International Association of Marine Aids to Navigation and Lighthouse Authorities

AISM Association of Internationale de Signalisation Maritime IALA

IALA Recommendation

E-200-1

On

Marine Signal Lights

Part 1 – Colours

Edition 1

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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

Recommendation on Marine Signal Lights, Part 1 – Colours

(Recommendation E-200-1)

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 need to provide guidance within which the colours and colour boundaries of lights on aids to navigation should be determined;

RECOGNISING ALSO that that such guidance should enable a common approach to be made world-wide, thus greatly assisting mariners, who, while passing through waters of different authorities, should not be confused by light colours that are ambiguous;

RECOGNISING FURTHER that this document supersedes the IALA “Recommendations for the Colours of Light Signals on Aids-to-Navigation” dated December 1977;

NOTING this document applies only to marine Aid-to-Navigation lights installed after its published date;

NOTING ALSO that from three years after the date of publication of this Recommendation, all lanterns placed in service should have colour coordinates in either the IALA Optimum or IALA Temporary regions but that to avoid colour confusion, the IALA Optimum region is preferred;

NOTING FURTHER that from ten years after the date of publication of this Recommendation, all lanterns placed in service should have colour coordinates in the IALA Optimum region;

ADOPTS the Recommendation on Marine Signal Lights in the annex of this recommendation; and,

RECOMMENDS that National Members and other appropriate Authorities providing marine aids to navigation services adopt the system for coloured light signals set out in the Annexes to this Recommendation.

* * *

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ANNEX I INTRODUCTION

1.1 Scope / Purpose

This document describes the IALA recommended chromaticity regions for marine signal lights and gives background information on how and why the chromaticity regions have been adjusted compared to previous IALA recommendations. This document supersedes the IALA “Recommendations for the Colours of Light Signals on Aids-to-Navigation” dated December 1977.

1.2 History

In 1968, IALA recommended a three-colour signal light system utilising red, green and white. In 1977, after the introduction of the IALA buoyage system, a fourth colour, yellow, was introduced and the original colour boundaries amended to reduce colour confusion. Historically, the colour boundaries associated with marine AtoN signal lights have been tighter than those for road and rail signals because marine AtoN signal lights are usually viewed over greater distances. This has two consequences:

- the light subtends a narrow angle in the observer’s eye (virtually a point source);
- the illuminance from the light at the eye of the observer is very low.

Both factors can lead to an increased risk of colours being confused by the observer and tighter boundaries reduce the risk of colour confusion. Accordingly, the colour regions recommended herein only apply to marine AtoN signal lights. They do not conform to the regional boundaries specified in [2].

1.3 Requirements for an Additional Colour

Due to the proliferation of lights and lighting affecting the marine environment, there is a demand for a fifth colour in the marine AtoN signal light system to increase conspicuity of marine AtoN lights in some areas. The additional colour chosen is blue. Work carried out by Soon and Cole [3] suggests that blue is a suitable signal colour, and indeed may be a more reliable signal colour than yellow in some circumstances. Work done by CIE in the 1990’s [5], leading to the CIE Standard for the Colours of Light Signals, S004/E-2001 [2], also recommends blue as a signal colour. However, S004/E-2001 [2] recommends that a maximum of four colours be used in any one colour system; this document recommends the use of five.

1.4 Colour Model

The colour model used throughout this recommendation is the chromaticity chart used in the CIE 1931 standard colorimetry system and *x, y* chromaticity (see Figure 1).

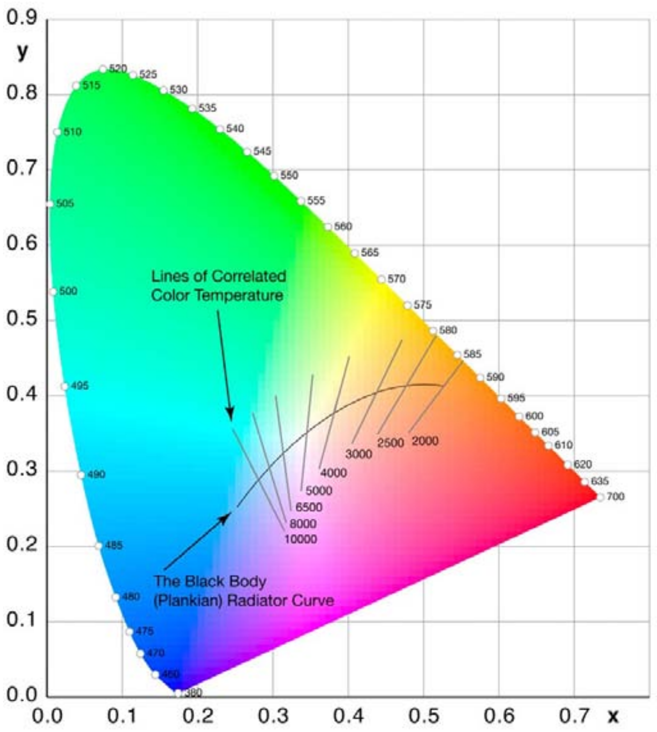

Figure 1 CIE 1931 Chromaticity Chart showing Planckian Locus (not to be used for reference)

