
**Small craft — Electric navigation lights
— Performance of LED lights**

*Petits navires — Feux de navigation électriques — Performance
des feux à LED*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 188, *Small craft*.

Introduction

This document was developed to provide uniform criteria for the performance, construction, and testing of LED navigation lights. Conflicting national standards might lead to confusion on the part of operators and manufacturers of craft, as well as manufacturers of LED navigation lights. These conflicts could lead to barriers to trade.

If the colour locus of navigation light is within the coordinates specified in this document, the COLREGs, CCNR^[1] and CEVNI^[2] requirements relating to colour loci are satisfied.

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Small craft — Electric navigation lights — Performance of LED lights

1 Scope

This International Standard applies to requirements and testing for navigation lights with permanently fixed light emitting diode (LED) assemblies for small craft up to 24 m length of the hull.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

CIE 15, *Colorimetry*

CIE 69, *Methods of characterizing illuminance meters and luminance meters — Performance, characteristics and specifications*

CIE 70:1987, *Measurement of absolute luminous intensity distributions*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60945:2002, *Maritime navigation and radiocommunication equipment and systems — General requirements — Methods of testing and required test results*

IEC 60068-2-27:2008, *Environmental testing — Part 2-27: Tests — Test Ea and guidance: Shock*

COLREGs, *International Regulations for Preventing Collisions at Sea, 1972*

3 Terms and definitions

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

3.1

flashing light

light flashing at regular intervals at a frequency of 120 flashes or more per minute

3.2

navigation light

coloured source of illumination used to signal a craft's position, heading, and status

3.3

signal light

light radiated by navigation lights

3.4

range of visibility

distance up to which the light of the navigation light can be seen

3.5

rated voltage

voltage or voltage range specified by the manufacturer for the operation of the navigation light

3.6

zero signal direction

horizontal direction of radiation of a navigation light in the centre-line plane or parallel to it

Note 1 to entry: The zero signal direction is designated in this standard as either 0° or “dead ahead”.

4 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

- CIE International Commission on Illumination
- COLREG International Regulations for Preventing Collisions at Sea, 1972
- LED Light Emitting Diode

5 Minimum requirements

5.1 Luminous intensity and range of visibility

I_0 is the photometric luminous intensity in candela (cd) that is measured in the laboratory at rated voltage.

I_B is the luminous intensity under operating conditions in candela (cd) which takes into account, for example, the ageing of the light source, contamination of the optical system, and voltage drop of the craft’s power supply system.

For the values listed in [Table 1](#), I_B is assumed to be 20 % less than the photometric luminous intensity I_0 .

The range of visibility given on the navigation light depends on the interval for I_0 in [Table 1](#) in which the luminous intensity I_0 actually measured lies. A navigation light shall not be marked with a higher or lower figure.

Table 1 — Range of visibility, luminous intensities and range of visibility designations

Nominal range of the navigation light nm	Minimum range value		Maximum range value		Operational luminous intensity (I_B) cd	Horizontal minimum photometric luminous intensity (I_0) ^a cd	Horizontal maximum photometric luminous intensity (I_0) ^a cd
	nm	km	nm	km			
1	1	1,85	2	3,70	0,9	1,1	5,4
2	2	3,70	5	9,26	4,3	5,4	65
3	3	5,56	5	9,26	12	15	65
5	5	9,26	7,5	13,9	52	65	257

^a To be measured in the laboratory.

5.2 Luminous intensity distribution

5.2.1 Horizontal luminous intensity distribution

The requirements of the COLREGs apply.

For the purpose of this document, the COLREGs expression “almost zero” or “practical cut-off” is defined as a value of not greater than 12,5 % of the average photometric luminous intensity . The angle between two measurements shall not exceed 0,2°.

In the case of two-colour or three-colour navigation lights, the luminous intensity distribution shall be uniform so that in the arc of visibility of 3° on each side of the zero signal direction, the maximum permissible photometric luminous intensity of the port and starboard segments shall not be exceeded and the minimum required photometric luminous intensity shall not be less than the required value.

The horizontal luminous intensity distribution of the navigation light shall be uniform over the entire radiation angle so that the maximum and minimum values of the photometric luminous intensity do not differ by more than a factor of 1,5.

5.2.2 Vertical luminous intensity distribution

The requirements of the COLREGs apply.

In addition, the maximum vertical luminous intensity shall not exceed the horizontal luminous intensity at 0° by more than a factor of 1,5. Navigation lights with vertical luminous intensity distribution according to COLREGs, Annex I, 10 (a) specified for engine-driven craft only shall be marked accordingly.

