Eyesafe® Standard for Display Devices

Blue Light Management and Color Performance for Device Display Manufacturers

Version 1.1

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Table of Contents

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This guidance represents the current assessment of Healthe and the Vision Health Advisory Board on this topic. It does not establish any rights for any person and is not binding on Healthe or the public. You can use an alternative approach if it satisfies the requirements of the applicable statutes and regulations. From time to time, this Standard will be updated based upon guiding research and the latest information.

1. Purpose

This document summarizes measurement methods and defines criteria to certify a display product including smartphones, tablets, notebook and desktop computers, commercial displays, and televisions, as Eyesafe.

The device in question would be a display module (e.g. smartphone, tablet) or a display module with an optical filter having a certain level of blue light emission and color performance requirements, herein referred to as “Eyesafe Requirements”. Passing the proposed criteria would lead to a certification according to quality characteristics to be identified as “Eyesafe” or to utilize “Retina Protection Factor” (English) or “Netzhaut Schutz Faktor” (German), and the label “Retina Protection Factor xx” according to the RPF classification.

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 [1-3], users are being exposed to increasing amounts of high-energy blue light from their devices.

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 on a daily basis.

Recent studies have shown growing concerns over potential long-term eye health impacts from digital screen usage and cumulative blue light exposure [4-6], in addition to recognized impacts of device use on circadian rhythms and sleep patterns [7-11]. 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 [6, 12, 13], with photoreceptor cell apoptosis seen early after the retina is damaged by blue light [5, 6, 13].

Several international standards have been published to quantify blue light radiation levels to humans. ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines on limits of exposure to broadband incoherent optical radiation (380 to 700 nm) [14] provide a spectral weighting function B(λ) for retinal blue light hazard. This standard will cover 300 to 780 nm to realistically oversee all optical hazards in this spectral area.

The Eyesafe standard identifies the amount of blue light emitted from displays within the range from 415 to 455 nm and evaluates the color accuracy of the display.

For external filters, the Eyesafe standard measures the level of retina protection 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) [15] in 2015.

The purpose of this certification 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 standard includes non-binding industry recommendations. From time to time, Healthe may adjust the Eyesafe standard to reflect new guiding research and the latest available information.

2. Scope

The Eyesafe standard defines test methods and retina protection factors for blue light reducing film, which is intended to be used with electronic display devices to reduce the hazard which might arise from blue light exposure.

This standard applies to accessory optical film and display product modules that have the function to reduce hazardous blue light.

The Eyesafe standard 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

3.1.1 Human vision system development

i - 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.

ii – What we should know about blue light

Light is made up of electromagnetic particles called photons that travel in waves. 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 380 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. [16-18]

iii – 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) — does 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. [12, 19]

The Eyesafe standard specifically addresses high-energy visible blue light (380 to 500 nm). Invisible UV radiation is beyond the scope of the standard.

3.1.2 *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 (380 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 [5, 7, 20].

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 [7, 20].

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.

3.1.3 *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 and bodies are still developing [3, 4].

3.2. Health and Safety Concerns

3.2.1 *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 [9, 10, 12, 16, 22, 23].

To capture the body of medical data that has and continues to be published, Healthe 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, Healthe'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 [24].

3.2.2 Potential damage 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 [16, 19, 22].

Recent growing concerns have been expressed in the eye care community over 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, 25-27], which is characterized by symptoms such as dry eyes, irritated eyes, blurred vision, sleep disruption, fatigue, reduced attention span, irritability, and neck and shoulder pain [25, 26].

By stimulating retinal ganglion cells, 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 [22, 25]. Several studies have shown the impact of digital technology on disruption of circadian rhythms in adolescents and adults [7-11, 20], resulting in reduced duration and quality of sleep, linked to various diseases such as obesity, depression and possibly cancer [3, 9, 11, 20, 28].

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 [29].

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 [28-30].

3.3. Recent Lighting Source Development

Methods used today to create artificial white light or enhancing the color of 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:

1. LED light bulbs today are steadily increasing in luminance per watt, and therefore creating intense bright light from very small sources
2. 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 sunlight is approximately 5600 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.

4. Eyesafe Requirements

4.1 Standards for Photobiological Safety

Eyesafe® Standards focus on HEV blue light that is emitted by digital devices and relies on two photobiological safety standards from the American National Standards Institute [15] to guide its products development: Z80.3-2018 and Z87.1-2015, and the IEC/EN 62471 from the International Electrotechnical Commission, in addition to guiding industry research.

Displays identified and certified Eyesafe® should adhere to these guidelines, while maintaining color transmission. As such, solutions must not only manage blue light, but also maintain color transmission and D65 [31] illumination ratings.