2 CHANGES MADE TO CHROMATICITY REGIONS

2.1 Colour Regions

The "general" colour regions recommended in 1977 [1] have been discontinued. The "general" regions were applicable to the part of the population that has good colour vision and accommodated existing, or legacy, lights that included glass filters and gas/oil lights. The narrower "preferred" regions [1] have largely been retained, being applicable to a more composite population, taking into account that a certain percentage of the population has impaired colour vision. These new regions are called "IALA Optimum regions". Users of marine AtoN's are not necessarily subject to compulsory eye testing and may therefore have defective colour vision.

However, there is a need to ensure that light sources currently in use as marine AtoNs are not proscribed by tighter boundaries. Accordingly, some colour regions have been assigned "IALA Temporary" boundaries that will be valid for ten years after the publication of this recommendation. Each IALA Temporary region includes the corresponding IALA Optimum region.

2.2 Changes Made to Colour Boundaries

An important reason for recommending the IALA Optimum regions is that they take into account the problems of people with defective colour vision, who are becoming more numerous at sea with the rapid growth of yachting as a leisure activity.

The boundaries of the IALA 1977 "general" regions have been abandoned and in some cases replaced with IALA Temporary regions. Recommended regions are as follows:

- The red IALA Optimum boundary is different from that of the 1977 "preferred" region [1] in that the region has been extended towards the blue so that region is in agreement with CIE class A[2] and EN 14744[8]. The boundaries towards purple and yellow follow those given in [2]. For protanopes (see ANNEX III) lacking a red-sensitive retinal pigment, long-wavelength reds will not be seen. A red region cut-off at y = 0.29 is for such observers. A red IALA Temporary region (which includes the red IALA Optimum region but is extended) has been provided to include a legacy of red filtered lights.

- The yellow IALA Optimum boundary follows that of the 1977 "preferred" region [1] except that the boundary towards the red has been aligned with the D65 point at 6500°K. Additionally, a yellow IALA Temporary region has been provided. This includes the yellow Optimum region but has an extended area towards red, which should include many yellow light-emitting diode (LED) light sources. The yellow IALA Optimum region is relatively small, close to the spectral locus. Longer wavelengths of yellow, known to improve low luminance recognition, were deliberately excluded from the IALA Optimum region in order to reduce potential confusion with white lights of low colour temperature, e.g. oil and gas, as well as filament lamps run below their design voltage to increase lamp-life. Although many marine signal lights have been updated since 1977, some of these low colour temperature sources are still in operation. Furthermore, the colour of a white light can shift along the Planckian locus, to a lower colour temperature, due to the effects of atmospheric extinction over distance. The proliferation of high-pressure sodium street lighting has also had an impact on the conspicuity of yellow and yellowy-white lights, reducing their usefulness in some areas. With a chromaticity close to the yellow IALA Optimum region, a background of high-pressure sodium lighting can effectively mask a foreground yellow signal. A further reason for the tight boundaries of the IALA Optimum region is to help reduce the likelihood of yellow/green confusion for protanomalous or protanope observers (see ANNEX III).
- The green IALA Optimum boundary follows that of the 1977 "preferred" region [1] except for the boundary towards the yellow, which has been aligned with that given in CIE S004/E-2001 [2] and EN 14744 [8]. "Yellow-greens" have been excluded from the green region in order to reduce the risk of confusion between green and red by protanomalous or protanope observers (see ANNEX III). This also compensates in part for the increase in the size of the red region. A green IALA Temporary region has been provided, which has an extended boundary towards the white, in order to include a legacy of green-filtered incandescent lights sources - and towards the yellow, to 540nm, to include some green high-power LEDs. The CIE green class A region, as laid down in their standard S004/E-2001 [2], shows the boundary extending further towards the blue than the IALA 1977 [1] preferred green region. Although this has been identified as a useful area of signal green, there is the concern of increased confusion with blue and white in a five-colour system (CIE recommends a maximum of four colours in any one system).
- The white IALA Optimum boundary follows that of the 1977 "preferred" region [1] on three of its boundary lines but the boundary towards the yellow has been extended to include incandescent filament lamps at 2856K (x -value of 0.453). The white region extends to beyond 9,500ºK (x-value of 0.285) and includes the majority of devices fitted with white phosphor-conversion LED's (pcLED's). Such devices are widely deployed by AtoN providers and many users prefer their colour, especially when viewed with a dark-adapted eye against a background of "yellowy" artificial lighting. A white IALA Temporary region has been provided that extends the white boundary towards the yellow. The extent of this IALA Temporary boundary towards yellow has an *x* value corresponding to a colour correlated temperature (CCT) of 2,500ºK (x-value of .48) that will include the majority of incandescent filament lamps operated at their designed voltage.
- A blue IALA Optimum region has been added. This region is a truncated version of that recommended in [2] with slight extension towards the green to include 470nm LEDs at high junction temperature. The truncated region is designed to reduce the risk of colour confusion with white and possibly green at low illuminance levels. It will also exclude the chromaticity values of most filtered blue lights (see ANNEX II of this recommendation for further discussion and recommendations on blue lights). CIE Technical Report 107-1994 [5] also recommends a truncated blue region for blue lights intending to be viewed at low illuminance.

