

IALA Recommendation E-108

On

The Surface Colours used as Visual Signals on Aids to Navigation

Edition 2

December 2009

Edition 1 / May 1998



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Document Revisions

Revisions to the IALA Document are to be noted in the table prior to the issue of a revised document.

Date	Page / Section Revised	Requirement for Revision
December 2005	Entire document	Reformatted to reflect IALA documentation hierarchy
December 2009	Section 2 New Section 10	Additional information about the influence on measurement. Introduction of colour collections.

IALA Recommendation on Surface colours used as visual signals on aids to navigation (Recommendation E-108)

THE COUNCIL:

RECALLING the function of IALA with respect to Safety of Navigation, the efficiency of maritime transport and the protection of the environment;

RECOGNISING the work of International Commission on Illumination (CIE) with respect to surface colour for visual signalling;

RECOGNISING ALSO the need to harmonise the surface colours used as visual signals on aids to navigation;

RECOGNISING FURTHER that there is a need to specify both ordinary and fluorescent colours:

CONSIDERING that the proposals of the IALA Engineering, Environmental and Preservation of Historic Lighthouses Committee;

ADOPTS the Guidelines on the surface colours used as visual signals on aids to navigation, set out in the Annex of this Recommendation; and,

RECOMMENDS that National Members and other appropriate Authorities providing marine aids to navigation services take into consideration the Annex to this Recommendation when identifying colours for use as visual signals on aids to navigation and that:

1. The ordinary colours used as visual signals on aids to navigation be Red, Yellow, Green, Blue, White and Black, and Orange for special purposes requiring high conspicuity; and that their colour limits (extent of chromaticity and luminance factor) be as specified in Table 1 of the Annex;
2. The fluorescent colours used as signals on aids to navigation be Red, Yellow and Green, and Orange for special purposes requiring high conspicuity; and that their colour limits be as specified in Table 3 of the Annex;
3. Any other surface colour that may be used be defined in accordance with the Recommendations of the International Commission on Illumination (CIE)¹ and in conformity, as far as practicable, with the colour limits of Table 1 of the Guidelines on the surface colours used as visual signals on aids to navigation; and
4. Any additional colours be defined in accordance with the recommendations of the CIE and be considered with extreme caution in regard to the confusions that might arise.

Revokes IALA Recommendation for the surface colours used as visual signals on aids to navigation dated May, 1998.

¹ CIE Surface colours for visual signalling

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Annex

Surface Colours Used As Visual Signals On Aids To Navigation

1 GENERAL

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. The chromaticity is defined by chromaticity coordinates, which may be plotted on a chromaticity diagram, 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 have 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 recommendations 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.

The recommended ordinary and fluorescent colours are specified in Tables 1 and 3, respectively. These tables provide the names of the colours, the equations and names of the boundary lines of the chromaticity regions, and the limits of the luminance factors. The co-ordinates of the corners of the chromaticity regions are given, in Tables 2 and 4, respectively. The chromaticity regions are shown on CIE standard chromaticity diagrams in Figures 1 and 2.

The luminance factor β and the chromaticity coordinates 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 D_{65} , 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 D_{65} (the illuminant point) is shown in the Figure 1 and Figure 2.

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 15 (point 5.1.2) 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 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 as aids to navigation 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 Aids to Navigation.

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.

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 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 aids to navigation, 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 character, 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 water colour 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 E-106 for the use of retro-reflecting material on aids to navigation marks within the IALA Maritime Buoyage System refers.

7 CHROMATICITY REGIONS

Recommended regions for the ordinary colours specified in Table 1, the co-ordinates of the corner points being provided in Table 2.

