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Working Group WG1

Author(s) / Submitter(s) China MSA

The Proposal of a Measurement Method

for Surface Colours of Visual Aids to Navigation

# 1 SuMMary

China Maritime Safety Administration conducted the in-depth research on the measurement method for surface color of visual aids to navigation in 2018, made detailed requirements and specifications for the measurement method, measurement environment and measurement instruments of the surface color of visual aids to navigation, and developed a method applicable to the surface color measurement of aids to navigation( excluding the measurement of retro-reflecting materials), which gave detailed guidance for the surface color measurement of visual aids to navigation.

## Purpose of the document

The purpose of this document is to provide a measurement method for surface colour of visual AtoN and a theoretical reference for the accurate measurement of visual AtoN in the industry.

## Related documents

IALA R0108(E-108)-2017 The Surface Colours Used as Visual Signals on Marine Aids to Navigation

IALA G1134-2017 Surface Colours used as Visual Signals on AtoN

CIE 15-2018 Colorimetry

# 2 BackgrounD

At present, the published recommendation and guideline of IALA include 《IALA R0108(E-108)-2017，The Surface Colours Used as Visual Signals on Marine Aids to Navigation》and 《IALA G1134-2017 Surface Colours used as Visual Signals on AtoN》. R0108 mainly specifies the colour used in the visual AtoN, which doesn’t include the surface colour measurement method. G1134 only briefly introduces the measurement method without detailed measurement requirements. This may easily lead to the difference and poor comparability among the measurement results due to different choices of various technical links in the measurement method by different manufacturers and test laboratories.

In order to solve above problems, it's necessary to conduct research on the surface colour measurement method of AtoN，so as to develop a unified and standard method to facilitate the quality control and maintenance of surface colours. This method will provide a basis for evaluation of surface colour performance in the material research, acceptance and maintenance of visual AtoN projects, and make the measurement results among different departments comparable ,so as to reduce the problems caused by inconsistent measurement methods and finally improve the safety of navigation.

# 3 DiscussioN

## 3.1 Summary

According to the existing standards for surface colours of AtoN and the development of current measurement technology, this method is the first to conduct a detailed research and analysis of the surface colour measurement for AtoN. It standardizes the measurement method of visual AtoN and makes specifications on the measurement environment requirements, measurement instruments requirements, sampling methods and measurement procedures. The specific are as follows:

## 3.2 Overall Measurement Requirements

CIE D65 is selected as the illuminant. CIE 2°standard colorimetric observer is adopted. A 45 °annular/normal geometry (45/0) is used for measurement. The measurement method is spectrophotometry. In addition to the above mentioned points, this measurement method also makes specific requirements for the measurement methods and measurement conditions of the surface colours of visual AtoN based on the performance and application requirements of the surface coloours of visual AtoN, which are embodied in the following aspects:

## 3.2.1 Surface Color Measurement by Spectrophotometry

There are two methods for surface colour measurement: spectrophotometry (using spectrophotometer) and photoelectric integration method (using colorimeter). Based on the previous practical research and analysis, photoelectric integration method has spectral mismatching problem due to the influence of matching technology and other factors, especially for the measurement of red and blue visual AtoN. In addition, it is very difficult to accurately simulate the standard illuminants, especially the standard D65, which will increase the error of photoelectric integration method.

## 3.2.2 Selection of Measurement Illuminant

The surface colour measurement of visual AtoN by spectrophotometry is based on the theoretical calculation of the measured spectral reflectance. Therefore, for the measurement of ordinary surface colour and surface colour of retroreflective materials, as long as the measurement illuminant has a continuous and stable luminous spectrum in the visible light range, but the visual aids of fluorescent materials have photoluminescence phenomenon, therefore, for the measurement of fluorescent materials, different measurement schemes must be selected based on the actual measurement requirements.

## 3.2.3 Selection of Sampling Points Location

For the submitted samples or AtoN to be measured, 3 to 5 testing points shall be selected for each colour and be scattered. And for on site measurement, the points shall also be selected in the direction of the sailing observation.

## 3.3 Measurement Methods

Due to material selection, quality control and maintenance of visual AtoN, different measurement environments require different measurement accuracy. On the basis of different measurement environments, measurement methods can be divided into laboratory measurement and on-site measurement. Compared with on-site measurement, laboratory measurement has higher requirements on measurement conditions and measurement instruments, and sample preparation and selection will be different.

**3.3.1 Laboratory Measurement**

**a. Environmental Conditions**

Temperature: 25℃±5℃.

Humidity：relative humidity ≤(85±5）%，no condensation.