3 IALA RECOMMENDED CHROMATICITY REGIONS FOR LIGHTS

3.1 CIE 1931 Colour Chart

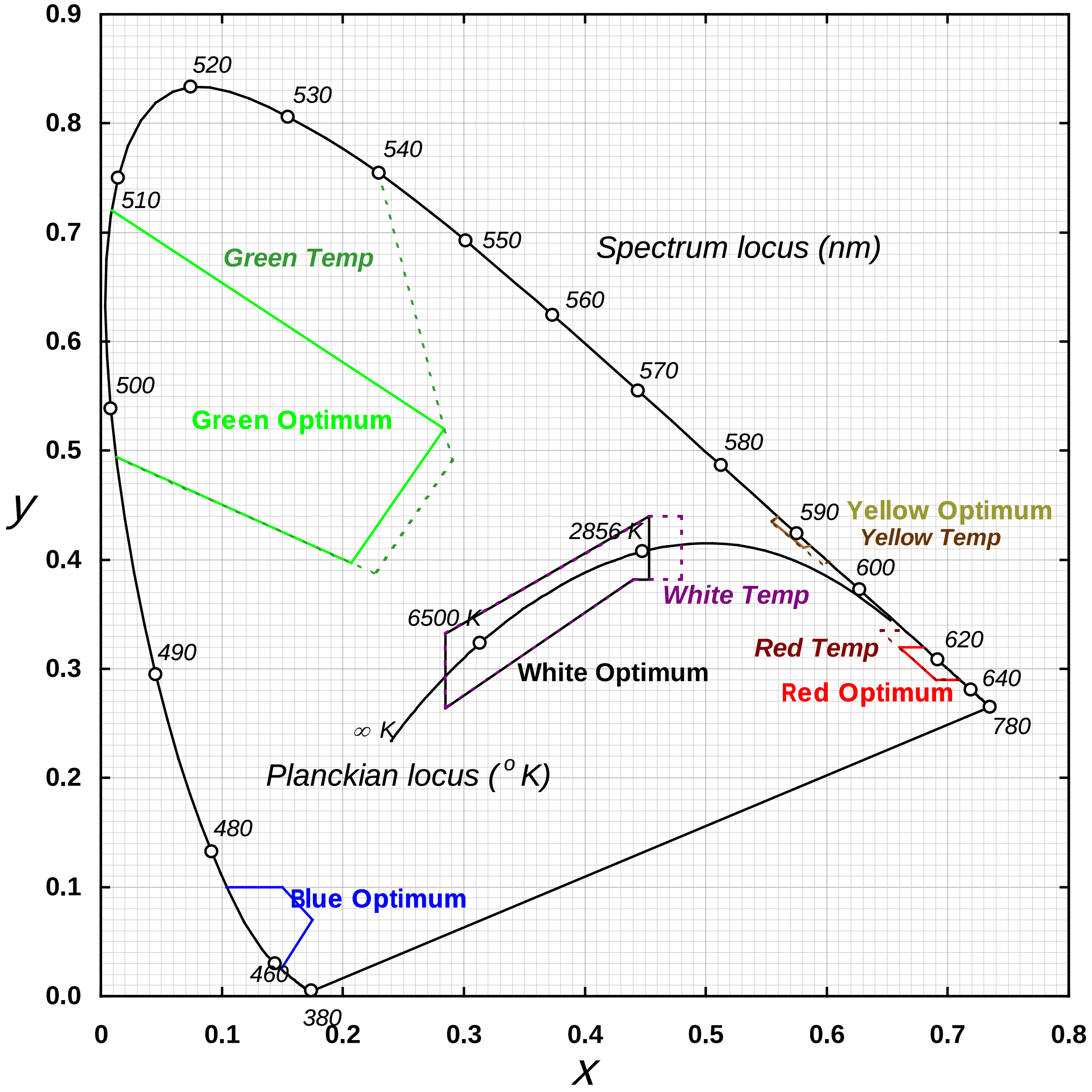

Figure 2 Chromaticity regions of the recommended IALA colours for lights in terms of the CIE 1931 Standard Colorimetric System.

