CIE S 004/E-2001

Standard

Colours of Light Signals

Couleurs des signaux lumineux

Farben von Signallichtern

CIE Central Bureau, Vienna
Kegelgasse 27, A-1030 Vienna, Austria

S 004/E

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Copy of CIE Standard for IALA Use

Dear Sir,

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) is a non-governmental, not-for-profit organisation that provides guidance on many marine Aids to Navigation (AtoN) related issues. One area work involves colours of AtoNs and it is in reference to this area that I am contacting you.

IALA supports a number of Committees to create, amend and update various Recommendations, Guidelines and Manuals. The Committees reviewing the documents on colours of AtoNs will be ensuring that they conform to the new CIE standard S004/E-2001 - Colours of Light Signals. To facilitate their work, it is necessary to have a number of copies of the standard available. The number of members on the Committees fluctuate from session to session, but are usually between 10-15 persons.

I am quite conscious of copy-right issues, and am therefore writing to clarify the availability of the standard for our work. I am aware that a Committee member had a copy of the standard with him during the fall sessions, and it was quite helpful in their deliberations. There will be further meetings on the issue of colours and AtoNs, and I would like to ensure the document is available to all members in order to move the work forward as quickly as possible.

To this end, I am writing to:
a) arrange to purchase the standard
b) ask for written permission to make copies of the document for the sole purpose of reviewing and updating IALA documents that refer to colours of AtoNs.

Of course, any and all references to the standard will be available to you either through the IALA web site (http://www.iala-aism.org/mainsite/index.html) or by contacting the IALA offices directly (iala-aism@wanadoo.fr).

I look forward to discussing this matter with you further. Please feel free to contact me by return mail, or via phone as indicated below.

Best Regards,
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****
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From: CIE CB [mailto:ciecb@ping.at]
Sent: 05 November 2002 21:02
To: jillian.carson@wanadoo.fr
Subject: CIE S004/E-2001

Dear Mr. Carson-Jackson,

We would propose that you purchase one copy of the CIE Standard from us for the price of EUR 19,-. If you prefer, this could be sent to you in pdf format instead of the paper copy.

With the purchase we authorize you to make copies for TC members only, for the sole purpose of reviewing IALA documents on AtoNs colour purposes.

We would of course be pleased if IALA would adopt the CIE Standard S004. For standards organisations that wish to adopt CIE standards or republish parts of it, the following rules apply:

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Please keep us informed which of the above procedure you would like to choose.

With best regards,

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FOREWORD

Standards produced by the Commission Internationale de l'Éclairage (CIE) are a concise documentation of data defining aspects of light and lighting, for which international harmony requires such unique definition. CIE Standards are therefore a primary source of internationally accepted and agreed data, which can be taken, essentially unaltered, into universal standard systems.

The CIE undertook a major review of its official recommendations for the colours of light signals in the period 1987 to 1993 and developed this Standard based on that review.

This Standard has been approved by the National Committees of the CIE and supersedes the recommendations made in CIE Publication 2.2 - 1975 *Colours of Light Signals*.

Table of contents

COLOURS OF LIGHT SIGNALS

INTRODUCTION

National and international standards for visual signal systems usually specify requirements for the colours of light signals to ensure that the colours can be correctly identified. The previous official recommendations of the CIE provided sound guidance on the choice of these colours and were utilised in the drafting of most relevant standards.

The CIE first adopted recommendations for light signal colours in 1959. These were based on three experiments carried out in the 1930s and 1940s and on the technical and practical knowledge of the experts serving on the CIE committees that prepared the recommendations. Account was also taken of current practices and standards as well as the practical limitations of coloured signal glasses and signal assemblies and the need to generate signals of sufficient intensity.

Following new experimental work as well as experience in the application of the 1959 recommendations, a revision of the recommendations was published by the CIE in 1975 as CIE Publication 2.2 - 1975 *Colours of Light Signals*.

In 1987 the CIE saw the need for another revision based on further experimental work and changing needs and technology in visual signalling. Committee TC4-14 (Colours of Signal Lights) of CIE Division 4 (Lighting and Signalling for Transport) undertook a detailed analysis of the experiments on the recognition of light signal colours and consulted widely among the international experts on visual signalling.

The Committee reported its findings in CIE Technical Report 107 *A Review of the Official Recommendations of the CIE for the Colours of Signal Lights,* which was published by the CIE in 1994. This Technical Report contains details of relevant experiments, arguments regarding colour discrimination, recommendations and an extensive bibliography.