The working environment of the instrument shall be free from direct light, corrosive gas, strong vibration or strong electromagnetic interference indoors.

**b. Measurement Samples**

The measurement samples shall be made of similar substrates and the same coatings as the measurement visual AtoN.

**c. Instrument Requirements**

In addition to meeting the CIE 45°/0°(0°/45°) geometry, the measurement instrument shall also meet the following requirements:

(1). Light Source: select the stable light source with continuous spectrum in 380nm~780nm for the measurement of ordinary surface colours and the surface colours of retro-reflecting materials. For fluorescent materials, use the polychromatic light simulating the standard illuminant D65( the category is evaluated according to CIE 51.2 and shall not be lower than category BC) and this method is called polychromatic light irradiation method. The tunable monochromatic light source in 250nm~800nm can also be used(monochromatic light excitation method).

(2). Spectrum Measurement: wavelength range is 380nm~780nm; The spectral resolution is not greater than 3nm; Wavelength accuracy is better than ±1nm

(3). Sampling Aperture: it is recommended that the ratio of instrument’s sampling aperture to the radius of the sample is less than 0.02, and the measurement surface shall be filled with the entire sampling aperture.

(4). Equipped with standard white standard plate and zero calibration device for instrument calibration.

**d. White Standard Plate**

For the measurement of ordinary colours and retro-reflecting materials, use spectral reflectance data of 380nm~780nm of the white standard plate under CIE45/0 or 0/45 geometry for calibration under illumination observation conditions.

For the surface colours measurement of fluorescent materials using the composite light irradiation measurement method, use spectral radiance data or chroma data under CIE45/0 or 0/45 or CIE BC grade D65 illumination conditions, which is similar to the tested samples.

**3.3.2 On-site Measurement**

**a. Environmental Conditions**

The surface of measurement AtoN shall be clean and dry.

There shall be no corrosive gas or strong electromagnetic interference in the surrounding environment.

**b. Measurement Instrument**

It is recommended to use integrated measurement instruments that can be self-calibrated for on-site measurement. It is also recommended to adopt the 45/0(0/45) annular or circumferential illuminance /observation geometry, and the following requirements shall be met:

(1). Light Source: select the stable light source with continuous spectrum in 380nm~780nm for the measurement of ordinary colours and the colours of retro-reflecting materials; use the light source with continuous spectrum in 380nm~780nm for the fluorescent materials with the adjustment of its UV component.

(2). Spectral Measurement: wavelength range is at least 380nm~780nm; The spectrum resolution is not greater than 10nm; Wavelength accuracy is better than ±2nm

(3). Sampling Aperture: it is recommended that the ratio of instrument’s sampling aperture to the radius of the sample is less than 0.02, and the tested surface shall be filled with the entire sampling aperture.

(4). Equipped with a white standard plate and a zero calibration device.

**c. White Standard Plate**

Use the spectral reflectance data of 380nm~780nm of the white standard plate under CIE45°/0°(0°/45°) geometry for calibration for measurement of ordinary colours and retro-reflecting materials.

Use the fluorescent standard for measurement of fluorescent materials, in addition to using the same white standard for ordinary material and retro-reflecting material surface colour measurement.

# 4 request

It is hoped that the committee will consider this measuring method described in this document as a new guideline of IALA or supplement to G1134.

Appendix

## Appendix A Measurement Procedures

**1 Laboratory Measurement**

**1.1 Selection of Measurement Points**

a. Select 3~5 measurement points of each color for the same sample to be measured;

b. Scatter the measurement points selected.

**1.2 Measurement Procedures**

**a. Mesurement of Ordinary Colours and Retro-reflecting Materials：**

(1) Calibrate the measurement instrument with the zero calibration device;

(2) Use the white standard plate to calibrate the instrument after the zero calibration of the instrument is accomplished;

(3) Place the sample to be measured, measure and obtain the spectral reflectance of the measured points of the sampleafter the white standard calibration.

**b. Colour Mesurement of Fluorescent Materials**

-- Polychromatic Light Irradiation Method

1. Calibrate the measurement instrument with the zero calibration device;
2. Use the white standard plate and the fluorescent standard to calibrate the instrument after the zero calibration of the instrument is accomplished;
3. Place the sample to be measured, measure and obtain the spectral reflectance of the measured points of the sample, after the calibration is completed.

--Monochromator Excitation Method

(1) Place the sample to be measured, , and obtain the Donaldson Matrix for the measured points of the sample with the 10nm wavelength interval( including the reflecting component and fluorescent component of the sample, according to Standard ASTM E2153);

(2) Calculate the total spectral radiance factor of the measured sample, i.e., the final value for subsequent color parameter calculation.