Note. IALA Optimum boundaries in solid lines, IALA Temporary boundaries in dashed lines.

3.2 Chromaticity Corner Coordinates of IALA Optimum Regions

Table 1 Chromaticity Corner Coordinates of IALA Optimum Regions

Colour	1		2		3		4		5	
	x	*y*	*x*	*y*	*x*	*y*	*x*	*y*	*x*	*y*
Red	0.71	0.29	0.69	0.29	0.66	0.32	0.68	0.32		
Yellow	0.5865	0.413	0.581	0.411	0.555	0.435	0.56	0.44		
Green	0.009	0.720	0.284	0.520	0.207	0.397	0.013	0.494		
White	0.44	0.382	0.285	0.264	0.285	0.332	0.453	0.44	0.453	0.382
Blue	0.104	0.1	0.15	0.1	0.175	0.07	0.149	0.025		

3.3 Chromaticity Corner Coordinates of IALA Temporary Regions

Table 2 Chromaticity Corner Coordinates of IALA Temporary Regions

Colour	1		2		3		4		5		6	
	x	*y*	*x*	*y*	*x*	*y*	*x*	*y*	*x*	*y*	*x*	*y*
Red	0.71	0.29	0.69	0.29	0.645	0.335	0.665	0.335				
Yellow	0.602	0.398	0.596	0.396	0.555	0.435	0.56	0.44				
Green	0.2296	0.7543	0.2908	0.4907	0.2260	0.3872	0.0130	0.4940				
White	0.48	0.382	0.44	0.382	0.285	0.264	0.285	0.332	0.453	0.44	0.48	0.44

