

GUIDELINE

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**SURFACE COLOURS USED AS VISUAL SIGNALS
ON AtoN**

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1 INTRODUCTION

A surface colour is a colour perceived to belong to a surface. The colour of an ordinary surface, such as an ordinary paint or an opaque plastic material, is the most common kind of surface colour and is known as an **ordinary** colour. Other kinds of colours include fluorescent (or luminescent) colours, **transilluminated** colours (for example, the colours of internally illuminated panels) and the colours of **retro-reflecting** materials.

A surface colour can be specified in terms of its chromaticity and its luminance factor. Chromaticity co-ordinates, which may be plotted on a chromaticity diagram, define the chromaticity and the luminance factor is a measure of the lightness of the colour relative to a pure white diffusing surface under the same illumination. As a specification must be made with respect to some type of illumination, the International Commission on Illumination (CIE) has precisely defined several standard illuminants. The results of the measurement of a colour can depend significantly on the degree of gloss on the surface, and the CIE has also recommended various geometries of illumination and measurement.

Two colours may be measured as having the same chromaticity and luminance factor under one illuminant, but dissimilar ones under a different illuminant. This phenomenon is known as metamerism, and its effect can be very significant. It is advisable to check that the appearance of a signal colour will remain reasonably constant under the various types of illumination by which the colour is expected to be seen.

A surface colour is usually seen in relation to other surface colours, and the perception of the colour can be quite markedly influenced by the presence of the other colours. Hence, a signal colour should always be checked, especially at a distance, for its appearance among the surrounding colours.

Deterioration of surface colours in use is a common occurrence, and care must be taken that signal colours always remain in compliance with their specifications. Particular attention should be given to fluorescent colours, as they are liable to undergo rapid changes of chromaticity and luminance factor on exposure to radiation and wear if they are not provided with special protective surfaces. Frequent inspections of fluorescent colours are advised until the normal useful life has been confidently ascertained for each typical situation where these colours are used. Special care may be needed if fluorescent and non-fluorescent colours of the same chromaticity are chosen to be used together, as different deteriorations might produce dissimilarities of the chromaticity.

2 SPECIFICATION AND MEASUREMENT OF THE COLOURS

The guidance in this document are based largely on experimental work involving the recognition and naming of colours, but they have also taken account of common practice and the limitations of materials. The method of specifying the colours is in conformity with the recommendations of the CIE. The recommended limits of the chromaticity of a colour are specified by means of limiting boundaries that enclose a chromaticity region on a CIE standard chromaticity diagram and can be found in IALA Recommendation R0108(E-108) - Surface Colours Used as Visual Signals on Marine Aids to Navigation.

The luminance factor β and the chromaticity co-ordinates x , y strongly depend on the measurement principle and the structure of the surface, texture, gloss, patterns etc. To make colour measurement precise and repeatable various specifications are necessary. It is stated that the chromaticity regions and the limits of the luminance factor are only valid, when the following specifications are fulfilled.

2.1 STANDARD ILLUMINANT

The standard illuminant specified for the measurement of a colour is D65, which represents a typical phase of daylight and has a correlated colour temperature of approximately 6500 Kelvin. It is a tabulation of values across and beyond the visible spectrum and does not exist as a real light source although fairly close approximations to it can be realized. The chromaticity of standard illuminant D65 (the illuminant point) is shown in the **Erreur ! Source du renvoi introuvable.**s 3 and 4.

2.2 MEASUREMENT GEOMETRY

To take the effects of the coloured surface into account a 45° annular/normal geometry (45/0) is used for measurements. The report CIE No. 15 (point 5.1.2) [3] emphasises this geometry as well. A 45° / normal (45/0), means that the colour should be illuminated at an angle of 45° to the normal to the surface from all azimuthal directions, and the colour should be measured in the direction of the normal. Measurement with a geometry of normal / 45° will usually produce an identical result.

2.3 STANDARD OBSERVER

The 2° standard observer (CIE No. 15, point 6.1) is used for large observation distances and above all to consider the attitudes of the human eye; this is the area with the highest cone density and is therefore relevant for colour perception. The 2° observer covers the application for Marine Aids to Navigation (AtoN) purposes.

2.4 GLOSSINESS OF THE SURFACE

A glossy surface produces a saturated colour, whereas a matt-finished surface has only a poor saturation even when both surfaces are based on the same colour pigment.

As a result, the recommended IALA chromaticity regions can only be achieved by a surface with enough glossiness. Therefore, it is recommended to use glossy colours for AtoN.