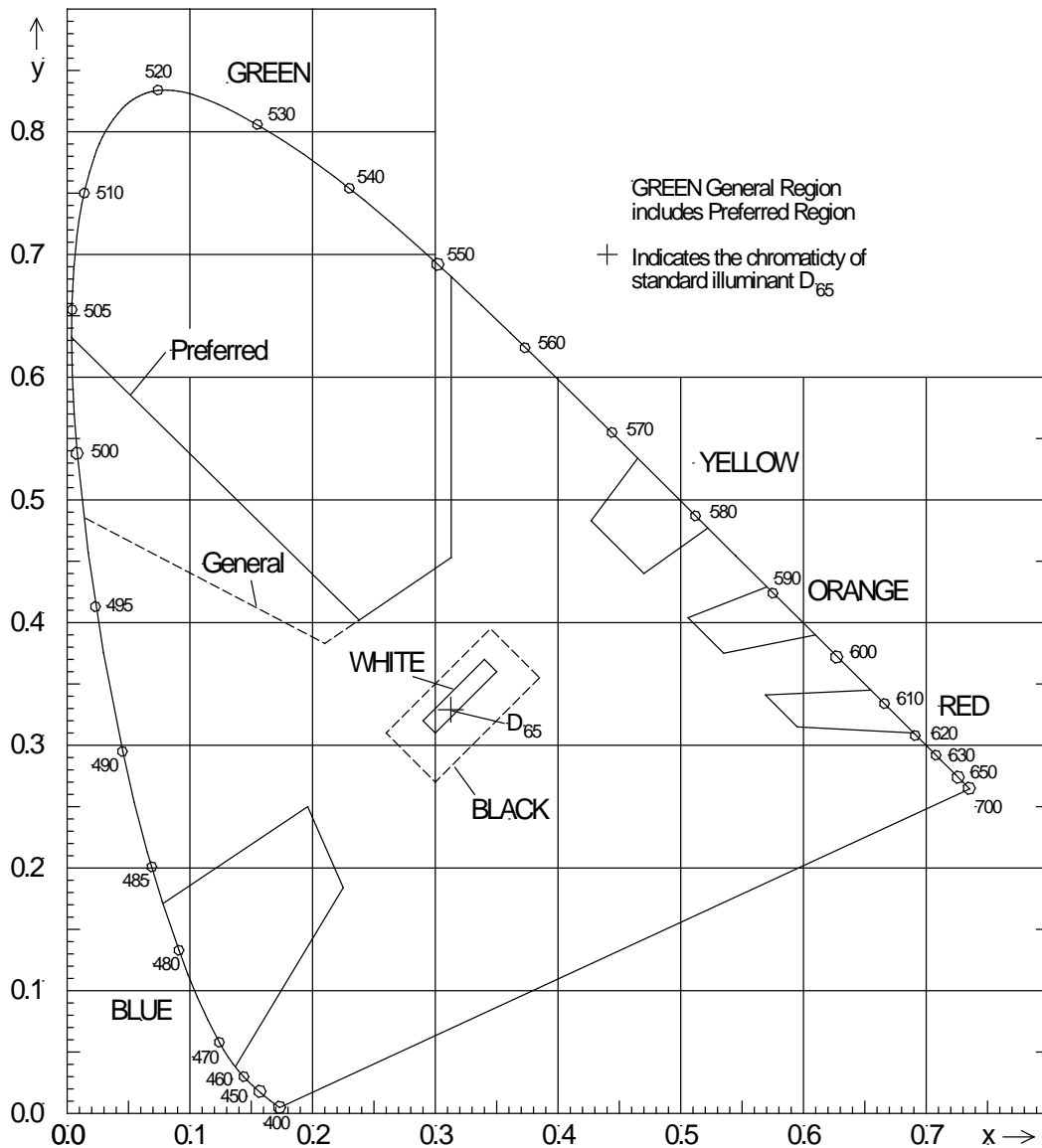


Figure 1 Chromaticity regions for ordinary colours

Recommended limits of ordinary Colours in terms of CIE Recommendations No. 39-2, 1983 for surface colours for visual signalling, including IALA preferred Regions where applicable.