The recommendations of the committee were adopted by Division 4 of the CIE in 1992 and have guided the preparation of this International Standard.

1. SCOPE

This Standard specifies the allowable colours for steady signal lights and flashing signal lights where the duration of the on period is at least one second.

It is applicable to the colours of signal lights used in sea, road, air and rail transport systems including signal lights on ships, aircraft, motor vehicles and trains, where the recognition of the colours involved is essential.

The Standard can also be used for guidance on the selection of the colours

- of light signals and warning lights on instrument panels in vehicles,
- of light signals and warning lights on instrument panels used for monitoring or control of industrial processes,
- used in visual display terminals when recognition of the colour code is important to interpreting the information displayed.

The Standard does not specify how signal lights should be used in the various transport modes nor does it specify the meanings to be associated with the different colours. Reference must also be made to international, regional and national conventions and regulations for sea, rail, road and air transport[1] which specify how the colours should be used for particular applications.

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[1] For motor vehicle lighting also refer to the applicable regulations annexed to the United Nations agreement, Geneva 1958 and later revisions, concerning the adoption of uniform technical prescriptions for wheeled vehicles; equipment and parts which can be fitted and/or used on wheeled vehicles and the conditions for reciprocal recognition of approvals granted on the basis of these prescriptions. For airport and aircraft signal lights consult also the pertinent International Civil Aviation Org. requirements.

This Standard is not applicable to the colours of surface colour codes. Guidance on the allowable colours for surface colour codes is given in CIE Publication 39.2-1983 *Recommendations for Surface Colours for Visual Signalling*.

2. NORMATIVE REFERENCES

The following standards contain provisions that, through reference in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying most recent editions of the standards indicated below. Members of CIE, the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO) maintain registers of currently valid international standards.

CIE 15.2-1986: *Colorimetry*

CIE 17.4-1987: *International Lighting Vocabulary (ILV)* - equivalent to IEC 50(845)

ISO/CIE 10527-1991: *CIE standard colorimetric observers*

3. DEFINITIONS

For the purpose of this Standard, the following definitions apply:

3.1 CIE 1931 standard colorimetric system (*X Y Z*) (see ILV 845-03-28)

A system for specifying colour by determining the tristimulus values of the spectral power distribution of a coloured light using the set of reference colour stimuli [*X*], [*Y*], [*Z*] and the three CIE colour matching functions $\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$, adopted by the CIE in 1931 (see CIE 15.2-1986), such that:

$$X = \mathrm{k}\int S_{\mathrm{e}\lambda}\bar{x}(\lambda)\mathrm{d}\lambda \qquad Y = \mathrm{k}\int S_{\mathrm{e}\lambda}\bar{y}(\lambda)\mathrm{d}\lambda \qquad Z = \mathrm{k}\int S_{\mathrm{e}\lambda}\bar{z}(\lambda)\mathrm{d}\lambda$$

where:

$S_{\mathrm{e}\lambda}$ the spectral power distribution of a coloured light,

X, Y, Z the tristimulus values,

$\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$ the three CIE colour matching functions adopted by the CIE in 1931,

k a normalizing constant. For self-luminous objects its value is equal to K_m, the maximum spectral luminous efficacy: 683 lm/W.

λ the wavelength

3.2 Chromaticity coordinates (see ILV 845-03-33)

Ratio of each of a set of three tristimulus values to their sum. In the CIE 1931 standard colorimetric system:

$$x = \frac{X}{X+Y+Z} \qquad y = \frac{Y}{X+Y+Z} \qquad z = \frac{Y}{X+Y+Z}$$

where

x, y the chromaticity coordinates of a colour which may be plotted on the 1931 CIE *x, y* chromaticity diagram to graphically represent the chromaticity in question ($x + y + z = 1{,}0$, thus *z* is redundant given *x* and *y*).

3.3 Luminous intensity (of a source in a given direction) (see ILV 845-01-31)

Quotient of the luminous flux ($\mathrm{d}\Phi$) leaving the source, propagated in an element of solid angle ($\mathrm{d}\Omega$) containing the given direction, by the element of solid angle.

$$I = \frac{\mathrm{d}\Phi}{\mathrm{d}\Omega}$$

where:

I the luminous intensity of a source in a given direction, in candelas (cd),

$\mathrm{d}\Phi$ the luminous flux leaving the source in the given direction, in lumens (lm),

$\mathrm{d}\Omega$ the element of solid angle containing the given direction, in steradians (sr).

