Eyesafe® Display Requirements 3.0

Blue Light Management and Color Performance for Device Manufacturers

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Developed in collaboration with the Eyesafe Vision Health Advisory Board.
For more information about Eyesafe® Requirements, product verification, and partner guidelines, please visit eyesafe.com.
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This guidance represents the current assessment of Eyesafe and the Eyesafe Vision Health Advisory Board on this topic. It does not establish any rights for any person and is not binding on Eyesafe or the public. You can use an alternative approach if it satisfies the requirements of the applicable statutes and regulations. From time to time, the Eyesafe Display Requirements will be updated based upon guiding research and the latest information.

1. Purpose

This document is designed to support manufacturers in product development, utilizing the industry-leading Eyesafe® Requirements , outlining key criteria and methodologies for testing of display products, including smartphones, tablets, notebooks, desktop computers televisions and commercial displays.

The device in question would be a display module (e.g. smartphone, tablet) or a display module having a certain level of blue light emission and color performance requirements, herein referred to as "Eyesafe Display Requirements". Passing the proposed criteria would lead to verification according to quality characteristics to be identified as "Eyesafe".

With the emergence of light-emitting diodes (LEDs) and organic light-emitting diodes (OLEDs) technology, and its increasing use in electronic display products, public interest and concern about blue light has increased. Additionally, with daily screen time continuing to increase and close-up use of devices occurring at all times during the day, users are being exposed to increasing amounts of high-energy blue light from their devices.[1-4]

Current digital devices deliver higher levels of blue light to the retina than do conventional domestic light sources, causing the public to be exposed to greater levels of high-energy visible (HEV) blue light than ever before. Long-term health implications are now being studied, but eye strain and other immediate effects of display use affect people daily.

Recent studies have shown growing concerns over potential long-term eye health impacts from digital screen usage and cumulative blue light exposure,[5-9] in addition to recognized impacts of device use on circadian rhythms and sleep patterns.[10-17] Blue light exposure research and studies on animals' cells have shown that blue light in a range of 415 to 455 nm generated the greatest phototoxic risk to retinal pigment epithelium cells,[7,18-21] with photoreceptor cell apoptosis seen early after the retina is damaged by blue light.[6,7,19,21-23]

Several international standards have been published to quantify blue light radiation levels to humans.[24,25] ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines on limits of exposure to broadband incoherent optical radiation (380 to 700 nm) provide a spectral weighting function $B(\lambda)$ for retinal blue light hazard. This standard will cover 300 to 780 nm to realistically oversee all-optical hazards in this spectral area.[5]

The Eyesafe display requirements measures the level of blue light based on the spectral weighting factors for blue-light hazard as published by the ICNIRP in 2013 and adopted by the American National Standard Institute (ANSI) in 2015.[26]

The purpose of Eyesafe Display verification is to show to the end user that the product design provides partial reduction (not complete elimination) of blue light exposure in certain wavelength ranges and meanwhile ensures front of screen performance, including color range and correlated color temperature (CCT).

The enclosed Eyesafe Display Requirement includes non-binding industry recommendations. From time to time, Eyesafe may adjust the Eyesafe display requirement to reflect new guiding research and the latest available information.

2. Scope

The Eyesafe display requirement is intended primarily for electronic products with displays that typically emit visible radiation in the range of 380 to 780 nm. Examples of these products include (but are not limited to): computer monitors, and flat-panel displays, notebook computers, tablet PCs, e-book readers, smartphones, televisions, and commercial point-of-sale (POS) displays.

3. Background

3.1 Human vision, light and display technology

The sunlight spectrum

The human visual system is primarily structured to receive and process natural light (sunlight). Each part of the eye receives and absorbs various amounts of sunlight energy. The human eye over time has become well equipped to process a wide spectrum of sunlight wavelengths under various bright and dim levels of illumination.

What we should know about blue light

Light consists of electromagnetic particles known as photons, which move in wave-like patterns. The wavelengths of visible and non-visible light are measured in nanometers (nm). In general, the shorter the wavelength, the higher the energy. Visible light is just a small portion of what's called the electromagnetic spectrum, which includes ultraviolet (UV) rays, x-rays, infrared radiation, microwaves, and other types of radiation.

Blue light, also known as high-energy visible (HEV) light, is the portion of the visible light spectrum that has the shortest wavelengths and therefore the highest amount of energy. The entire visible light spectrum comprises electromagnetic radiation with wavelengths ranging from 380 to 780 nm. Blue light is visible light with wavelengths ranging from 400 to 500 nm.