3.4 Expanded Charts showing Individual Regions

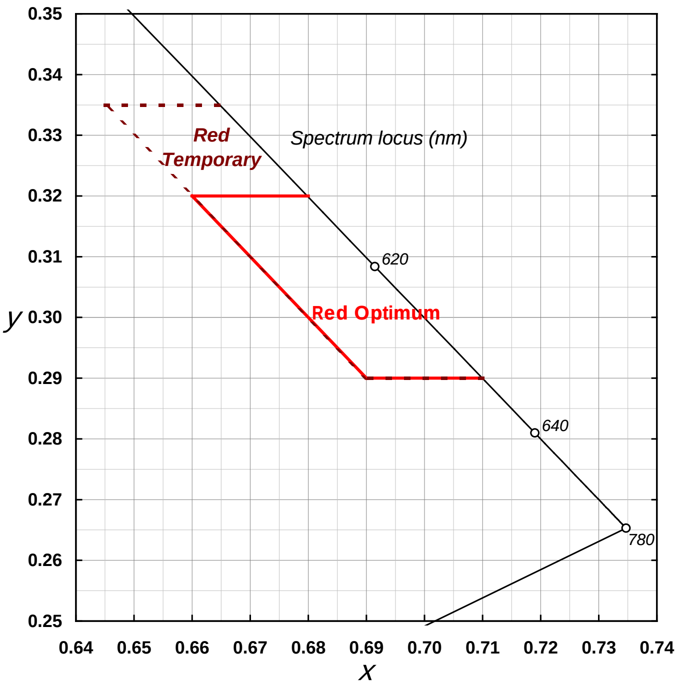

Figure 3 Expanded Chart showing Red Region

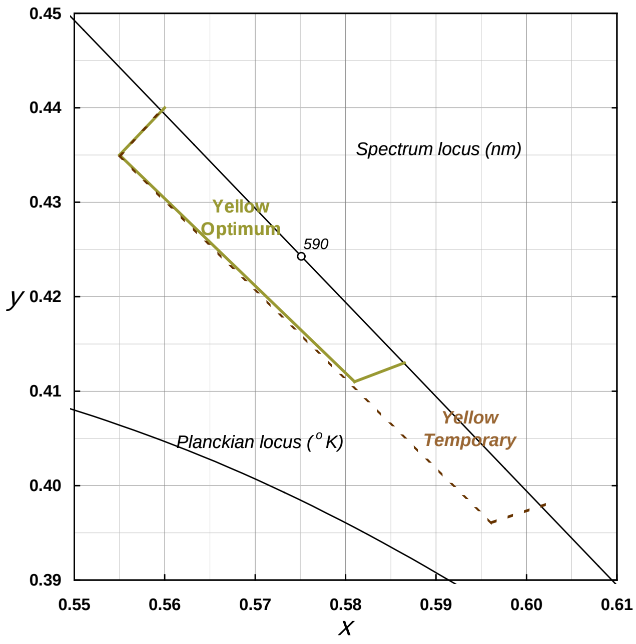

Figure 4 Expanded Chart showing Yellow Region

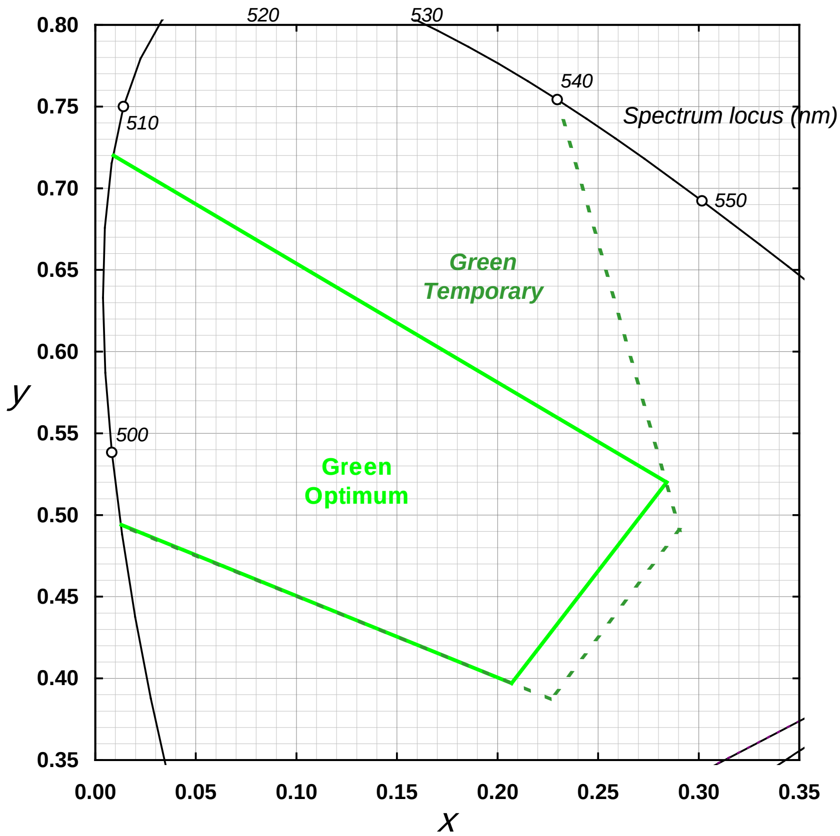

Figure 5 Expanded Chart showing Green Region

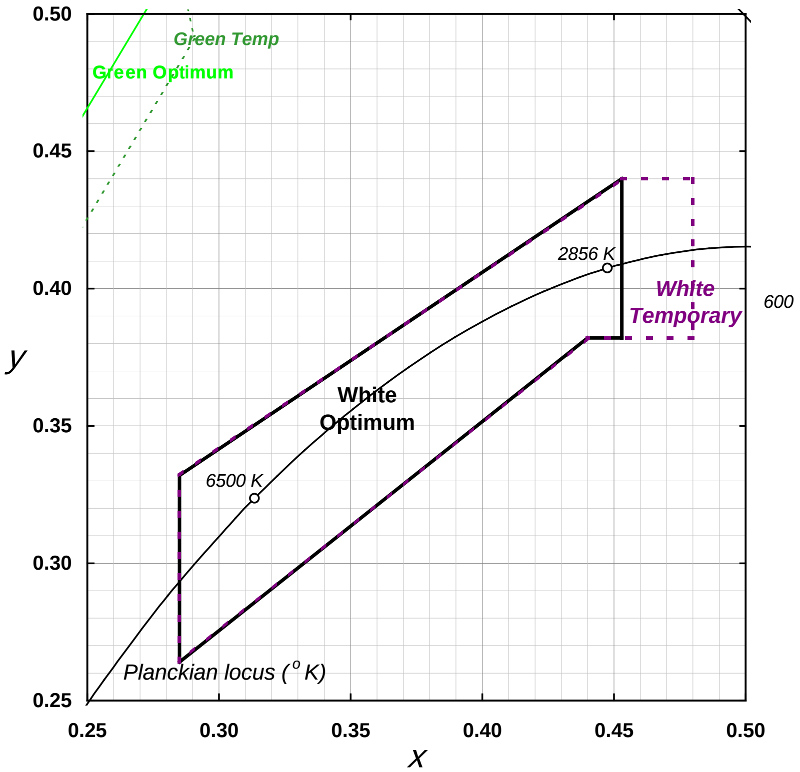

Figure 6 Expanded Chart showing White Region

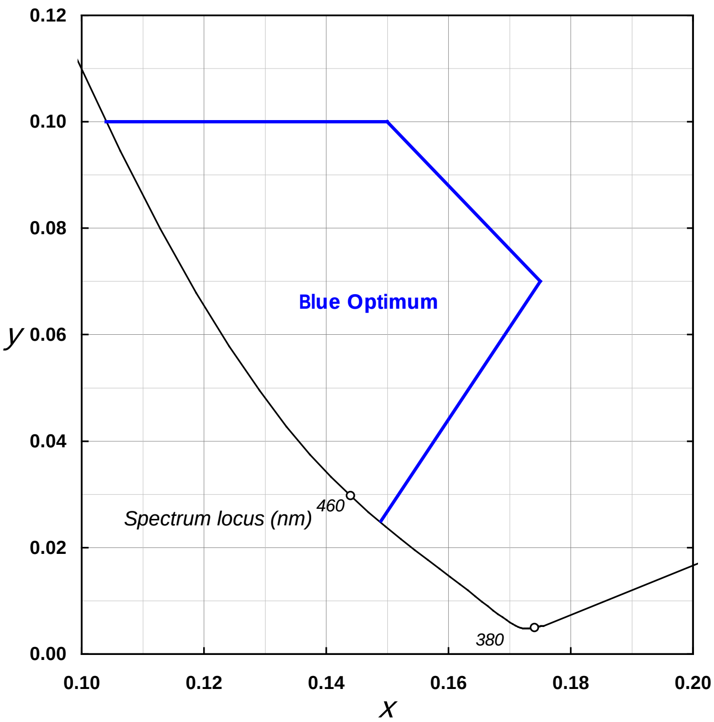

Figure 7 Expanded Chart showing Blue Region

4 MEASUREMENT OF COLOUR OF SIGNAL LIGHTS

4.1 Method used for Colour Measurements

Methods of colour measurement, used to find the *x, y* values of chromaticity, are described in E200-3.

5 CONSIDERATIONS FOR LED TECHNOLOGY

LEDs emit light with a narrow spectral distribution. The junction temperature has a significant effect on the radiant intensity and dominant wavelength of light emitted. A temperature increase causes a decrease in radiant intensity and wavelength. Lower than nominal values of junction current can also affect the spectral distribution of an LED, typically causing an increase in dominant wavelength.

White phosphor-conversion LEDs rely on two components for their broadband spectral distribution, these being an LED chip (usually blue) and a phosphor that converts some of the blue light to yellow light. Thus the light emitted from the device is a mixture of blue and yellow that the eye percieves as white. However, the amount of blue and yellow light may vary independently with angle of emission, thereby causing colour variation over viewing angle.

6 REFERENCES

[1] IALA, December 1977 - “Recommendations for the colours of signal lights on aids-to-navigation”.