Note: If 45/0(0/45) single plane geometry is adopted, the measured result shall be produced according to the average value of rotation measurement result, 4 times or more rotation measurement is done until there is no obvious difference between the two measurements adjacent. Then the average value is taken as the final result of the measured points for calculation of color parameters.

**2 On-site Measurement**

**2.1 Selection of Measurement Points**

a. Select 3~5 measurement points of each color for the same sample to be measured;

b. Select the measurement points in the direction of navigation observation;

c. Scatter the measurement points selected.

**2.2 Measurement Procedures**

**a. Measurement of Ordinary Colours and Retro-reflecting Materials:**

(1) Calibrate the measurement instrument with the zero calibration device;

(2) Use the white standard plate to calibrate the instrument after the zero calibration of the instrument is accomplished;

(3) Place the sample to be measured, measure and obtain the spectral reflectance of the measured points of the sampleafter the white standard calibration.

**b. Measurement of Fluorescent Materials:**

(1) Calibrate the measurement instrument with the zero calibration device;

(2) Use the white standard plate to calibrate the instrument after the zero calibration of the instrument is accomplished;

(3) Use the fluorescent standard to calibrate the instrument after the calibration of the white standard is accomplished;

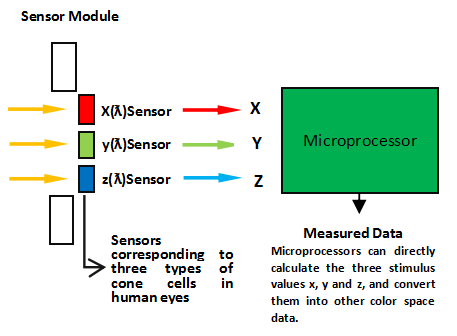
(4) Measure the AtoN and obtain the spectral reflectance of the measured points of the sample after the calibration;

(5) Obtain the measurement result of different UV radiation components through the adjustment of UV components of light source.

## Appendix B Spectral Mismatching of Color Measurement

## by Photoelectric Integration Method

Photoelectric integration method performs integrating on the measured spectral power by matching the spectral response of the detector to the CIE standard colorimetric observer、、, to get the related colour parameters of the samples, as shown in figure C.1.

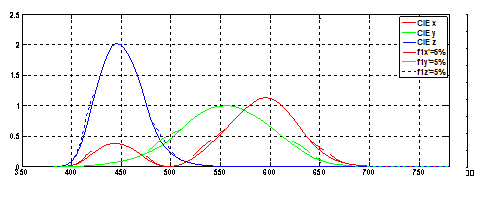


*Figture C.1 The principle of photoelectric integration method*

In fact, there is always a spectral mismatching problem in this method with the limitation of technology. The relative spectral sensitivity of the detector cannot match perfectly with the curve corresponding to the standard observer 、、, and there is somewhat deviation. Generally, ,,  are used to evaluate the spectral mismatch degree of the detector. The larger the value is, the worse the matching degree is, the greater the error of the measurement result will be, especially for the red, blue and other color visual AtoNe samples.

 (C.1)

，，is relative spectral power distribution of standard source A， is spectral sensitivity curve of detector.



Wavelength/nm

*Figure C.2 Simulation of detector with 5% of* , and 



red

yellow

green

**Wavelength/nm**

**Reltive Spectral Distribution**

*Figure C.3*  Typical red, green and yellow color samples (left) and their spectral distribution (right)

In the research process, the detector system with,and  as shown in Figure C.2 is simulated to measure the chromaticity coordinates of typical red, green and yellow color samples as shown in Figure C.3. The measurement results are shown in Table 1. When =,== 5%, the chromaticity coordinate error is as high as 0.0031. While in the market, there are more detector systems with =,=≥ 7% in addition, if there is a narrow-band spectrum in the spectrum of the sample to be measured, the detection error will be greater. Therefore, spectrophotomery method is recommended for high-precision color measurement.

*Table 1 Measurement results of detector spectral mismatch*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Chromaticity coordinates**  **Mismatch**  **error** | | Red | | Yellow | | Green | |
| x | y | x | y | x | y |
| 0% | | 0.3466 | 0.3101 | 0.2632 | 0.4733 | 0.2903 | 0.4127 |
| 5% | Result | 0.3471 | 0.3089 | 0.2638 | 0.4741 | 0.2894 | 0.4158 |
| Deviation | -0.0005 | 0.0012 | -0.0006 | -0.0007 | 0.0009 | -0.0031 |

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