3.4 Illuminance (at a point on a surface) (see ILV 845-01-38)

Quotient of the luminous flux ($\mathrm{d}\Phi$) incident on an element of the surface containing the point, by the area (dA) of that element, such that

$$E = \frac{\mathrm{d}\Phi}{\mathrm{d}A}$$

where:

E the illuminance at a point on the surface, in lux (lx),

dA the area of the surface element containing the point, in square metres (m^2),

$\mathrm{d}\Phi$ the luminous flux incident on an element of that surface containing the point, in lumens (lm).

3.5 Illuminance in the plane of the observers eye (see ILV -11-27, Allard's law)

In this Standard, illuminance refers to the illuminance in the plane of the observer's eye which is dependent on the intensity (I) of the source (or signal) and the inverse of the square of the distance of the observer from the source, such that

$$E = \frac{I}{d^2} \cdot T^{d/d_0}$$

where:

E the illuminance in the plane of the observer's eye, in lux (lx),
I the intensity of the source in the direction of the observer's eye, in candela (cd),
d the distance of the observer from the source, in metres (m),
d_0 the distance specified in the definition of T
T the atmospheric transmissivity.

or

$$E = \frac{I}{d^2} \cdot 0{,}05^{d/v}$$

where v is the meteorological optical range.

3.6 Meteorological optical range *T* (see ILV 845-11-20)

Length of the path in meter in the atmosphere that is required to attenuate by 95% the luminous flux in a collimated beam from a light source at a colour temperature of 2700 K.

3.7 Atmospheric transmissivity *v* (see ILV 845-11-19)

Regular luminous transmittance of the atmosphere over a specified path d_0

4. REQUIREMENTS

4.1 Allowable light signal colours

The allowable colours for light signals are red, yellow, white, green and blue. No other colours shall be used.

NOTE 1 Purple is not a suitable colour for light signals since it is often confused with red especially since the atmosphere selectively absorbs the blue component of purple. Moreover, the chromatic aberration and/or refractive error of the eye will often cause a purple signal to be seen as a red signal with a blue halo or as a blue signal with a red halo.

NOTE 2 Violet is not a suitable colour for light signals as it is often confused with blue, has a limited visibility range and may be seen as blue with red haloes or red with blue haloes as for purple.

NOTE 3 Orange is not a suitable colour for light signals because it is often confused with red and yellow.

NOTE 4 Signal systems should normally comprise no more than four colours.

4.2 Specified chromaticity areas

The colours of light signals shall have chromaticity coordinates (*x, y*) that lie inside the chromaticity areas defined by the boundaries specified in Table 1 and, where applicable, by the spectral locus and its linear extension across the purple range of colours between the red and blue extremities of the spectral locus.

NOTE 1 For convenience in plotting the chromaticity areas, the intersection points of the chromaticity boundaries, spectral locus and purple line are given in Table 2 and the areas are illustrated in Figures 1 to 5.

NOTE 2 The chromaticity coordinates for plotting the spectral locus in Figures 1 to 5 are given in ISO/CIE 10527-1991.

4.3 Red light signal colours

4.3.1 Class A

Red light signal colours shall lie within the chromaticity area ABCD except as provided in subclauses 4.3.2 and 4.3.3.

4.3.2 Class A1

When the user group includes persons with defective colour vision, the red light signal colour shall lie within the chromaticity area ABC'D'.

4.3.3 Class B

When reliable recognition of red light signal colours is not so important, the red light signal colour can lie within the chromaticity area A'B'C'D'.

NOTE 1 Approximately 8% of men and 0,5% of women have defective colour vision and many of them will have difficulty in recognising light signal colours correctly. One quarter of these people have a protan colour vision defect due to either a lack of the red sensitive cone pigment or to the presence of an abnormal red sensitive cone pigment in the retina of their eyes. Protans have difficulty seeing red lights: their visual range for red lights is reduced to about half that of normal observers. Their difficulty seeing red lights is greatest for deep reds (smaller values of *y*). The boundary C'D' excludes deep reds that will cause protan observers greatest difficulty.