Specifically, the following criteria must be met:

- Reduced light emissions in the blue-violet segment of the blue light spectrum (wavelengths of 415 to 455 nm)
- Meet photobiological safety guidelines
- Maintain CCT value in acceptable range

Reduced light emissions in the 415 to 455 nm range is achieved by integrating the weighting factors from the ANSI Z87.1-2015 Occupational and Educational Personal Eye and Face Protection Devices standard, which identifies a peak blue light hazard factor at 435 to 440 nm. (cf. Table C4. Spectral Weighting Factors for Blue-Light Hazard, p. 36 of the ANSI Z87.1-2015 standard).

Maintaining spectral transmittance of visible light is achieved by following indications from the ANSI Z80.3-2018 Nonprescription Sunglasses and Fashion Eyewear Requirements standard, which includes data for computing blue light transmittance.

4.2 New Standards and Certifications

4.2.1 TÜV Rheinland

TÜV Rheinland, (hereafter referred to as TÜV) is the world's leading third-party testing and certification company. In 2014, TÜV introduced its Low Blue Light Certification Method 1, which requires the ratio of blue light to luminance level of a light source to be less than 20 percent.

In 2016, TÜV published its second certification, Method 2, which is defined as the ratio of blue light in the 415 to 455 nm range, compared to the 400 to 500 nm range, must be less than 50 percent. TÜV Method 2 also specifies the CCT of the light source must be between 5500 and 7000 K.

In 2018, TÜV announced in partnership with Healthe the creation of a new blue light filtration certification for accessory screen protection for digital devices called the Retina Protection Factor (RPF).

The RPF testing and evaluation protocol measures the level of blue light protection based on the Spectral Weighting Factors for Blue-Light Hazard, published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP)[14] in 2013 and adopted by the American National Standards Institute [15] in 2015.

ZAGG, the global leader in screen protection with its InvisibleShield products was the first company to achieve RPF blue light management certification for accessory products.

4.2.2 RPF – Retina Protection Factor for Accessory Screen Protection

The RPF standard provides consumers with a retina protection factor or RPF value, which is an easy to understand numbered rating that designates the level of high-energy visible blue light being filtered from a digital display. The standard and associated RPF value also ensures overall display color quality is maintained, so the visual experience is not impacted.

In order to receive the RPF certification, a blue light filter must satisfy three requirements and follow the RPF classification rules (Table 1).

Requirement 1: Luminance reduction ratio

$T = 100 * (L_{without\ film} - L_{with\ film}) / L_{without\ film}$

where:

$L_{with\ film}$ is the luminance level measured at the screen center with the film;
$L_{without\ film}$ is the luminance level measured at the screen center without the film

Requirement 2: Change of CCT

The CCT of display color shall not shift more than the limit specified for each RPF level (see below)

Requirement 3: Retina Protection Factor

$RPF_{Level} = 100 * (LB_{without} - LB_{with}) / LB_{without}$,
where:
$LB_{without}$: is the blue light hazard weighted irradiance calculated without film;
LB_{with}: is the blue light hazard weighted irradiance calculated with the film.
$LB = \sum L(\lambda) \times B(\lambda) \times \Delta\lambda$
$L\lambda = E\lambda(\lambda,t)$ is the spectral irradiance in $W/m^{-2}/nm^{-1}$
$B(\lambda)$ = Blue-Light Hazard Function (ICNIRP)
$\Delta\lambda = 1$

Table 1: RPF Classification Rules

Classification Requirement	RPF Level	Luminance reduction	Change of CCT
RPF 15	15	≤ 20 %	≤ 250 K
RPF 20	20	≤ 20 %	≤ 350 K
RPF 30	30	≤ 20 %	≤ 500 K

4.3 Eyesafe Display Requirements

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

	KPI	2019 Requirements
Standard and Blue Light Management	Blue Light 415-455 nm Requirements	The ratio of light in the range from 415-455nm compared to 400-500nm must be less than 50%
	Blue Light Toxicity Scaling based on ICNIRP	Blue light toxicity factor [Blue light toxicity ($\mu W/cm^2$)] vs. total lux must be less than 0.085
	Photobiological Safety	The product must meet exempt group limits as outlined in IEC/EN 62471
Color Performance	Color Gamut %	Gamut must be 72% of NTSC(i) or greater
	Color Temperature	The CCT shall be within the range of 5500K and 7000K

(i) Adjusted based on display type.

Eyesafe® Certificate will provide a report with collected results data:

- Pass/Fail of low blue light 415-455nm criteria
- Pass/Fail of blue light toxicity scaling criteria based on ICNIRP

- Pass/Fail of photobiological safety classification based on IEC/EN 62471
- Pass/Fail of color gamut percentage
- Pass/Fail based on color temperature (CCT)

Each unique display hardware combination must be tested for certification. Documentation must be supplied to demonstrate this hardware configuration. Healthe should be notified for any product specification change. Any such changes will require recertification.