[2] Commission Internationale de l’Eclairage (CIE), S004/E-2001 - “Colours of Light Signals”.

[3] Soon & Cole, 1999 - “Critical Test of the CIE Domains for Signal Colours”.

[4] GLA R&D Department, Technical Report No. 31/IT/2004, “Recommendation E-200-1 – Colours Proposed New Colour Boundaries for IALA Light Signals”.

[5] Commission Internationale de l’Eclairage (CIE), Technical Report 107-1994 - “Review of the Official Recommendations of the CIE for the Colours of Signal Lights”.

[6] Commission Internationale de l’Eclairage (CIE), Technical Report 2.2-1975 - “Colours of Light Signals”.

[7] Chapman and Hall, London 1968 - “Light, Colour and Vision”.

[8] European Committee for Standardisation EN 14744, August 2005, “Inland Navigation Vessels and Sea-going Vessels – Navigation Light”.

ANNEX II BLUE LIGHTS

1 LUMINOUS RANGE OF BLUE LIGHTS

When visibility is moderate to good, blue light is preferentially scattered by the atmosphere (due to aerosol scattering). Therefore, the luminous range of a blue light under these conditions will be less than for that of a red light of the same intensity (see IALA E-200/2). Therefore, if a blue light is to be used at ranges of more than five nautical-miles (5M), it is recommended that the published range be reduced by one nautical-mile in order to provide reliable detection over this distance.

1.1 Filtered blue light - Effects of Scattering on Perceived Colour

The use of blue lights consisting of a white light source and a blue filter may cause confusion when viewed at a distance because of the significant red content present in most filtered blue lights (see figure 2.1).