Table 1 Specification of ordinary colours

Colour	Boundary	Equation of the boundary limits	Luminance factor	
			Minimum	Maximum
Red	Purple White Orange	$y = 0.345 - 0.051 x$ $y = 0.910 - x$ $y = 0.314 + 0.047 x$	0.07	-
Orange	Red White Yellow	$y = 0.265 + 0.205 x$ $y = 0.910 - x$ $y = 0.207 + 0.390 x$	0.20	-
Yellow	Orange White Green	$y = 0.108 + 0.707 x$ $y = 0.910 - x$ $y = 1.35 x - 0.093$	0.50	-
Green	Yellow White Blue (Preferred) Blue (General)	$y = 0.313$ $y = 0.243 + 0.670 x$ $y = 0.636 - 0.982 x$ $y = 0.493 - 0.524 x$	0.10	-
Blue	Green White Purple	$y = 0.118 + 0.675 x$ $y = 0.700 - 2.30 x$ $y = 1.65 x - 0.187$	0.07	-
White	Purple Blue Green Yellow	$y = 0.010 + x$ $y = 0.610 - x$ $y = 0.030 + x$ $y = 0.710 - x$	0.75	-
Black	Purple Blue Green Yellow	$y = x - 0.030$ $y = 0.570 - x$ $y = 0.050 + x$ $y = 0.740 - x$	-	0.03

(*x*, *y*) chromaticity coordinates of the corners of the recommended regions for ordinary colours specified in Table 1.

Table 2 Corners of the chromaticity regions of ordinary colours

Colour	1		2		3		4	
	x	y	x	y	x	y	x	y
Red	0.690	0.310	0.595	0.315	0.569	0.341	0.655	0.345
Orange	0.610	0.390	0.535	0.375	0.506	0.404	0.570	0.429
Yellow	0.522	0.477	0.470	0.440	0.427	0.483	0.465	0.534
Green (Preferred)	0.313	0.682	0.313	0.453	0.238	0.402	0.004	0.632
Green (General)	0.313	0.682	0.313	0.453	0.210	0.383	0.015	0.485
Blue	0.078	0.171	0.196	0.250	0.225	0.184	0.137	0.038
White	0.350	0.360	0.300	0.310	0.290	0.320	0.340	0.370
Black	0.385	0.355	0.300	0.270	0.260	0.310	0.345	0.395

Recommended regions for the fluorescent colours specified in Table 3, the co-ordinate of the corner points being provided in Table 4.