5.3 Colorimetric requirements

The chromaticity areas given in [Table 2](#) apply.

Table 2 — Colour range vertices

Signal light colour	Coordinates of the vertices						
White	x	0,310	0,443	0,500	0,500	0,453	0,310
	y	0,283	0,382	0,382	0,440	0,440	0,348
Red	x	0,690	0,710	0,680	0,660		
	y	0,290	0,290	0,320	0,320		
Green	x	0,009	0,284	0,207	0,013		
	y	0,720	0,520	0,397	0,494		
Yellow	x	0,612	0,618	0,575	0,575		
	y	0,382	0,382	0,425	0,406		
Blue	x	0,136	0,218	0,185	0,102		
	y	0,040	0,142	0,175	0,105		

5.4 Flashing light

The ruling dimension for the range of visibility is the visually effective luminous intensity (I_{EFF}). I_{EFF} is a measure for the conspicuity and efficiency of the flashing light emitted.

I_{EFF} shall attain at least the minimum horizontal photometric luminous intensity values I_0 in [Table 1](#).

I_{EFF} is calculated as follows from the maximum instantaneous luminous intensity in the observation direction (I_{MAX}) according to the Blondel-Rey equation:

$$I_{\text{EFF}} = \frac{\int_{t_1}^{t_2} I_{\text{MAX}} dt}{0,2 + (t_2 - t_1)}$$

where

I_{EFF} is the effective luminous intensity, in candela;

I_{MAX} is the instantaneous value, in candela;

0,2 is the Blondel-Rey constant for night observation, in seconds;

t_1, t_2 are the integration time limits, in seconds.

If the duration of the light phenomenon less the rise time and decay time, i.e. the time in which the instantaneous luminous intensity attains or exceeds the required minimum luminous intensity, is greater than 0,3 s, the light may be regarded as a steady light. The effective luminous intensity shall not then be determined.

The luminous intensity ranges of visibility and chromaticity areas in 5.1 and 5.3 apply, but without the upper limit for the luminous intensity.

The vertical radiation shall be at least 4°.

With an inclination of the flashing light to the horizontal of up to ±2°, the luminous intensities shall still be at least 80 % of the luminous intensity at 0°.

5.5 Electrical safety

The electrical safety shall be ensured as described in IEC 60945:2002.

5.6 Reflectors

Reflectors are permitted only in hermetically-sealed systems.

5.7 Power supply

The requirements of IEC 60945:2002 apply except for those regarding the following:

- a) extreme power supply;
- b) excessive conditions;
- c) power supply failure.

5.8 General requirements

5.8.1 General

Unless otherwise indicated in this International Standard, the requirements of IEC 60945:2002 apply.

5.8.2 Equipment category

Navigation lights belong to the equipment category “exposed to the weather” as specified in IEC 60945:2002.

5.8.3 Vibration

The requirements of IEC 60945:2002 apply with the additional requirements described in [6.3.5](#).

5.8.4 Rain and spray

The requirements of IEC 60945:2002 apply with the addition that a navigation light in continuous duty shall meet the requirements of IP66 without any change.

The test shall be as described in [6.3.6](#).

5.8.5 Solar radiation

The test shall be as described in [6.3.7](#).

5.8.6 Corrosion (salt mist)

The test shall be as described in [6.3.1](#).

5.8.7 Electromagnetic compatibility

The test shall be as described in IEC 60945:2002.

5.8.8 Compass safe distance

The requirements of IEC 60945:2002 do not apply to navigation lights that consist mainly of non-magnetic materials.

5.8.9 Housing temperature

Housing parts of electrically powered navigation lights that can be accessed by hand during normal operation shall meet the requirements of the test described in [6.4.2](#).

5.8.10 Mechanical shock

The test shall be as described in [6.4.1](#).

5.9 Deviations caused by service life conditions

The manufacturer shall provide indication when the required range of visibility can no longer be attained, for example as a result of degradation, ageing, or failure of parts of the light source.

5.10 Influence of temperature

5.10.1 Influence of temperature on chromaticity coordinates and luminous intensity

Navigation lights shall be tested at ambient temperatures of -25 °C to $+30\text{ °C}$ and it shall be ensured that the luminous intensity and chromaticity coordinates meet the requirements of this document both 1 min after switching on and after 120 min operation.

The test shall be as described in [6.2.4](#).

5.10.2 Dry heat and low temperature

The navigation light in the energized state shall withstand ambient temperatures of -25 °C to $+55\text{ °C}$ without damage.