2.5 MEASUREMENT DEVICES

There are two methods of measuring surface colours.

2.5.1 SPECTROPHOTOMETRY – ABSOLUTE MEASUREMENTS

A spectrophotometer measures the amount of light energy reflected from an object at several intervals along the visible spectrum. It consists of four main parts; the light source (an approximation of the standard illuminant, usually a xenon light source), the sample (the surface colour), the detector and the output (a display or connected to a PC via software), as shown in Figure 1. The spectral data is shown as a spectral reflectance curve and can be weighted with a standard illuminant and standard observer.

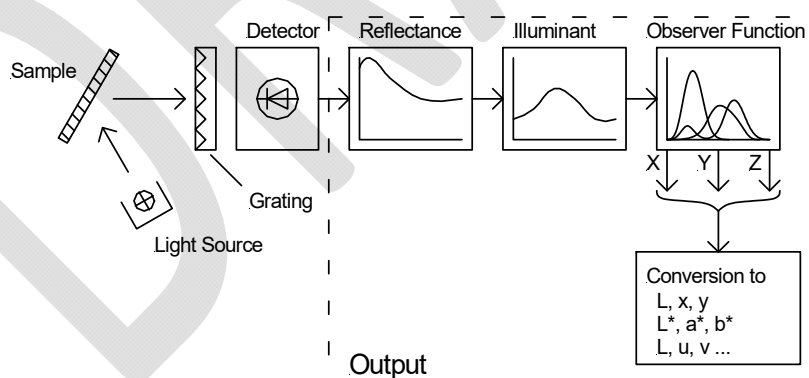


Figure 1 *Component Parts of a Spectrophotometer*

2.5.1.1 Charge Coupled Device (CCD) Spectrophotometer

A CCD is a type of image sensor that detects light. It is an integrated circuit made up of an array of linked/coupled light-sensitive receptors. The light-sensitive receptors detect the intensity of light received and convert it into an electrical signal. The CCD detector corresponds to the range of wavelengths on a spectrophotometer. Each pixel on the CCD represents a specific wavelength of light, and the more photons absorbed, the more electrical signal generated. Therefore, the electrical signal output by the CCD at each pixel is proportional to the light intensity at

each corresponding wavelength. The resultant output is a reflectance curve, which can then be weighted against an illuminant and observer. Further conversions to alternative units can then be performed.

This type of instrument is often used for in-situ (outdoor) measurements. However, there are some limitations in wavelength accuracy (<10 nm).

2.5.1.2 Scanning Monochromator

A scanning monochromator uses a diffraction grating that 'steps' through the visual spectrum to separate the individual wavelengths (1-5 nm). These instruments are generally quite large and heavy and are more suited to laboratory measurements due to the time it takes to perform the measurement. However, they are very accurate (~1 nm).

2.5.2 COLORIMETRY - RELATIVE MEASUREMENT

Colorimeters are tristimulus (three-filtered) devices that make use of red, green, and blue filters to emulate the response of the human eye to light and colour as shown in Figure 2. Due to filter imperfections and not recording the spectral reflectance of the sample, tristimulus colorimeters are not suitable for assessing IALA's surface colour requirements.

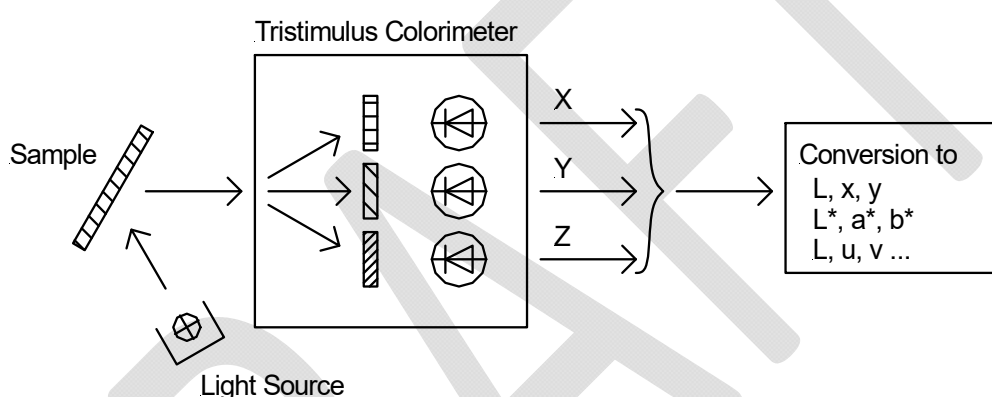


Figure 2 *Component Parts of a Colorimeter*

However, colorimeters used as colour difference meters do provide reasonable results.