NOTE 2 In the chromaticity area ABB'A', individuals with normal colour vision will make errors on 10% to 20% of occasions under a variety of viewing conditions, so this chromaticity area cannot be relied upon to provide red signals that will be correctly identified. This area should only be used when other cues to the meaning of the signal are available.

4.4 Yellow light signal colours

Yellow light signal colours shall lie within the chromaticity area EFGH.

NOTE 1 When a yellow signal has a high intensity such that at the usual distance of observation the illuminance at the eyes of the observer is greater than 1 000 µlx, the colour of the signal should lie near the boundary EF.

NOTE 2 When a yellow signal has a low intensity such that at the usual distance of observation the illuminance at the eyes of the observer is less than 1 µlx, the colour of the signal should lie near the boundary GH.

4.5 White light signal colours

4.5.1 Class A

White light signal colours shall lie within the chromaticity area IJKL except as provided in subclause 4.5.2.

4.5.2 Class B

White light signal colours can lie within the chromaticity area IJJ'K'KL when:

- yellow signals are not included in the same signal system,
- the signal does not need to be distinguished from extraneous yellowish lights in the background (such as sodium and low colour temperature incandescent lamps used for street lighting),
- the signal is at a distance less than 5 km, and
- the signal will not be subject to substantial attenuation due to atmospheric pollution or poor weather.

NOTE 1 Where possible, white and yellow signals should not be used together in a signal system because there is a high probability of confusing the two colours, especially when the signals are viewed from long distances or are observed under conditions of poor visibility. If white and yellow signals must be used together, then only Class A white shall be used.

NOTE 2 The colour of a white signal shifts toward orange-yellow when viewed from longer distances (> 5 km) as a result of atmospheric attenuation, even in clear air. The shift is much more pronounced when visibility is reduced due to atmospheric pollution or poor weather. White signals that may be observed under conditions of reduced visibility should have a chromaticity located close to the boundary IL before any effect due to atmospheric attenuation.

NOTE 3 Dimming of a white signal by reducing the applied voltage causes its colour to shift toward orange-yellow. The colour of the signal should remain within the area IJKL for class A or IJJ'K'Kl for Class B through the full range of dimming.

NOTE 4 Class A is attainable with incandescent or halogen lamps using a light blue filter.

4.6 Green light signal colours

4.6.1 Class A

Green light signal colours shall lie within the chromaticity area MNOP except as provided in subclause 4.6.2.

4.6.2 Class B

When the user group does not include persons with defective colour vision, the green light signal colour can lie within the chromaticity area M'N'OP.

NOTE 1 The yellow-green colours in the area MNN'M' may be confused with yellow or red by persons with defective colour vision and should not be used when colour vision defectives are in the user group.

NOTE 2 Colour vision defective observers are likely to confuse white and green. They may be assisted by the use of green close to OP and white close to JK. However, despite these measures, many persons with defective colour vision are still likely to make errors when distinguishing green and white.

4.7 Blue light signal colours

4.7.1 Class A

Blue light signal colours shall lie within the chromaticity area QRST except as provided in subclause 4.7.2.

4.7.2 Class B

When reliable recognition of blue light signal colours is not so important, the blue light signal colour can lie within the chromaticity area QR'S'T.

NOTE 1 Blue is not a suitable colour for long distance visual signals because:
the eye is relatively insensitive to blue light,
blue and green are confused by normal observers for signals that have small angular subtense or a low illuminance,
blue is preferentially scattered by the atmosphere.

NOTE 2 When a blue signal has a low intensity so that at the usual distance of observation the illuminance at the eyes of the observer is less than 1 µlx, better recognition will be achieved if the colour of the signal is such that $y \leq 0{,}060$.

5. TEST METHODS

The spectral power distribution of the light emitted by a signal light should be measured using a spectroradiometer and the 1931 CIE chromaticity coordinates (*x, y*) shall be calculated using the methods and tables of $\bar{x}(\lambda), \bar{y}(\lambda)$ and $\bar{z}(\lambda)$ defined in CIE 15.2-1986.

An alternative method may be used provided it has been validated by reference to the spectroradiometric method.

The measurement shall be made for the complete assembled signal light fitted with the lamp specified for use in practice.

The voltage applied to the lamp shall be the specified operating voltage of the signal light. If the operating voltage is known to vary in practice, either because of fluctuations of the electricity supply or because the signal is operated at different voltages depending on ambient conditions, measurements shall be made at the lowest and highest likely operating voltage in addition to measurements made at the specified operating voltage.

