



ISA Recommendation

Human Factor Testing on the Index of Healthy and Comfortable Lighting: Overview

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Preface

This series of standards describes the test system of visual comfort for the LED lighting products and provides a basis for the evaluation of visual comfort on the LED lighting products, thus leading the enterprises with concern on the “Health” feature of people orientated during the development of lighting products with “High Efficiency and Energy Conservation”.

This series of standards consists of 6 parts:

- Part 1: Overview
- Part 2: Test method- test method and technical requirement based on physiological function of human eyes
- Part 3: Test method- test method and technical requirement based on fundus function
- Part 4: Test method- test method and technical requirement based on mental and cognitive load
- Part 5: General requirements on indoor lighting
- Part 6: General requirements on outdoor lighting

Introduction

With the coming of information society, the information intake has become an integral part of human life, learning, work, growth and development. Moreover, 70%-90% of information accessed by human is from the vision, thus the visual health not only affects the health of human body, but also plays an important role in the human life, learning, work and growth.

LED is an emerging lighting product, and it is necessary to take quantitative evaluations on the user experiences with it, especially for its various effects on the human eyes in high illuminance. Thus, the differences among LED lighting products with different light parameters can be found so that they are given full consideration during the whole process of design, manufacture, test and use. Also, these evaluations will guide the manufacturers to produce healthy products with minimum safety risk, enhance the competitiveness of their products, and create living and working conditions with “safety, health and efficiency”.

Visual comfort is the most important human factor for lighting products or systems design. The researches showed that the evaluation of visual comfort should be based on the following aspects: (1) the effect on physiological function of the human eyes; (2) the effect on the fundus; (3) the effect on fatigue of mental and cognitive load. Furthermore, the lighting products are classified into indoor lighting and outdoor lighting based on the type and working environment. Therefore, test items shall be taken according to the specific use of lighting products under two kinds of test environment.

This series of standards will provide the quantitative test procedures and methods for the various effects of lighting products on the visual comfort to guide enterprises on effectively evaluating the influence degree of lighting of the human visual system and provide efficient, healthy and comfortable lighting products.

Part 1: Overview

1. Scope

This standard specifies the evaluation requirements on the visual comfort of LED lighting products, and is applicable to indoor and outdoor lighting with LED lights, such as: LED lamps, LED down lamps, LED spotlights, LED street lamps and so on.

2. Normative references

The terms in the following documents are referred to be part of this standard. For dated references, their subsequent revisions are all inapplicable to this standard. For undated references, their latest editions apply to this standard.

ISO 8995-1-2002 Lighting of work places - Part 1: Indoor

ISO 8995-3-2006 Lighting of work place - Part 3: Lighting requirements for safety and security of outdoor work places

BS EN 62471-2008 Photobiological safety of lamps and lamp systems

IEC 62031-2008 LED modules for general lighting - Safety specifications

3. Terms and definitions

3.1 Vision

It is the awareness of the outside world by the perception of lights produced by the radiation into the eyes.

3.2 Illuminance

The illuminance at a point on the surface is the quotient of the incident luminous flux on the binning containing the point divided by the binning area, in lux (lx).

$$E = \frac{d\Phi}{dA}$$

In the formula: $d\Phi$ - luminous flux, lm;

dA - area, m².

[BS EN 62471-2008 3.13 illuminance (at a point of a surface) (E_v) (see ILV 845-01-38)

Quotient of the luminous flux $d\Phi_v$ incident on an element of the surface containing the point, by the area dA of that element.

$$E_v = \frac{d\Phi_v}{dA}$$

Unit: lx]

3.3 Luminance

It characterizes the brightness of light or object, in candela per square meter (cd/m²).

$$L = \frac{d\phi}{dA \cdot \cos\theta \cdot d\Omega}$$

In the formula,

The luminous flux of elementary beam from a given point in the specified direction of the solid angle element $d\Omega$, in lumens (lm);

Including the cross-section area of beam at a given point, in square meters (m²);

The angle between the cross-section normal and the direction of the beam, in degrees (°);

The solid angle element in the specified direction, in steradian (sr).