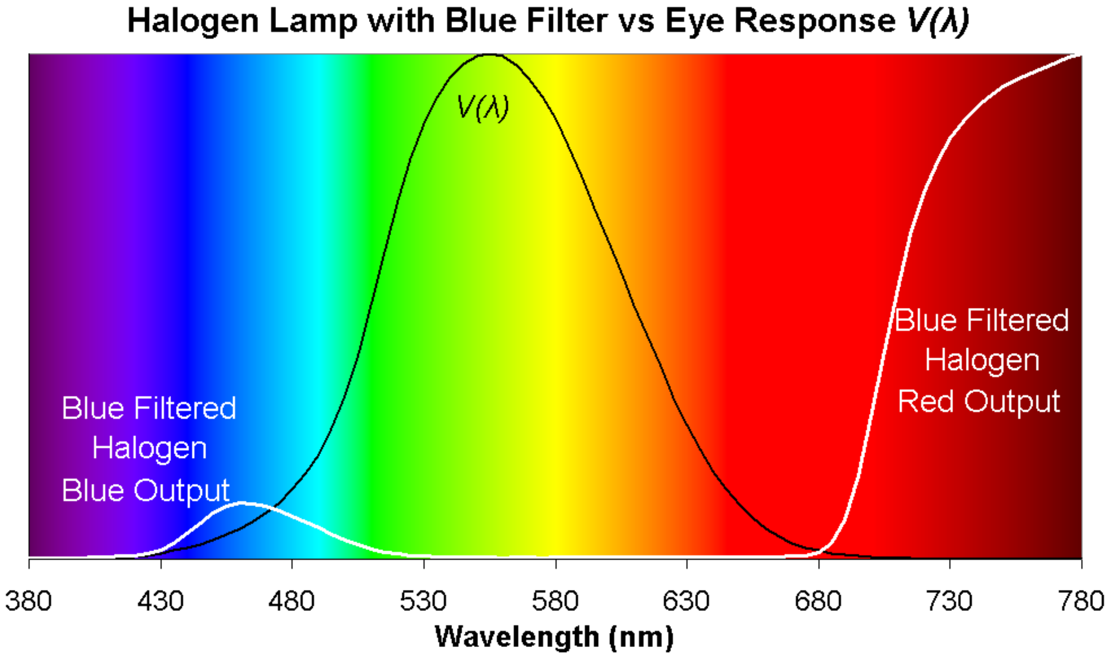

Figure 8 The significant red content of a halogen lamp with a blue filter

Note. The white line shows a spectral plot of the blue-filtered incandescent light.

Over distances of a few miles, the blue content of the light will be scattered more than the red. Therefore, when in close proximity the light will appear blue, but at a distance it will appear as a red or purple light with a blue halo. Thus the effects of scattering can cause a blue filtered white light to appear red at distances of a few miles. This is highly undesirable.

The colour confusion caused by this preferential scattering can be reduced by ensuring that the red content of the blue light is suppressed to less than 1.5% of the total visible light emitted. This can be done by selecting light sources with low emission in the red spectrum or by careful filter selection, including secondary filtering if necessary.

Accordingly, it is recommended that the red emission conforms to the following formula [6]:

$$\frac{\int_{650}^{830} S(\lambda)\cdot\tau(\lambda)\cdot V(\lambda)d\lambda}{\int_{380}^{830} S(\lambda)\cdot\tau(\lambda)\cdot V(\lambda)d\lambda} \leq 0.015$$

where: *S(λ)* is the relative spectral power distribution of the illuminant
τ(λ) is the spectral transmittance of the filter
V(λ) is the photopic luminous efficiency function

1.2 Possible Confusion with Blue Lights in Emergency Services

Most people associate flashing blue lights with emergency service vehicles and vessels. In order to ensure that blue marine AtoN signal lights are not confused with emergency services warning beacons, they should where possible, be exhibited as a continuous light and not flashed. Where flashing blue lights are to be used as marine AtoN's, they should be used only in an emergency and their rhythmic character should be restricted to 'on' periods of one second or greater.

1.3 Advantages of New Light Sources

Light Emitting Diode (LED) technology is emerging as a preferred option for the provision of AtoN signal lights of low to medium intensity. Coloured LED sources have the advantage of a narrow spectral distribution resulting in colour of high purity that does not requiring filtering. Colour confusion is less likely between two lights of high colour purity. Furthermore, although the effects of scattering cannot be ignored, the colour of near-monochromatic light does not change over distance.

1.4 Further Notes on Blue Light

- At low illuminances and small angular subtense, the eye tends towards tritanopic myopia (short-sightedness to blue light) and this causes the light to appear blurred.
- Older observers typically suffer from a yellowing of the cornea so that blue may appear less bright than to a younger observer, it may also be more easily confused with green, white and yellow.
- Peripheral vision is more sensitive to blue light, especially when viewed with a dark-adapted eye. A blue light may therefore be more noticeable than other colours when viewed not directly but a few degrees peripherally.
- The blue region recommended is designed to enhance reliable recognition of blue at low illuminance levels but this may preclude many light sources, including some blue LEDs. A small shift in LED wavelength, for example as a result of junction temperature increase, may be enough to cause the chromaticity of some 470nm blue LEDs to cross the long-wavelength boundary (towards the green). Recommendations given in CIE documents [2][5] suggest restricting the blue region to below a y value of 0.06 ($y < 0.06$). However, it may be difficult to reliably maintain any light source within this small chromaticity triangle.
- The Ishihara plate test, commonly used to test mariners, is not a suitable test for blue colour vision deficiency.