Because of its higher energy, blue light has greater potential than other wavelengths of visible light to cause harm to tissues of the eye.[27-29]

Visible and non-visible light

Only the visible light spectrum — electromagnetic radiation with wavelengths ranging from 380 to 780 nm — is perceived by the human eye.

Ultraviolet (UV) radiation is adjacent to high-energy visible blue light on the electromagnetic spectrum.

UV rays have shorter wavelengths (100 to 380 nm) and greater energy than visible blue light. Ultraviolet radiation sometimes is called "UV light," but UV rays are invisible to the human eye.

Most UV radiation is absorbed by the atmosphere and does not reach the Earth's surface. However, longer-wavelength UV rays — especially the UVA range (315 to 380 nm) — do reach our eyes. Most UVA is absorbed by the cornea, lens and other structures of the eye, but some longer UVA rays can penetrate the eye and reach the light-sensitive retina at the back of the eye.[18, 30]

The Eyesafe display requirement specifically addresses high-energy visible blue light (400 to 500 nm). Invisible UV radiation is beyond the scope of the standard.

Artificial lighting vs. natural lighting

Natural light comprises a wide array of colors whose intensities and hues vary throughout the day.

LED and OLED-based artificial lighting and LCD backlight systems contain high energy blue light (400 to 500 nm), in a light spectrum that is mostly static. Our physiology is naturally better adapted to the dynamic spectrum of natural sunlight than to artificial lighting that constantly is emitting high levels of blue light.

Research has demonstrated that acute exposure to intense blue light causes photochemical damage ("phototoxic effects") to retinal cell physiology, and potential harmful effects of cumulative exposure to HEV blue light may cause premature aging of the retina, according to some sources.[6, 10, 31]

Also, exposure to blue light in the evening and near bedtime from even low-level sources has been linked to sleep disruption and circadian rhythm changes that have been associated with multiple health problems.[10, 31]

Therefore, a major concern is how best to protect eye health and systemic health by optimizing the spectral distribution of display lighting and simulating the periodical changes of natural light.

Display technology development

Display technology has accelerated dramatically in recent years. From CRT to CCFL, LCD, LED, and OLED, displays are becoming brighter and the concentration of HEV light has increased. Potential health issues from increased blue light exposure is especially concerning for children and adolescents, who typically spend many hours each day staring at display screens and whose eyes are still developing.[3, 5]

3.2 Health and Safety Concerns

Potential dangers of blue light

While the dangers of overexposure to ultraviolet (UV) radiation have been known for decades, potentially harmful effects of cumulative blue light exposure, have only recently begun to be understood [12, 13, 18, 27, 32]

To capture the body of medical data that has and continues to be published, Eyesafe has assembled an advisory team of noted optometrists and ophthalmologists that maintain a current awareness of published research and methods for treatment of critical exposures to damaging portions of the color spectrum.

Also, Eyesafe's research and technical teams are continually reviewing and cataloging the latest published research about blue light to offer a clear understanding of which portions of the blue light spectrum have the greatest impact on retinal health, macular degeneration risks, and disruption of human melatonin modulated sleep cycles. [34] For more information, please visit eyesafe.com/research.

Potential risks to vision and health

A growing number of studies suggest that cumulative exposure to blue light over time could lead to premature eye health issues, among them damage to photoreceptor cells in the retina that may increase risks of vision problems such as age-related macular degeneration.[27, 30, 32]

Recent growing concerns have been expressed in the eye care community over the potential long-term eye and health impacts from digital screen usage and cumulative blue light emitted from digital devices. A combination of factors including viewing distance, frequency and duration of use, physical responses to screen habits, and exposure to blue light, have been reported to cause visual discomfort in 65 percent of Americans.[1]

Exposure to blue light from digital devices has been cited as a contributor to digital eye strain,[1,35-37] which is characterized by an ensemble of symptoms such as dry eyes, irritated eyes, blurred vision, sleep disruption, fatigue, reduced attention span, irritability, and neck and shoulder pain.[35, 36]

By stimulating retinal ganglion cells, natural blue light in the 460 to 480 nm wavelength range suppresses melatonin production and therefore plays an important role in alertness, memory, attention span and learning ability, and cognitive performances.[32,35] Several studies have shown the impact of digital technology, and the blue light they emit, have on disruption of circadian rhythms in adolescents and adults, [10-14,31] resulting in reduced duration and quality of sleep, linked to various diseases such as obesity, depression, and possibly cancer.[3,12,14,31,38]