[BS EN 62471-2008 3.25 luminance (in a given direction, at a given point of a real or imaginary surface) (L_v) (see ILV 845-01-35)

Quantity defined by the formula³ where $d\Phi_v$ is the luminous flux transmitted by an elementary beam passing through the given point and propagating in the solid angle $d\Omega$ containing the given direction; dA is the area of a section of that beam containing the given point; Φ is the angle between the normal to that section and the direction of the beam.

$$L_v = \frac{d\Phi_v}{dA \cdot \cos\theta \cdot d\Omega} \quad .$$

Unit: cd·m⁻²]

3.4 Color temperature

The absolute temperature of the complete radiator is the color temperature of the light source when the chromaticity of the light source is the same as that of the complete radiator at a certain temperature. The color temperature is denoted by T_c in K units.

[CIE S 005:1999 3.6 colour temperature]

3.5 Color rendering index, CRI

It is a measurement for color rendering of light sources.

It is expressed in the matching degree of object color in the measured light source to that in the reference light source, in a natural number within 100.

[CIE 013.3-1995]

3.6 Refractive status, RS

It refers to the refraction conditions of the tested eye, that is the imaging conditions in the retina of objects at infinity. The inspection on the refractive status of the eye is called optometry.

3.7 Accommodative convergence/accommodation ratio, AC/A

The ratio of accommodative convergence (AC) to stimulus accommodation (A) can

reflect the relationship of associative motion between accommodative convergence and accommodation. AC refers to the convergence accompanied by accommodation and caused by the excitement of regulating center when the eyes stare at the object in limited distance, and the eye regulation stimulates the eye axis inward convergence. A refers to the change in refractive ability of eyes during the attention changing process between distant and nearby objects.

3.8 Higher order aberrations, HOAs

A dot-like target does not form an ideal image through an optical system, but occurs an optical defect and forms a blurred diffuse spot. At this moment, the shape of the image is very similar to the object, but not exactly the same, and the difference between them is called aberration. If the order expansion of aberration is greater than or equal to 3, it is called high order aberration.

3.9 Modulation transfer function, MTF

Optical transfer function (OTF) is an optical function that evaluates the imaging quality of an optical system. And it reflects the attenuation degree of the amplitude of the sinusoidal intensity distribution function after passing through an optical system. That is, the change of image over modulation degree. When the modulation degree varies with the spatial frequency, it is called the modulation transfer function.

3.10 Visual Comfort, VICO

The human visual system can maintain the predetermined working condition, and keep normal physiological function. From the physical and psychological aspects, there is usually no discomfort for the human body to the objective environment.

3.11 Binocular fusion

It refers to the fusion or binding ability of the binocular retinal imaging for both eyes to obtain binocular vision, which includes the sense fusion and the motion fusion. And the sense fusion is the ability of both eyes to combine the sensory information to form a single image; the motion fusion is the ability of both eyes to keep the image in motion consistent.

3.12 Binocular balance

The image size, shape, clarity, contrast, and orientation of the same object on the left and right retina are all the same. And when observing the object with same distance, the regulation and tracking ability of both eyes are also the same.

4. General requirements

This series of standards does not contain the requirements on electrical safety and

environmental protection. Therefore, the lighting products shall meet the relevant standards of quality and environmental protection on their labels before the test on visual comfort is taken.

5. Test index

5.1 Physical parameters

According to the use conditions and functional requirements of lighting products, the physical parameters of products (color temperature, color rendering index, illuminance, luminance, flicker, etc.) shall be within a certain range and limits to ensure the health of user's eyes.

5.2 Test index of physiological function of human eyes

The lights produced by LED lighting products can stimulate directly the human eyes, and affect their physiological functions such as axial length, corneal diopter, visual imaging and others. Thus, it is necessary to evaluate the physiological functions impacted by lighting products.

Visual Comfort Index (VICO Index) is an index to evaluate the effects of lighting products on the physiological function changes of human vision and visual fatigue based on visual optometry and subjective cognition. Moreover, VICO Index is independent of the physical indexes of lighting products (color temperature, color rendering index, illuminance, luminance, flicker, etc.), and it reflects an objective and quantitative evaluation on the effects of lighting products to the physiological function of human vision completely from the perspective of visual function of human eyes. And it is mainly applied to evaluate the effects of lighting products on the visual fatigue of human eyes in visual optometry - axial length and corneal diopter. Visual Comfort Index (VICO Index) is classified into five levels, and the higher the level the higher the fatigue degree of human vision, that is, the greater the effect of lighting environment provided by the lighting product being tested on the visual comfort of human eyes. The specific quantitative classification is shown in Table 1.