2.6 FLUORESCENCE

Fluorescence is the process by which electromagnetic radiation of one wavelength is absorbed and re-radiated at another wavelength. Sometimes a fluorescent material will absorb non-visible light and emit it as visible light. Fluorescence and ordinary reflectance of radiation take place simultaneously and at the same wavelengths. When the colour of a fluorescent sample is measured, the fluoresced light is added to the reflected light at those wavelengths. Therefore, reflectance can exceed 100%. The UV contribution from the reference light of the measurement instrument is often not included and can vary from instrument to instrument. However, instruments that use a Xenon light source as the reference light can give an approximation of UV daylight.

The chromaticity region recommended for each fluorescent colour is identical to the region of the corresponding ordinary colour. The colour of a fluorescent material should be measured with any protective surface that is normally used with the material.

2.7 ADDITIONAL CONSIDERATIONS

The boundary lines of a chromaticity region, and the restrictions that may apply to the appropriate luminance factor, can together be referred to as the colour limits of a colour. The recommended colour limits are extreme values that should not be transgressed (except as mentioned in sections 3.1, 3.4, 3.5 and 3.6). More restrictive limits may be defined as appropriate to particular requirements; and they may be desirable for the signal colours



used within one signalling system if substantial differences in appearance, either of chromaticity or luminance factor, are to be avoided. Also, the recommended colour limits of a colour are intended to apply throughout its entire service life, so examination of its condition may be required from time to time.

It should be noted that, with the exception of the purple boundary of Red, the specifications have not been designed to assist people with severely defective colour vision, most of whom will have great difficulty distinguishing between red and green.

3 CONSIDERATIONS OF PARTICULAR COLOURS

3.1 RED

A minimum value of 0.07 is specified in Table 1 for the luminance factor of ordinary red, but significantly higher values can usually be realized and, in most circumstances, a value greater than 0.10 should be maintained.

The chromaticity region of red, which is identical for both ordinary and fluorescent colours, has been defined on the basis of achieving a very high probability of correct recognition for the colour, and it should prove to be quite practicable for ordinary reds with glossy surfaces and for fluorescent reds. There is doubt though, if their surfaces are matt or even semi-matt, whether serviceable materials of various kinds can always be manufactured in compliance with the restriction imposed by the white boundary of the chromaticity region for ordinary red. Also, it is not yet certain that serviceable materials, with glossy surfaces when new, can necessarily be manufactured so that their compliance continues throughout a reasonable service life if considerable loss of gloss occurs.

Therefore, it is proposed that the chromaticity region for ordinary Red may be extended, but only for materials with matt or semi-matt surfaces, to a revised white boundary of $y=0.840 - x$. This provision for ordinary red colours should not be used unless it is necessary, and then only with the understanding that the probability of correct recognition of the colour will be significantly reduced. The problem discussed here is not expected to arise with any of the other chromatic colours.

3.2 ORANGE

The probability of correct recognition of orange is usually not as high as that of red or yellow; moreover, when these colours subtend very small visual angles, orange and red, or orange and yellow, are very likely to be confused. Hence, in considering signal colours that need to be recognized at a distance, orange does not provide a satisfactory additional colour to a system that includes red and yellow. If orange is completely excluded from a system of signal colours for AtoN, the adjacent hue boundaries of red and yellow should remain as recommended in the Tables, since, otherwise, correct identification may not be made even at close ranges and the colours will not exhibit a reasonably consistent appearance world-wide.

Nevertheless, orange is probably the best ordinary colour for conspicuity against the sea, and it should preferably be reserved for those objects for which detection in the water is more important than recognition of their colours. The objects that require this consideration are items of emergency equipment, such as life-jackets and life rafts. The highest conspicuity will be obtained with fluorescent colours, and then fluorescent red-orange may be used and may, in some situations, be more conspicuous than fluorescent orange, but fluorescent red-orange is not likely to be seen as distinct from fluorescent red.

3.3 YELLOW AND WHITE

Discrimination between yellow and white is not practicable when they subtend very small visual angles, so they should not be considered as separate colours except for close viewing. In particular, it would be inadvisable to create any circumstances that required unequivocal distinction between yellow and white in retroreflecting materials, whether by day or by night.