Recent research has shown that filtering blue light from digital displays before bedtime produced significant positive health benefits among teenagers by curbing the LED-induced melatonin suppression and decreased alertness.[39]

Other studies have shown that blue light filters reduce visual acuity loss among digital device users who have dry eyes and reduce glare and photo-stress associated with prolonged exposure to intense light.[38-40]

Recently, some governmental agencies have taken some steps to limit the exposure of blue light to groups of populations at risk, such as infants and young children. Indeed, the French government, following an expert report from the ANSES (French Agency for Food, Environmental and Occupational Health & Safety) will take steps to limit children' exposure to certain technologies involving LEDs (toys and devices).[24,42]

The State of California has taken a stand on the blue light issue: in 2019, the State Blue Light Resolution SCR-73 was unanimously passed. Its purpose is to encourage all Californians (and their children) to "consider taking protective safety measures in reducing eye exposure to high-energy visible blue light." The Resolution designates October 10th as "Blue Light Awareness Day".[43]

Protective measures to reduce blue light exposure can include the use of blue light filtering glasses, the use of a blue light filter placed at the source of the emission, i.e., a filter applied directly onto the digital screen, alternatively the use of a low blue light certified device.

3.3 Recent Lighting Source Development

Methods used today to create artificial white light or enhancing the color of the lighting to make it pleasing to the eye are very sophisticated. LED and OLED display technology and color-altering phosphors can precisely blend red, green, and blue to very accurate levels.

Two key development trends should be noted:

- LED light bulbs today are steadily increasing in luminance per watt, and therefore creating intense bright light from very small sources
- In general, displays are increasing in luminance, with many operating at color temperatures of 7500 K and higher. By comparison, the color temperature of natural daylight is approximately 6500 K, and indoor light bulbs range from 2700 K (warm hue) to 7500 K (bright cool hue).

These trends are concerning, since there is growing evidence that overexposure to blue light (characterized by higher color temperatures) may have significant vision and health consequences.

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4. Eyesafe® Display Requirements 3.0

Eyesafe® Display Requirements focus on high energy visible (HEV) blue light that is emitted by digital devices and relies on photobiological safety standards from the American National Standards Institute to guide its development: Z80.3-2018 and Z87.1- 2015, and the IEC/EN 62471 from the International Electrotechnical Commission, in addition to guiding industry research.[26] Additionally, the International Commission on Illumination (CIE) published the universally recognized standard action spectra for melanopic impact that is used by all industries that work with artificial light. The peak sleep-wake impact is at 490 nm, which is between traditional blue and green on RGB displays.

In the wake of increasing research indicating potential negative effects of blue light on the eyes and circadian rhythms, Eyesafe Display Requirements 3.0 measure both Radiance Protection Factor (RPF®) and a new optional metric, Circadian Protection Factor (CPF). This approach provides a more comprehensive measure of blue light on health, evaluating blue light emissions in the wavelengths affecting both eye health (peak 435-440 nm) and melatonin/sleep-wake cycles (peak 480-500 nm).

The following requirements were developed to assist device manufacturers in effective blue light filtration, color accuracy and adherence to leading industry standards.

Eyesafe® Display Requirements 3.0		
High Energy Visible Light – Toxicity	Weighted blue light toxicity emissions based on ICNIRP Guidelines	Radiance Protection Factor (RPF®) Pass/Fail of verification will be at RPF35. Measurement of blue light toxicity is based on extensive health research and optical testing. The RPF scale is third-party tested and verified. Higher RPF numbers indicate greater reduction of toxic high-energy blue light emissions. $\mathbf{RPF = 260 \times \frac{(BLTF_{D65} - BLTF_{Tested})}{BLTF_{D65}}}$ In which: • $BLTF_{D65} = 0.098$ • 260 = Scaling factor • $BLTF_{Tested}$: The BLTF of the tested sample • D65: D65 corresponds roughly to the average midday light in Western Europe / Northern Europe (comprising both direct sunlight and the light diffused by a clear sky). There are no actual D65 light sources, only simulators *Note: The scaling factor was set based on the current technological limits of recent LCD and OLED technologies.*
Color Performance	Color Gamut Coverage %	For sRGB color mode: ≥95% of standard sRGB color space in CIE 1931; 1976 For Adobe RGB color mode: ≥90% of standard Adobe RGB color space in CIE 1931; 1976 For DCI-P3 color mode: ≥90% of standard DCI-P3 color space in CIE 1931; 1976 For NTSC color mode: ≥72% of standard NTSC color space in CIE 1931; 1976* **For battery powered products NTSC color mode : ≥45% of standard NTSC color space in CIE 1931; 1976*
	Color Temperature	5500-7000K** *** Only applicable to AIO, NB, Monitors*
Optional: Eyesafe® Circadian Display Requirements		
High Energy Visible Light – Circadian	Emissions based on the CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light	Circadian Protection Factor (CPF) Pass/Fail of verification will be at CPF35. Measurement of circadian impact is based on extensive health research and optical testing. The CPF scale is third-party tested and verified. Higher CPF numbers indicate greater reduction of circadian impacting emissions. **CPF** = -0.12 x MEDL* + 93 In which: • MEDL is Melanopic α-opic equivalent daylight (D65) luminance, (cd.m-2) • MEDL is calculated with the CIE S 026 alpha-opic Toolbox • Final CPF rating is rounded down to next lower multiple of 10 (except for 35 <= CPF < 40 which rounds to 35) • D65 corresponds roughly to the average midday light in Western Europe / Northern Europe (comprising both direct sunlight and the light diffused by a clear sky). There are no actual D65 light sources, only simulators *Note: The scaling factor was set based on the current technological limits of recent LCD and OLED*