Table 1 Quantitative classification of Visual Comfort Index (VICO Index)

Level	Level 1	Level 2	Level 3	Level 4	Level 5
Test Score	$0 < \text{VICO} \leq 1$	$1 < \text{VICO} \leq 2$	$2 < \text{VICO} \leq 3$	$3 < \text{VICO} \leq 4$	$4 < \text{VICO} \leq 5$
Vision State	No feeling of fatigue	Mild feeling of fatigue	Obvious feeling of fatigue, but within the tolerable	Increased feeling of fatigue, with various symptoms of	Severe feeling of fatigue, with obvious and intolerable

			range	eye discomfort	discomfort symptoms
Test Conclusion			Pass	Failed	

Note: the symptoms of eye discomfort include tears, blurred vision, eye itching, photophobia, eye swelling, foreign body sensation, vertigo, dry eyes, headaches, dizziness, nausea, vomiting and other syndromes.

5.3 Test index of effect on fundus function

The spectral parameters (especially the blue light spectrum) in the optical parameters of LED lighting products can cause organic harm to the human eyes, and affect the growth and development of human visual function. A stable evaluation model on the light injury to retinal cells shall be established to take stable, accurate, reproducible and quantitative evaluations on the light injury to retinal cells (such as photoreceptors, pigment epithelium, etc.).

The test based on the function of eye cells shall specify the limits on several parameters of LED lighting products including the peak limits of spectrum, radiation energy and other parameters.

5.4 Test index of mental and cognitive load

Mental and cognitive load are closely related to the optic nerve response. Visual fatigue is usually accompanied by mental fatigue, so it is necessary to evaluate the influence of lighting products on the human stress response, mental load, work efficiency and other behaviors.

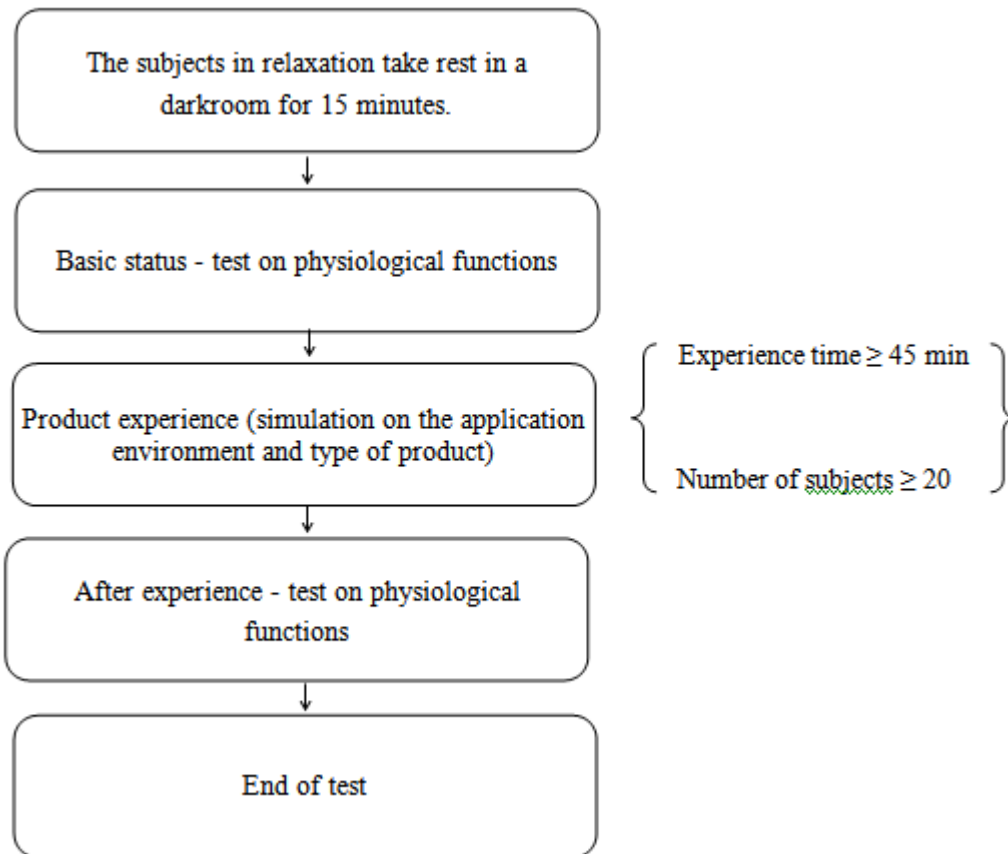
The tests on such indexes as EEG waveform (α wave, θ wave, δ wave, and β wave), stress response time, sympathetic nerve changes and others shall be based on EEG signal, reaction time, pulse wave and other means, and on this basis an evaluation model for the signal of physiological signs and the optical parameters of lighting products is established to evaluate the health and comfort of lighting products.