At sea, the probability of recognizing, or even detecting, white on its own will often be low.

3.4 GREEN

As an ordinary colour, green does not usually show well at sea. However, colours of fluorescent green can be obtained with exceptionally high purities, and they will be very much more recognizable in most conditions.

It may be desirable, if green is required as a background colour on a sign with symbols or alphanumeric characters, to use a special dark colour – for example, one having a value of luminance factor lower than the minimum value recommended in Table 1. There is a possibility of confusing green with blue at the blue boundary of the green colour. To avoid this, IALA has introduced an IALA preferred green zone. This is shown on the chromaticity regions graph and associated tables.

3.5 BLUE

On inland waterways, and in estuaries and harbours, where colours may be seen at close range, blue may prove to be a useful signal colour; but, at a distance, particularly at sea, it is unlikely to be easily recognized.

Although the recommended value of minimum luminance factor in Table 1 is 0.07, values significantly higher are attainable, and they should be required whenever possible if blue is to be seen alone.

It may be desirable, if blue is required as a background colour on signs with symbols or alphanumeric characters, to use a special dark colour, that is, one having a value of luminance factor lower than the minimum value recommended in Table 1. In such circumstances, a value as low as 0.05 may be considered for this special dark blue, which should anyway have a chromaticity conforming with the specification for ordinary blue, and which should never be used alone anywhere as signal colour.

3.6 BLACK

A maximum value of 0.03, as specified in Table 1, is recommended for the luminance factor of ordinary black if surfaces are glossy, but, if surfaces are matt or semi-matt, then it may be necessary to allow a maximum value of 0.04 although the probability of correct recognition will thereby be lowered.

4 DEGRADATION OF PIGMENTS

It should also be recognized that as soon as a coloured surface is exposed to the atmosphere the colour will begin to change. This is due to the degradation of pigments and dyes in sunlight, the breakdown of the glossy surface film, and the production of light coloured particles due to the breakdown of the coloured surface. Bright colours (particularly fluorescent colours) breakdown most rapidly while darker colours last the longest.

Coloured surfaces on buoys and other structures close to the water are also subject to salt deposits, marine growth, bird fouling, etc. Effective colour retention will depend on regular maintenance cleaning which will be simplified by utilising paint with a hard and high gloss surface.

It is important to remember that signal colours should be clearly recognisable in the conditions in which the mariner will view them. The perception of a colour will vary depending on the ambient lighting conditions, the background colour against which the colour is viewed and the surface finish of the colour (the gloss in the case of a paint finish).

They should contrast sufficiently with the local background and watercolour for them to be easily recognised. Dark green colour should be used on buoys on inland waterways where they are viewed against a predominantly light green background. For example, in Nordic countries, light colours are more easily visible in twilight and also against background luminance.

In recent years, health and safety regulations have prohibited the use of many traditional pigments and alternatives may not have the long-term stability of those used in the past.

5 SYMBOLS AND ALPHANUMERIC CHARACTERS

Good legibility requires that symbols and alphanumeric characters should have a good contrast with the colours against which they are seen. A contrast of luminance factors is usually of more advantage than one of hues, and the ratio of the luminance factors should be made as large as is possible. Thus black should be applied on yellow, and, in general, white should be used on red, green or blue. However, if the luminance factors of red or green are particularly high, as they may be if these colours are fluorescent, then a contrast of black may be more satisfactory. Sometimes a symbol or an alphanumeric character may be clearer if it is outlined in a contrasting colour or is shown on a distinct panel of contrasting colour.

6 COLOURS OF RETROREFLECTING MATERIALS

Two different specifications for the colours of retro-reflecting materials are required if the colours are to be defined adequately for the purposes of this document. The specifications need to define the colours for conditions of illumination that are representative of those occurring both by day and by night. With regard to this document, a specification of the colours for night-time conditions is unquestionably the more useful, but the methods of measurement have not yet been internationally resolved. A specification of the colours for daytime conditions has been undertaken by the CIE. A particular problem with a specification for daytime conditions relates to the geometry of measurement and the limits of the luminance factors. IALA Recommendation R0106(E-106) - The Use of Retro-reflecting Material on Aids to Navigation Marks Within the IALA Maritime Buoyage System refers [4].

7 COLOUR COLLECTIONS

This guideline uses the CIE 1931 Standard Colorimetric System [1] to specify ranges of colours by their chromaticity and luminance factors. This provides a scientifically correct method of defining colour. Although the use of chromaticity coordinates and luminance factor is well established, there are practical reasons to choose different methods to describe a colour. One of the reasons is that paint manufacturers can more easily work with colour collections.