UL Eyesafe Verification

Eyesafe is partnering with UL Solutions to offer industry-leading marketing claim verification for Eyesafe Display Requirements 3.0. Verification empowers brands to confidently communicate their product's efficacy in reducing blue light, through independently validated claims. UL Solutions will provide a report with collected results data:

- Pass/Fail of Radiance Protection Factor (RPF) for display and RPF number
- Pass/Fail of Circadian Protection Factor (CPF) for display and CPF number (optional, device manufacturers may elect to test product against CPF after passing RPF requirements, but it is not required).
- Pass/Fail of color gamut coverage
- Pass/Fail based on color temperature (CCT)

Each unique display hardware combination must be tested for verification. Documentation must be supplied to demonstrate this hardware configuration. Eyesafe should be notified of any product specification change. Any such changes will require re-verification.

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5. Testing and Protocols

5.1 Setup

The manufacturer should define the product's default (Standard) operating mode under which the product will be tested. The tested unit needs to be powered on for 20 minutes before the test procedure. The display must be set at 100% brightness, with automatic brightness changes disabled. Optional (non-default) modes such as "Low Blue Light" may not be selected for measurement.

Test images are full screen solid white (255,255,255), Red (255,0,0), Green (0,255,0), and Blue (0,0,255). These images must be displayed in full screen mode because some display technologies change brightness according to content due to power limits.

5.2 Laboratory condition

Tests are to be performed at an ambient temperature of 23±5 °C (73±5 °F) and humidity range between 30-60 % RH. To decrease error in the measurement, it must be taken under darkroom conditions where ambient light is < 2 Lux.

5.3 Measurement equipment

A qualified spectroradiometer will be used to measure light emission from the display by wavelength from 380 to 780 nm for color and visible light intensity measurement from 380 to 780 nm for all display types with at least accuracy of ± 0.002 or higher in CIE 1931 x, y and luminance accuracy of ± 5% or higher from 100 to 5000 cd/m^2.

5.4 Recording

The following items should be recorded at the default (Standard) mode:

- Emission radiance spectrum values between 380 to 780 nm of the display when set at 100% full-screen brightness will be collected for red, green and blue primary colors and the white point.
- The calculated x, y coordinates for the spectrum measurement of red, green, blue and white point.
- The CCT of the white point of the display for the above spectrum measurement.

5.5 Calculation of Blue light Toxicity

Data from spectral power distribution (SPD), over the range 380-780 nm and with an increment of 1 nm is preferably used for the calculation of the blue light toxicity.
Blue Light Toxicity Factor (BLTF) corresponds to the ratio of the display's blue light effective radiance over the calculated display's luminance and must be less than 0.085.

$$\textbf{BLTF} = \frac{100}{683} \times \frac{\int_{380}^{780} L(\lambda) \times B(\lambda) \times d\lambda}{\int_{380}^{780} L(\lambda) \times \bar{Y}(\lambda) \times d\lambda}$$

In which:

- $d\lambda = 1$ nm
- $L(\lambda)$: spectral radiance in µW x cm^{-2} xnm^{-1}
- $B(\lambda)$: Blue Light Hazard Function
- $\bar{Y}(\lambda)$: CIE 1931 XYZ luminosity function
- 683 - maximum spectral luminous efficacy constant (683 lumens per Watt at 555nm)