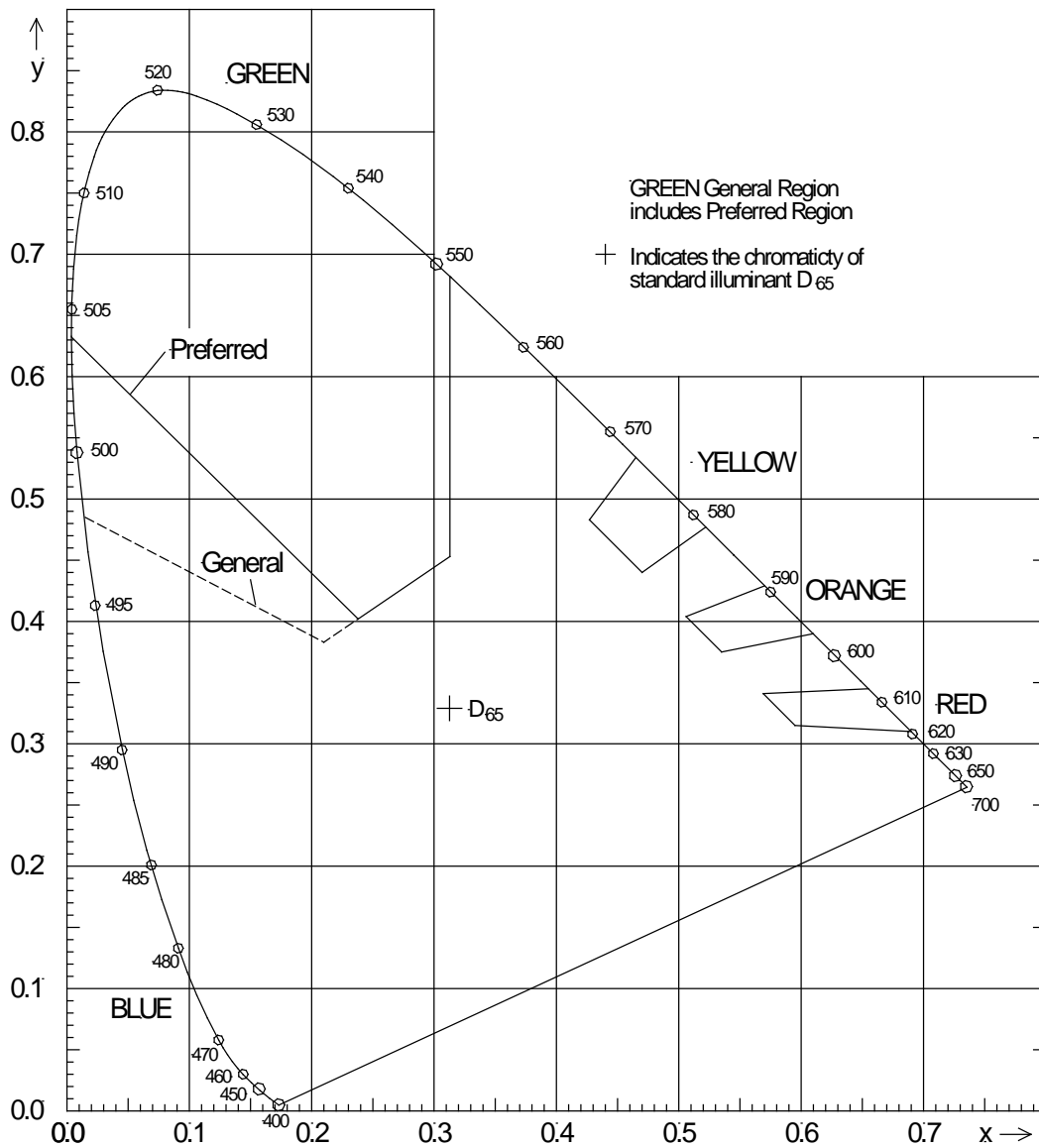


Figure 2 Chromaticity regions for fluorescent colours

Recommended limits of fluorescent colours in terms of CIE Recommendations No. 39-2, 1983 for surface colours for visual signalling, including IALA preferred Regions where applicable.

Table 3 Specification of fluorescent colours

Colour	Boundary	Equation of the boundary limits	Minimum Luminance factor
Red	Purple White Orange	$y = 0.345 - 0.051 x$ $y = 0.910 - x$ $y = 0.314 + 0.047 x$	0.25
Orange	Red White Yellow	$y = 0.265 + 0.205 x$ $y = 0.910 - x$ $y = 0.207 + 0.390 x$	0.40
Yellow	Orange White Green	$y = 0.108 + 0.707 x$ $y = 0.910 - x$ $y = 1.35 x - 0.093$	0.60
Green	Yellow White Blue (Preferred) Blue (General)	$y = 0.313$ $y = 0.243 + 0.670 x$ $y = 0.636 - 0.982 x$ $y = 0.493 - 0.524 x$	0.25

(*x*, *y*) chromaticity coordinates of the corners of the recommended regions for fluorescent colours specified in Table 3.

Table 4 Corners of the chromaticity regions of fluorescent colours

Colour	1		2		3		4	
	x	y	x	y	x	y	x	y
Red	0.690	0.310	0.595	0.315	0.569	0.341	0.655	0.345
Orange	0.610	0.390	0.535	0.375	0.506	0.404	0.570	0.429
Yellow	0.522	0.477	0.470	0.440	0.427	0.483	0.465	0.534
Green (Preferred)	0.313	0.682	0.313	0.453	0.238	0.402	0.004	0.632
Green (General)	0.313	0.682	0.313	0.453	0.210	0.383	0.015	0.485

8 COLOUR COLLECTIONS

This Recommendation uses the CIE 1931 standard colorimetric system 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.

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.

8.1 RAL CLASSIC Colour Collection

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

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

8.1.1 Ordinary Colours

Table 5 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%

It should be noted that RAL 2009 Traffic Orange and RAL 5017 Traffic Blue do not meet the specifications of this recommendation. There are some more RAL-Colours that meet the specifications but are not as saturated as the colours recommended in Table 5.

8.1.2 Fluorescent Colours

Table 6 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 is no RAL number that meet the specifications of this recommendation.

8.2 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.

Table 7 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

9 REFERENCES

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² The recommended colours for NCS for green and red are not equivalent to the recommended RAL Colours. Especially for green a very bright but not saturated colour is chosen.