ANNEX III COLOUR DEFICIENT OBSERVERS

1 PERCENTAGES OF COLOUR VISION DEFICIENT OBSERVERS [7]

Table 3 Percentages of Colour Vision Deficient Observers

Type of Deficiency		% males	% females
Overall		~8%	~0.5%
Anomalous trichromasy	Protanomaly	1%	0.01%
	Deutanomaly	5%	0.4%
	Tritanomaly	rare	rare
Dichromasy	Protanopia	1%	0.01%
	Deuteranopia	1.5%	0.01%
	Tritanopia	0.008%	0.008%

2 DESCRIPTION OF DIFFERENT TYPES OF COLOUR VISION DEFICIENCY [7]

Table 4 Description of Different Types of Colour Vision Deficiency

Protan	Protanope	Dichromat	missing longer wavelength (red) cone pigment
	Protanomal	Anomalous Trichomat	anomalous (misaligned) longer wavelength cone pigment
Deutan	Deuteranope	Dichromat	missing middle wavelength (green) cone pigment
	Deuteranomal	Anomalous Trichomat	anomalous (misaligned) middle wavelength cone pigment
Tritan	Tritanope	Dichromat	missing shorter wavelength (blue) cone pigment
	Tritanomal	Anomalous Trichomat	anomalous (misaligned) shorter wavelength cone pigment

3 LINES OF COLOUR CONFUSION FOR COLOUR DEFICIENT OBSERVERS [7]

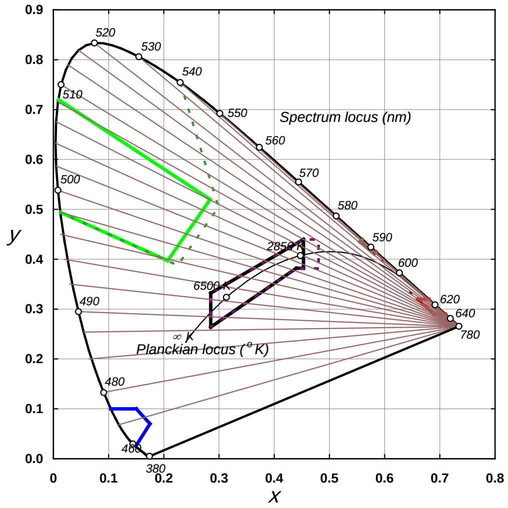

Figure 9 Protanope

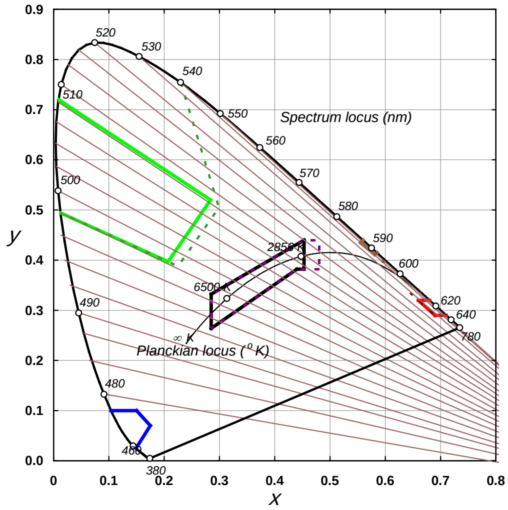

Figure 10 Deuteranope

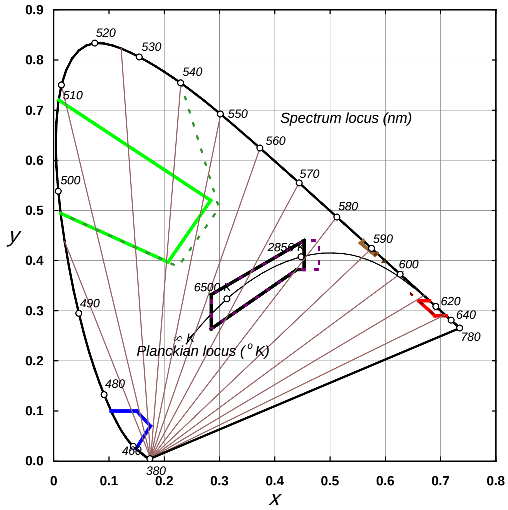

Figure 11 Tritanope