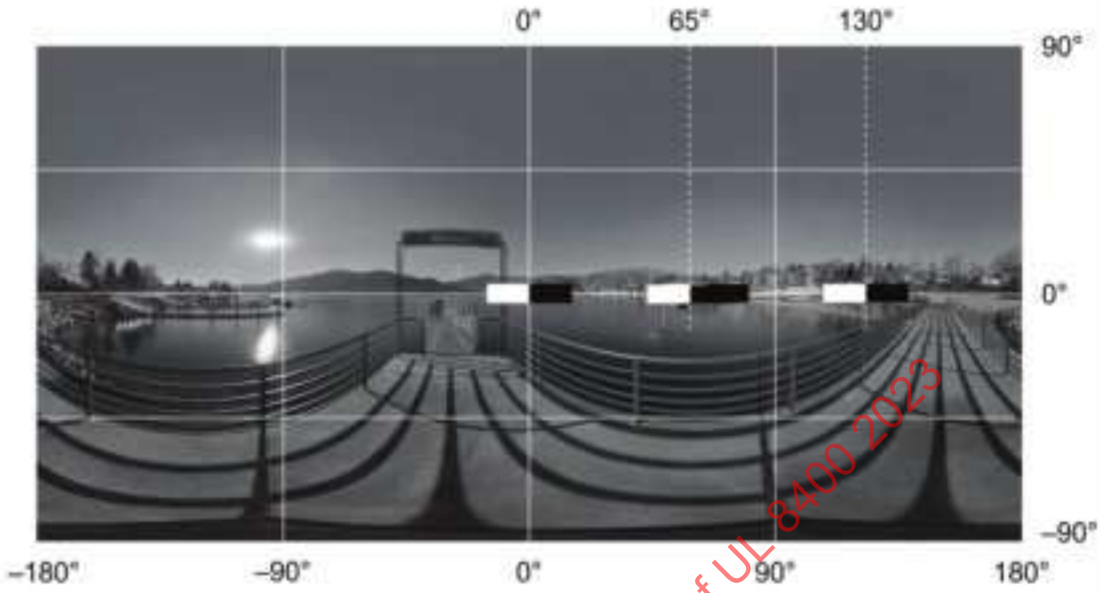
Figure D.2

Five-point measuring locations

D.2.5 Test image

The raw test image used for the test should be an equirectangular depiction of a 360 spherical panoramic picture with a resolution not less than 13,312 x 6,656 pixels and a file size not less than 20 MB or the maximum permitted by the DUT. The image is modified to incorporate three equal-size white-black rectangles forming a test patterns with the respective white-black junctions centred in the coordinates of (0°, 0°), (0°, 65°) and (0°, 130°) respectively, as illustrated in Figure D.3. The resultant test image is imported to the DUT.

EXAMPLE Such test image may be obtained from some street view services.



su4564

Figure D.3

Test image incorporating test pattern (excludes the dotted and grid lines)

D.2.6 Test procedure

The start (zero) position is initialized. The DUT is secured to the turntable with one lens aligned with the centre of the beam splitter such that the maximum FOV is obtained (D.2.1). The DUT is then slowly rotated to the test image coordinates of (0°, 0°) as evidenced by the photoelectric sensor centring on the vertical edge of the test pattern (dividing the test pattern into white and black). The position initialization is repeated with the other coordinates, (0°, 65°) and (0°, 130°) respectively. The position of the third coordinate (0°, 130°) represents the final position.

The t_{RE} and t_{50} measurements (t_{VE} by calculation) are made under the following conditions:

– the DUT is accelerated from the start position according to the motion profile as illustrated in Figure D.4 and maintained at a constant angular velocity until it arrives at the final position. The travel time, t_{RE}, between the start and final positions is measured.