5.10.3 Pulse frequency

If the light of a navigation light is timed electrically, this shall be done at a frequency of at least 100 Hz for steady lights so that the human eye does not notice the pulsing.

6 Testing

6.1 General

6.1.1 Validity of IEC 60945:2002

Unless otherwise specified in this document, the test conditions in IEC 60945:2002 apply.

6.1.2 Performance test and performance check

A performance test (PT) according to IEC 60945:2002 is a complete photometric and colorimetric test as described in this document.

A performance check (PC) according to IEC 60945:2002 only requires the navigation light to function after being switched on.

A performance check (PC) shall be carried out after or during all the tests specified in IEC 60945:2002. A performance test (PT) shall be carried out after the sequence described in the "Order of the tests" and after the corrosion test.

6.1.3 Order of the tests

The vibration, shock, dry heat, low temperature, solar radiation, and rain and spray tests shall be carried out in the listed order on the same navigation lights.

At the conclusion of the above-listed tests, these navigation lights shall be subjected to a performance test (PT) without any intervention.

All remaining tests could be carried out in any order.

6.1.4 Documentation

All tests shall be documented.

6.1.5 Light source

The navigation light manufacturer shall specify the light source used in the navigation light. If the manufacturer changes the light source after the approval of the navigation light, photometric and colorimetric tests shall be reconfirmed.

6.2 Photometric and colorimetric tests

6.2.1 Test voltage

During the photometric and colorimetric tests, the navigation lights shall be supplied with their rated voltage with a tolerance of $\pm 0,1$ %.

If the manufacturer gives the navigation light a rated voltage range for the operation of his product, the photometric and colorimetric tests shall be carried out at the lowest and highest rated voltages that lie within the rated voltage range specified by the manufacturer.

See [6.2.2.2.9](#) for procedure details.

6.2.2 Photometric test

6.2.2.1 Purpose and application

This test is to determine the luminous intensity, the horizontal and the vertical luminous intensity distribution, and the uniformity of the light output over the entire required radiation sector.

6.2.2.2 Procedure

6.2.2.2.1 Number of navigation lights to be tested

The photometric test shall be carried out on at least one navigation light of each type, of each signal light colour, and of each rated voltage.

6.2.2.2.2 Goniophotometer

The photometric test shall be carried out with a goniophotometer with an accuracy of at least $0,1^\circ$ in the horizontal and vertical directions (see CIE 70:1987, Clauses 1, 2, 3 and 5). The navigation light shall be mounted on the goniophotometer by means of a suitable clamping device in the same way as it is intended to be attached onboard, and be turned and inclined horizontally and vertically around the mid-point of the light source as the centre of rotation in accordance with the specified requirements.

6.2.2.2.3 Photometer

The luminous intensity shall be measured with a photometer with a measuring range of at least 10^{-3} lux to 10^4 lux.

The $V(\lambda)$ adjustment error of the photometer ξ according to CIE 69 shall not exceed 1,5 %. The photometer shall have a tube of neutral colour reducing the internal reflections but not covering parts of the detector surface.

The photometer head detector shall be temperature-stabilized so that, as far as possible, it is not affected by the ambient temperature.

The photometer shall be adjusted to the national standard or regulation accepted by the country of test by calibration.

6.2.2.2.4 Measuring distance

The measuring distance between the centre point of the navigation light and the measuring surface of the photoelectric detector shall lie in a range in which the product of the illuminance measured and the square of the distance in metres remains constant when the distance changes, i.e. the distance shall be greater than the limiting photometric distance.

When the limiting photometric distance is determined experimentally, it shall be taken into account that when the navigation light is inclined to the optical axis of the photometer, the limit distance might be greater than when the navigation light is standing vertical to the optical axis of the photometer.

6.2.2.2.5 Calibration of the measuring device

The calibration of the whole measuring set-up shall be checked with the aid of a suitable calibration lamp that has also been calibrated to the national standard or regulation accepted in the country of test at the measuring distance selected for the test to be carried out. The check shall be documented.

6.2.2.2.6 Scattered light

The photometric test shall be carried out in a darkened room in which the limiting surfaces shall be designed to have low reflectivity to ensure that only the light emitted directly by the navigation light to be tested is measured by the photoelectric detector.

The effect of scattered light on the measured result shall be tested, e.g. by cutting off the light falling directly onto the measuring detector from the navigation light (see CIE 70:1987, 15.4).

6.2.2.2.7 Power supply

During the test, the navigation light shall be operated with the test voltage, principally DC voltage, via a quickly and finely adjustable power supply unit that keeps the current and voltage constant. The voltage shall be measured as close to the navigation light as possible.