5. Vision Health Advisory Board Commentary

The Vision Health Advisory Board [32] comprises leading eye care professionals across ophthalmology and optometry. They help to define and shape the future of eye health and vision related to use of digital devices. The Vision Health Advisory Board collaborates with Healthe to provide the latest guiding research and implications to eye and human health for the display industry.

In review of the current research, the known and unknown health impacts from cumulative use of digital devices, [7, 9, 10, 23] our guidance to manufacturers centers around the high-energy blue light spectrum.

The research indicates there is a certain band of blue light which may be categorized as “healthy” and another as “toxic” [17, 19, 22], the topic of light emissions from displays and human impact is getting more and more prominent and should be managed effectively by the display industry.

Studies show the intense blue light emitted from digital devices can contribute to eye health issues and potential sleep disorders [7, 9, 20]. Given that eyes are still developing through the teenage years, this issue of prolonged screen use is concerning for children’s eyes [1, 25].

Additionally, studies undertaken in laboratories have shown that cumulative blue light exposure is linked to slow degeneration of the retina [5, 12], which could accelerate long-term vision problems such as age-related macular degeneration (AMD) and cataracts [13].

Recent research has found that filtering out blue light from LED screens before bedtime produced significant positive health benefits for teenagers by curbing LED-induced melatonin suppression and decreased alertness [29]. Other studies have shown that patients with unstable tear film achieved better results in visual acuity tests when using a blue light filter, and that filtering blue light can reduce the glare and photo-stress associated with prolonged exposure to intense light [28-30].

The Eyesafe® 2019 Display Requirements [33] are based on the growing body of research that suggests potential health impacts of blue light exposure and the industry’s requirements for accurate color quality. The Eyesafe Standard has been developed to provide transparency to consumers and is further built upon existing standards and guidelines developed by the American National Standards Institute (ANSI), the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and TÜV Rheinland.

While we anticipate evolution of Eyesafe standards around each of the variables indicated above, we support the efforts of display manufacturers and suppliers to meet Eyesafe standards to protect human health and promote greater industry transparency.

6. Testing and Protocols

6.1 Setup

The display must be set at 100% brightness level. The standard test image is a white display image and should be loaded to display output for measurement of full visible light emission.

6.2 Laboratory condition

Tests are to be performed at an ambient temperature of 73±5 degrees F and humidity range between 30-60 % RH. To decrease error in the measurement, it must be taken under dark room conditions where ambient light is < 1 Lux.

6.3 Measurement equipment

A qualified spectroradiometer (such as the GS-1160 spectroradiometer, Photo Research PR-655 or similar) 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.

6.4 Recording

The following items should be recorded:

- Emission spectrum values between 380 to 780 nm of the display when set at the maximum level of red, green and blue as well as measurement of the white point at full brightness.
- The calculated x, y coordinates for the spectrum measurement of red, green, blue and white point
- The CCT of white point of the display for the above spectrum measurement

6.5 Calculation of 415-455 nm requirements

The ratio of display emission light in the range from 415-455 nm to the display emission of 400-500 nm shall be less than 50%.

6.6 Blue light toxicity scaling based on ICNIRP

Blue light toxicity factor [Blue light toxicity (μW/cm^2)] vs. total lux must be less than 0.085 ratio. This is the display emission weighted by the BLH (Blue light hazard) factors as outlines by ICNIRP[14].

6.7. Photobiological safety

The product must meet exempt group limits as outlined in IEC/EN 62471[34]

6.8. Color gamut

The color gamut must be 72% of NTSC or greater. For this measurement, the color data for base red, green and blue image should be collected and the area between these three points falling within the NTSC color standard should be calculated according to CIE 1931. The resulting area calculated from the measured points must be above 72% of the NTSC standard. This may change according to the design requirements of the display and reference to other standard gamut.

6.9. Correlated color temperature (CCT)

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

7. 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 qualified products.

Eyesafe®, Retina Protection Factor, RPF® and registered trademarks of Healthe and their use is subject to partner agreements. The Eyesafe Partner must adhere to the following partner commitments:

Qualifying Products

- Comply with current Eyesafe Eligibility Criteria, which define performance requirements and test procedures.
- **Prior to associating the Eyesafe name or mark with any product**, obtain written certification of Eyesafe qualification from Healthe.

Using 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.

Ongoing Product Qualification

- Certify products have achieved Eyesafe requirements with Healthe or an agreed third party for verification if agreed upon in advance.

Training and Consumer Education

Partner shall comply with the following, product-specific requirements concerning training and education. Provide Eyesafe sales training to all sales staff. This training shall include:

  - Identification of Eyesafe-qualified products;
  - Tips for selling Eyesafe-qualified products; and
  - Tips for answering questions about Eyesafe

8. Guiding Research & Sources

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