A collection contains a number of colours and gives a name to them. Behind the collections stands an exact procedure to reproduce the surface colours.

A colour 'swatch' can often be obtained for each colour in a colour collection. These can be used to compare the colour of a surface to the 'swatch'. However, this is a subjective method and should only be used under natural light, to give an indication of how different a colour appears compared to its original state. Swatches should be stored in darkness when not in use.

The use of a colour collection simplifies the definition of a colour and produces a number of colours that lie within the colour regions. However, because of the strong influence of gloss on the saturation of colour, there may not be a single chromaticity co-ordinate for each colour.

Throughout the world different types of colours are used depending on local circumstances. Some countries use darker colours because of light backgrounds; others need lighter colours in twilight to make the object more visible.

7.1 RAL CLASSIC COLOUR COLLECTION

The IALA regions can be achieved with the RAL CLASSIC Colour collection for glossy colour shades RAL 841-GL [5].

The following numbers are a subset of the RAL collection. They were chosen to ensure a high distance of recognition and good conspicuity and so the colours have a high saturation and luminance factor.



7.1.1 ORDINARY COLOURS

Table 1 *RAL colours that meet the specifications for ordinary colours*

Number	Name	Luminance factor β
RAL 3028	Pure Red	> 13%
RAL 6037	Pure Green	> 15%
RAL 1023	Traffic Yellow	> 50%
RAL 2008	Bright Red Orange	> 25 %
RAL 5019	Capri Blue	> 7%
RAL 9016	Traffic White	> 80%
RAL 9017	Traffic Black	< 1%

There are other RAL-Colours that meet the specifications but are not as saturated as the colours shown in Table 5.

7.1.2 FLUORESCENT COLOURS

Table 2 *RAL colours that meet the specifications for fluorescent colours*

Number	Name	Luminance factor β
RAL 3024	Luminous Red	> 25%
RAL 6038	Luminous Green	> 25%

For the fluorescent colours orange and yellow there are no RAL numbers that meet the specifications of this recommendation.

7.2 RECOMMENDED NATURAL COLOUR SYSTEM (NCS) COLOUR NUMBERS

NCS is a system with the help of which all conceivable surface colours (not fluorescent or metallic colours) can be described [6].¹

Table 3 *NCS colours that meet the specifications for ordinary colours*

NCS-Code	Name	Equivalent RAL
S 1085-Y80R	Red	--- ²
S 2070-G10Y	Green	---
S 1080-Y	Yellow	RAL 1023
S 0585-Y40R	Orange	RAL 2008
S 4050-R90B	Blue	RAL 5019
S 0500-N	White	RAL 9016
S 9000-N	Black	RAL 9017

¹ The recommended colours for NCS for green and red are not equivalent to the recommended RAL Colours

² The recommended colours for NCS for green and red are not equivalent to the recommended RAL Colours



8 DEFINITIONS

The definitions of terms used in this IALA guideline can be found in the International Dictionary of Marine Aids to Navigation (IALA Dictionary) at <http://www.iala-aism.org/wiki/dictionary> and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

9 ACRONYMS

CCD	Charge Coupled Device
CIE	Commission Internationale de l'Eclairage (International Commission on Illumination)
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities - AISM
NCS	Natural Colour System (Sweden)
nm	nanometre
RAL	RAL colour system (Reichs-Ausschuß für Lieferbedingungen und Gütesicherung)
UV	Ultra Violet (light) (10 – 380 nm)

10 REFERENCES

- [1] CIE 1931 Standard Colorimetric System has become a Joint ISO/CIE Standard On Colorimetry: ISO 11664-1 / CIE S014 (series of standards).
- [2] CIE No. 39.2, Recommendations for Surface Colours for Visual Signalling (2nd ed.), 1983.
- [3] CIE No. 15, Technical Report: Colorimetry, 2004.
- [4] IALA Recommendation R0106(E-106) (June 2017) - The Use of Retroreflecting Material on Aids to Navigation Marks within the IALA Maritime Buoyage System.
- [5] RAL-Colour Collections: www.ral-farben.de, RAL Gemeinnützige GmbH, St. Augustin, Germany.
- [6] NCS Natural Colour System: www.ncscolour.com, NCS Colour AB, Stockholm, Sweden.
- [7] NCS Translation Key NCS RAL, July 2007 (with English, French, Swedish and German translation).