The equipment used for setting and controlling the current and voltage shall be calibrated to a national standard or regulation accepted in the country of test.

6.2.2.2.8 Ageing and stabilizing

The navigation light shall be aged, stabilized, and burned in before the test.

The minimum time for the ageing and stabilizing of navigation lights shall be 50 h.

The minimum time for the burning-in period of navigation lights shall be 1 h directly before the test.

The ageing, stabilizing, and burning-in shall each be carried out at test voltage.

The measuring instruments shall also have stabilized before use.

The navigation light is photometrically stable if the change of the luminous intensity is less than 5 % over a period from 1 h to 50 h from the beginning of operation.

During stabilization, the ambient temperature shall not differ more than ± 3 °C.

The stabilization check of the luminous intensity shall be made at regular intervals. A spot check measurement inside the required sectors is sufficient. The required photometric and colorimetric values shall be attained.

6.2.2.2.9 Procedure

The luminous intensity shall be measured in the horizontal plane in the middle of the light source of the navigation light and be continuously measured in an arc extending at the sector limits 20° in each case beyond the specified arc of the horizon. The angle between two measurements shall not exceed $0,2^\circ$.

These measurements shall also be made with a navigation light inclined around the horizontal axis in all angles corresponding to the angles required in the COLREGs, Annex I, Clause 10.

Further measurements shall be taken in two vertical planes at right angles to the horizontal sector limits, except for sidelights where the vertical planes are intended to lie at an angle of 60° and 30° to the forward sector limit and in the "dead ahead" direction. For all-round lights, the two vertical planes shall lie at the point of the least established luminous intensity, and the other at 180° to it. The luminous intensity shall be measured in the specified vertical planes in the middle of the light source of the navigation light and be continuously measured in an arc extending at the vertical sector limits at least 10° in each case beyond the vertical sectors specified in the COLREGs, Annex I, Clause 10. The angle between two measurements shall not exceed $0,2^\circ$.

These procedures shall be carried out at the rated voltages. At the other voltage test points of rated voltage ± 10 % spot check measurements to check possible deviation are sufficient. The required photometric and colorimetric values shall be attained.

6.2.2.3 Required test result

The luminous intensities, and their distributions, of the navigation light shall meet the requirements of this document.

All the measured values (luminous intensity, distribution curves, current and voltage during the measurements, ambient temperature, checking of the calibration of the measuring section) shall be documented.

6.2.3 Colorimetric test

6.2.3.1 Purpose and application

This test shall determine the colour of the signal light over the horizontal and vertical radiation range and the uniformity of the colour over the whole required radiation sector.

The base documents used for the test and assessment are this document (see [Table 2](#)) and CIE 15.

6.2.3.2 Procedure

6.2.3.2.1 Number of navigation lights to be tested

The colorimetric test shall be carried out on at least one of each type, each signal colour, and each rated voltage from the photometric test.

6.2.3.2.2 Colorimeter

Testing of the signal light colour of the navigation light under simulated operating conditions shall be carried out with a maximum-precision colorimeter for absolute measurement, e.g. in accordance with the tristimulus colorimetry method described in CIE 15. The photoelectric detector for the colorimetry shall be matched very finely to the standard colour matching functions " $\bar{x}(\lambda)$ ", " $\bar{y}(\lambda)$ ", and " $\bar{z}(\lambda)$ " for the 2° field size as specified in ISO 11664-1 on partial filtering.

For measuring the signal light colour, the sensitivity of the measuring system shall be at least 1 lux.

The photoelectric detector for the colorimetry shall have a neutral colour tube reducing the internal reflections but not covering parts of the detector surface. The detector shall be temperature-stabilized so that, as far as possible, it is not affected by the ambient temperature.

6.2.3.2.3 Calibration of the measuring section

The measuring system for the colorimetry shall be checked before each test with a suitable calibrated light source and calibrated colour filters. The check shall be documented. The colorimeter, the light source, and the colour filters shall be calibrated to a national standard or regulation accepted by the country of test.

6.2.3.2.4 Scattered light

The colorimetric test shall be carried out in a darkened room in which the limiting surfaces particularly close to the mounted navigation light shall be of a neutral colour and be designed to have low reflectivity to ensure that only the light colour emitted directly by the signal light of the navigation light to be tested is measured by the photoelectric detector of the colorimeter.

6.2.3.2.5 Goniometer table

The colorimetric test shall be carried out on a goniometer table. The navigation lights shall be assembled on the goniometer table with suitable clamping devices in the same way as they are fitted on board

and be rotated and inclined horizontally and vertically around the mid-point of the light source as the centre of rotation in accordance with the requirements set out in [6.2.3.2.9](#).