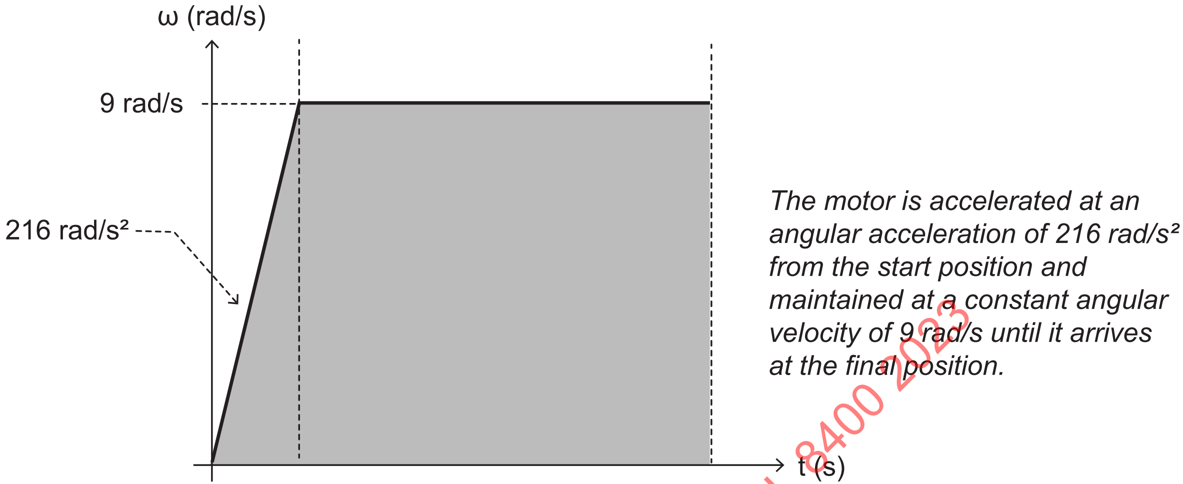
NOTE 1 The DUT needs not to be turned on during the start position measurement.

– the DUT is then turned on and running the test image which is recognized by using the photoelectric sensor to detect when the relative luminance drops below 50%, t_{50}, as illustrated in Figure D.5.

– prior to starting the test, the turntable motor is synchronized with a refresh sequence of the DUT. As soon as the pixel at the centre refreshes, that is, the coordinate of (0°, 0°), the DUT is accelerated from the start position according to the motion profile as illustrated in Figure D.4 and maintained at a constant angular velocity until it arrives at the final position.

– the time between the start position t_{50} (of the first test pattern in the test image) and the final position t_{50} (of the third test pattern in the test image) is the t_{VE}.

NOTE 2 t_{50} occurs where the test pattern changes from white to black.



su4565

Figure D.4

Motion profile of the turntable

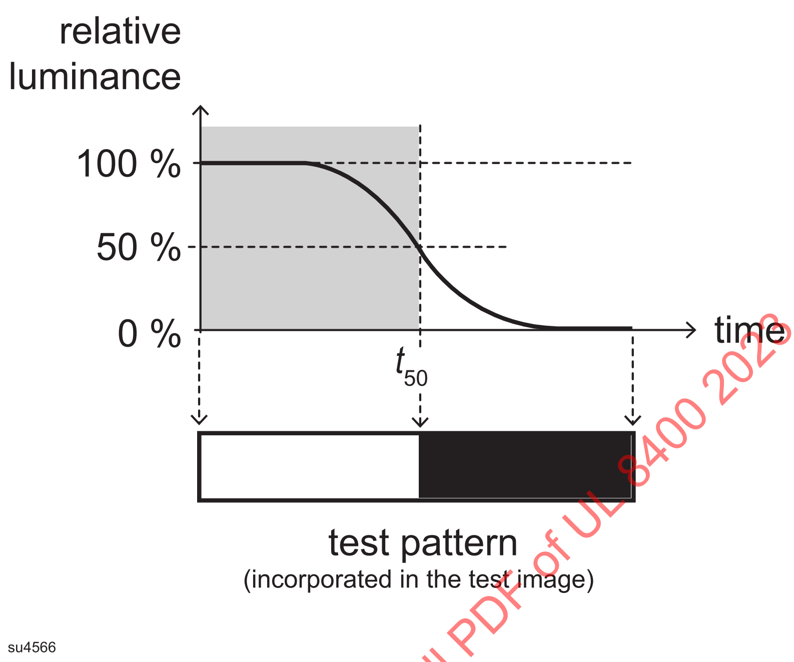


Figure D.5
Test pattern recognition

D.3 IPD-IAD fit

To address VIMS induced by IPD-IAD unfit and consequent falls and collisions owing to degraded spatial acuity and false judgment in depth and distance, an NST or VST HMD should comply with all of the following:

– the indicated IPD should match the IAD, (D.3.1)

– the range of IAD should be adequate to accommodate the majority of recommended users (D.3.2),

– the optical axis of the optical elements (e.g., lenses) should be aligned with the defined mechanical axis or perpendicular to the plane onto which the lenses are mounted (D.3.3), and

– the optical axes of binocular lenses should be parallel to each other (D.3.4).

NOTE The brain uses binocular disparity to extract depth information from the two-dimensional retinal images in stereopsis. Incorrectly configured IPD can impair stereoscopic depth perception and consequent distance misperception.

D.3.1 Validation of IAD

The indicated IPD should be accurate and should match the IAD.

The indicated values of the IAD should not deviate from the measured IPD by more than ±1.5 mm.

D.3.2 Adjustable range of IAD

The range of adjustable IAD should be adequate to accommodate the majority of recommended users. This includes offering various sizes of HMDs which could adequately address IAD.

The user should be informed how to obtain the correct IPD prior to initial use (see 12.2.3).

NOTE This may be a set of self-assessment procedure or as specified by an optometrist or optician.

The IAD should extend the adjustable range from 50 mm to 75 mm, which may be achieved by either hardware or software, or both.

D.3.3 Perpendicular alignment

The optical axis of the optical elements (e.g., lenses) should be aligned with the defined mechanical axis. In the absence of the defined mechanical axis, the optical axis should be perpendicular to the plane onto which the lenses are mounted.

D.3.4 Optical alignment

The optical axes of the binocular lenses should be parallel to each other.

For the purpose of this standard, vertical misalignment is defined as the angular deviation from which one optical axis has to tile up or down (in vertical dimensions) to coincide with the other. Likewise, horizontal misalignment is the extent two axes point inward (convergence) or outward (divergence), horizontally.

The vertical misalignment should not exceed 30 arcmin while also the horizontal misalignment should not exceed 40 arcmin in horizontal convergence and 100 arcmin in horizontal divergence.

D.4 Motion-induced blur

To address VIMS on account of blurry peripheral vision and consequent postural instability and unsteady gait, an NST or VST HMD should be subject to the measurement of the motion-induced blur, as specified in D.4.1 – D.4.4.

NOTE 1 Research has shown that peripheral rather than central vision contributes to maintaining a stable standing posture.

NOTE 2 Motion-induced blur arises when the observer's eyes track or follow the apparent motion of the image, while the display presents an individual frame that persists for significant fractions of a frame duration, or longer. As a result, the image smeared across the retina during the frame hold-up time.

NOTE 3 Motion-induced blur may be induced or mitigated by various software and applications installed on the NST or VST HMD and may not be a product of the device itself.

NOTE 4 Need to consider tolerance. Specifically, need to look at blurring across different environmental context (e.g., variety of contrasting color pallets in the environment), as peripheral perception of blur may be altered by different environmental context.

The extent of perceived motion-induced blur is measured and assessed by MESP (moving-edge spatial profile, in D.4.2) and METP (moving edge temporal profile, in D.4.3), and quantified by BD (blur duration, in D.4.4).

Averaged blur duration, neither $BD_{10–90(F)}$ nor $BD_{10–90(R)}$ nor $BD_{10–90}$ should exceed 8 ms.

D.4.1 Test pattern

The test pattern should be a vertical edge dividing two regions, the initial and final gray levels, as depicted in Figure D.6.