6. Test procedure and requirements

6.1 Test procedure

The general test procedure is shown in Figure 1.

Fig.1 General test procedure



6.2 Test environment

The setting of the test environment shall be simulated in accordance with the applicable environment of the LED lighting products, and the cross-effects of other light sources on the test products shall be avoided. The lighting environment in which the test subjects are exposed shall be provided by the LED lighting product being tested. The test environment shall be based on the physical comfort of the test subjects, and the operational requirements on the test equipment. And it recommends that the test temperature is $20^{\circ}\pm 2^{\circ}\text{C}$, and the relative humidity of test is $60\% \pm 5\%$.

6.3 Subject requirements

6.3.1 Sample size

In general, the number of subjects involved in the test (VICO index, mental load, subjective evaluation, etc.) shall be ensured more than or equal to 20. Depending on the specific objectives of the study, a stricter test may be required to increase the sample size.

6.3.2 Eyesight screening

The current clinical test methods of vision shall be used to collect and screen the basic information of subjects from the refraction, the dominant eye, binocular fusion, binocular vision balance, color recognition, regulation and convergence, intraocular pressure and other aspects. And the subjects with severe refraction and recessive eye disease shall be excluded to avoid the effects on the test results due to the eye disease.

6.3.3 Subject instruction

The tester shall explain to the participants the object of experiment and any adverse effects when exposed to the LED light source used in the test. And the “Informed Consent Form” shall be signed to ensure the test taken under the true will of subjects.

6.3.4 Subject preparation

Subjects shall ensure adequate rest and sleep before the test, so as not to affect the test results due to accumulative fatigue. Prior to each test, subjects shall take a rest in the dark room with both eyes closed at least fifteen minutes to ensure the best vision function.

7. Structure of this series of standards

Regarding the complicated, comprehensive and multipurpose features of visual comfort for LED lighting products, this series of standards consists of multiple parts in structure, with each part only involved in one aspect of LED lighting products or test methods. And the overall conditions for each part are summarized in Table 2.

Table 2 Summary on each part of this series of standard

Part	Name	Summary	Application Range
1	Overview	The introduction of the standard system, and the main contents on each part of the standard	General
2	Test method- test method and technical requirement based on physiological function of human eyes	The description on the test methods for the physiological function of human eyes and the determination on limits of test index based on the effects of LED on human visual fatigue.	General

3	Test method- test method and technical requirement based on fundus function	The description on the test methods for the cell damage of human eyes and the determination on limits of test index based on the effects of LED on fundus function of human eyes.	General
4	Test method- test method and technical requirement based on mental and cognitive load	The description on the test methods for mental and cognitive load and the determination on limits of test index based on the effects of LED on working efficiency of humans.	General
5	General requirements on indoor lighting	The description on the technical requirements for indoor LED lighting products and the requirements for indoor lighting environment.	Indoor lighting
6	General requirements on outdoor lighting	The description on the technical requirements for outdoor LED lighting products and the requirements for outdoor lighting environment.	Outdoor lighting

8. Requirements on the compliance with the standards of all parts

This standard is a union standard of multiple parts, so the compliance is only related to a single part, not the whole union standard. Any compliance statement shall state the basic information about the product type, application background and intended use, and also indicate which parts of the series of standards are met respectively.

If a LED lighting product is claimed to meet the requirements of these sections, it shall be specified the operating procedures for the development, design and evaluation of the product manufacture, and the manufacturer shall be supervised on its true capability of product manufacture. And the details about the procedures shall be determined by all the parties concerned.