6.2.3.2.6 Geometry

The measuring distance between the mid-point of the navigation light or of the light source and the measuring surface of the photoelectric detector for the colorimetry shall be set so that the detector surface is illuminated fully and uniformly without any structural projections of the light-emitting surface of the navigation light surface.

6.2.3.2.7 Power supply

During the test, the navigation light shall be operated with the test voltage, principally DC voltage, via a quickly and finely adjustable power supply that keeps the current and voltage constant. The voltage shall be measured as close to the navigation light as possible.

The equipment used for setting and controlling the current and voltage shall be calibrated to the national standard or regulation accepted by the country of test.

6.2.3.2.8 Ageing and stabilizing

For ageing and stabilizing, see [6.2.2.2.8](#).

6.2.3.2.9 Procedure

The colour shall be measured with goniometers and the measurements shall be taken in the horizontal and vertical directions at least every 10° within the specified sectors.

6.2.3.3 Required test result

The chromaticity coordinates of the measured navigation light shall lie within the chromaticity areas specified in this document (see [Table 2](#)) for the particular signal colour.

All the measured values (chromaticity coordinates, current and voltage during the measurements, ambient temperature, checking of the calibration of the measuring section) shall be documented.

6.2.4 Measurement of luminous intensity and chromaticity coordinates under the influence of temperature

The influence of the ambient temperature on the luminous intensity and the chromaticity coordinates of the navigation light shall be tested. Absolute measurements are not required for this test; it is adequate to compare the luminous intensity and chromaticity coordinates in a specific direction of radiation at the ambient temperatures given in [5.10.1](#) with the luminous intensity and chromaticity coordinates at room temperature. This may be done, for example, in a conditioned cabinet with a glass door and without the use of a swivelling or inclining device. After each temperature change, thermal equilibrium shall be attained before recording the measured values. The shifts in the measured results caused by the influence of the ambient temperature shall then be inserted in a relationship to the results of the previous absolute measurements.

The test is successful if the requirements are still met taking into account the shifts.

6.2.5 Measurement of flashing lights

In the case of flashing lights, the following deviations from [6.2.2](#) and [6.2.3](#) shall be taken into account:

- a) three horizontal luminous intensity distribution curves shall be recorded, one at 0° inclination, one at -2° inclination, and one at +2° inclination;

- b) at the point where the smallest luminous intensity was determined when recording these three curves, a further vertical curve with an inclination from -10° to $+10^\circ$ and a step size not exceeding 1° shall be recorded;
- c) the required minimum luminous intensity shall be attained at all the measuring points in the range of the vertical angle of -2° to $+2^\circ$ (see 5.4);
- d) the chromaticity coordinates shall be determined at 10 points that shall be distributed over the four curves recorded.

6.3 Explanations, supplements, or amendments to points in IEC 60945:2002

6.3.1 Corrosion (salt mist)

The test may only be waived if the navigation light is an enclosed system (at least IP66 according to IEC 60529:1989) and the housing materials are corrosion-resistant.

6.3.2 Extreme power supply

Unless otherwise specified in this standard, all the tests in this standard deviating from IEC 60945:2002 shall be carried out at rated voltage only.

6.3.3 Dry heat

The test for resistance to dry heat shall be as specified in IEC 60945:2002. For deviating temperature ranges, see 5.10.2.

6.3.4 Damp heat

A damp heat test is not required.

6.3.5 Vibration

The test shall be carried out according to IEC 60945:2002 with the following deviations.

The resonance search shall be carried out in the range 2 Hz to 15 Hz with an amplitude of $\pm 2,5$ mm and from 15 Hz to 100 Hz with a constant acceleration of 2,3 g.

NOTE It should be taken into account that navigation lights mounted on masts are often subjected to vibration stress that is greater than the stress (vibration) occurring on the bridge, for example.

The vibration amplitudes above also apply to the vibration endurance test.

The navigation light shall be operated with rated voltage during the test.

The test is regarded as having been successful if the navigation light continues to function and no damage has occurred to the navigation light or its subassemblies and components.

6.3.6 Rain and spray

This test is omitted if the navigation light is proven to meet the requirements of IP67 according to IEC 60529:1989 at least.

The "Rain and spray" (exposed equipment) test described in IEC 60945:2002 shall be carried out on a navigation light in operation. The navigation light shall be switched on 1 h before the test. Cold water with a temperature not exceeding 15°C shall be used for the test.

The degree of protection of the navigation light shall be IP66 as specified in IEC 60529:1989.