Note - The scaling factor of 0.001 was used for 700 to 780nm - The blue light hazard function is interpolated for every 1 nanometer

5.6 Radiance Protection Factor (RPF) for Display

As described in section 5.1, the measurement will be collected at 200 nits. Please verify that the automatic brightness feature is turned off for this test.
RPF for display is calculated based on the blue light toxicity factor. RPF represents an easy-to-understand metric for the end customer to identify and compare different display products and their blue light emission in specific brightness levels.

$$\textbf{RPF} = 260 \times \frac{(BLTF_{D65} - BLTF_{Tested})}{BLTF_{D65}}$$

In which:

- $BLTF_{D65} = 0.098$
- 260 = Scaling factor
- $BLTF_{Tested}$: The BLTF of the tested sample
- D65: D65 corresponds roughly to the average midday light in Western Europe / Northern Europe (comprising both direct sunlight and the light diffused by a clear sky). There are no actual D65 light sources, only simulators

Note: The scaling factor was set based on the current technological limits of recent LCD and OLED technologies.

5.7 Circadian Protection Factor (CPF) for Display

As described in section 5.1, the measurement will be collected at 200 nits. Please verify that the automatic brightness feature is turned off for this test.

CPF for display is represents emissions based on the CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light. CPF represents an easy-to-understand metric for the end customer to identify and compare different display products and their blue light emission in specific brightness levels.

CPF = -0.12 x MEDL* + 93

In which:

- MEDL is Melanopic α-opic equivalent daylight (D65) luminance, (cd.m-2)
- MEDL is calculated with the CIE S 026 alpha-opic Toolbox

- Final CPF rating is rounded down to next lower multiple of 10 (except for 35 <= CPF < 40 which rounds to 35)
- D65 corresponds roughly to the average midday light in Western Europe / Northern Europe (comprising both direct sunlight and the light diffused by a clear sky). There are no actual D65 light sources, only simulators

Note: The scaling factor was set based on the current technological limits of recent LCD and OLED technologies.

5.8 Color Gamut

For this measurement, the color data for base red, green and blue image should be collected under the product's default (Standard) operating mode and the area between these three points falling within the color standard should be calculated according to CIE 1931. The resulting area calculated from the measured points must be above the required value.

The color gamut coverage ratio of each client specified color mode shall meet at least one of the requirements:

- For products with sRGB color mode: ≥95% of standard sRGB color space in CIE 1931.
- For products with Adobe RGB color mode: ≥90% of standard Adobe RGB color space in CIE 1931.
- For products with DCI-P3 color mode: ≥90% of standard DCI-P3 color space in CIE 1931.
- For products with NTSC color mode: ≥72% of standard NTSE color space in CIE 1931.

Note: Maximum ±5% deviation to the specified limit is allowed for the mass production Correlated color temperature (CCT)

5.9 Correlated color temperature (CCT)

The CCT of display white displaying the white image at 100% brightness should be within the range of 5500K and 7000K.

Note: this requirement is only applicable for laptop, monitor and AIO computer.

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6. Partner Commitments & the Eyesafe Name and Marks

Following are the terms of the Eyesafe Partnership Agreement as it pertains to the manufacture and labeling of Eyesafe validated products.

Eyesafe and registered trademarks of Eyesafe and their use is subject to partner agreements. The Eyesafe Partner must adhere to the following partner commitments:

Qualifying Products

- Comply with current Eyesafe Display Requirement criteria, which define performance requirements and test procedures.
- Prior to associating the Eyesafe name or mark with any product, obtain written permission from Eyesafe.

Use of the Eyesafe Name and Marks

- Comply with current Eyesafe Identity Guidelines, which define how the Eyesafe name and marks may be used. Partner is responsible for adhering to these guidelines and ensuring that its authorized representatives, such as advertising agencies, dealers, and distributors, are also in compliance. The Eyesafe Identity Guidelines are available at: eyesafe.com/standards.

- Use the Eyesafe name and marks only in association with qualified products. Partner may not refer to itself as an Eyesafe Partner unless at least one product is qualified and offered for sale in the U.S. and/or Eyesafe partner countries.
- Provide clear and consistent labeling of Eyesafe products. The Eyesafe mark should be clearly displayed on the front of the product, on the product packaging, in the product literature (i.e. user manuals, spec sheets, etc.) and on the manufacturers site where information about Eyesafe qualified models is displayed.

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