The colour of the emitted light shall conform to the requirements of this Standard at each voltage.

6. BIBLIOGRAPHY

CIE **107**-1994: *Review of the Official Recommendations of the CIE for the Colours of Signal Lights.*

7. TABLES

Table 1 - Boundaries of the allowed chromaticity areas for the colours of light signals

Colour	Notation	Equation of boundary
RED LIGHT SIGNAL COLOURS		
Class A		
Yellow boundary	AB	y = 0,320
Purple boundary	AD	y = 0,980 - x
Class A1		
When persons with defective colour vision are included in the user group		
Restricted long wavelength boundary	C'D'	y = 0,290
Class B		
When reliable recognition of red is not so important		
Extended yellow boundary	A'B'	y = 0,335
Restricted long wavelength boundary	C'D'	y = 0,290
Purple boundary	A'D'	y = 0,980 - x
YELLOW LIGHT SIGNAL COLOURS		
Green boundary	EF	y = 0,727x + 0,054
Red boundary	GH	y = 0,387
White boundary	EH	y = 0,980 - x
WHITE LIGHT SIGNAL COLOURS		
Class A		
Blue boundary	IL	x = 0,300
Green boundary	IJ	y = 0,150 + 0,640x
Yellow boundary	JK	x = 0,440
Purple boundary	KL	y = 0,047 + 0,762x
Class B		
When yellow signals are not included in the signal code, there is no risk of confusion with extraneous background lights and there is no likelihood of significant atmospheric attenuation		
Extended Green boundary	JJ'	y = 0,370 + 0,140x
Extended Yellow boundary	J'K'	x = 0,500
Extended Purple boundary	K'K	y = 0,382
GREEN LIGHT SIGNAL COLOURS		
Class A		
Yellow boundary	MN	y = 0,726 - 0,726x
White boundary	NO	x = 0,625y - 0,041
Blue boundary	OP	y = 0,400
Class B		
When persons with defective colour vision are not included in the user group		
Extended yellow boundary	M'N'	x = 0,310
Extended white boundary	N'O	x = 0,625y - 0,041
BLUE LIGHT SIGNAL COLOURS		
Class A		
Green boundary	QR	y = 1,141x - 0,037
White boundary	RS	x = 0,333 - y
Violet boundary	ST	x = 0,134 + 0,590y
Class B		
When reliable recognition of blue is not so important		
Extended green boundary	QR'	y = 1,141x - 0,037
Extended white boundary	R'S'	x = 0,400 - y
Extended violet boundary	S'T	x = 0,134 + 0,590y

Table 2 - Coordinates of intersection points of allowed chromaticity area boundaries

Colour	Chromaticity coordinates				
RED LIGHT SIGNAL COLOURS **Class A**	 *x* *y*	A 0,660 0,320	B 0,680 0,320	C 0,735 0,265	D 0,721 0,259
Class A1 *When persons with defective colour vision are included in the user group*	 *x* *y*	A 0,660 0,320	B 0,680 0,320	C' 0,710 0,290	D' 0,690 0,290
Class B *When reliable recognition of red is not so important*	 *x* *y*	A' 0,645 0,335	B' 0,665 0,335	C' 0,710 0,290	D' 0,690 0,290
YELLOW LIGHT SIGNAL COLOURS	 *x* *y*	E 0,536 0,444	F 0,547 0,452	G 0,613 0,387	H 0,593 0,387
WHITE LIGHT SIGNAL COLOURS **Class A**	 *x* *y*	I 0,300 0,342	J 0,440 0,432	K 0,440 0,382	L 0,300 0,276
Class B *When yellow signals are not included in the signal code, there is no risk of confusion with extraneous background lights and there is no likelihood of significant atmospheric attenuation*	 *x* *y*	I 0,300 0,342	J 0,440 0,432	J' 0,500 0,440	K' 0,500 0,382
	 x *y*	K 0,440 0,382	L 0,300 0,276		
GREEN LIGHT SIGNAL COLOURS **Class A**	 *x* *y*	M 0,009 0,720	N 0,284 0,520	O 0,209 0,400	P 0,028 0,400
Class B *When persons with defective colour vision are not included in the user group*	 *x* *y*	M' 0,310 0,684	N' 0,310 0,562	O 0,209 0,400	P 0,028 0,400
BLUE LIGHT SIGNAL COLOURS **Class A**	 *x* *y*	Q 0,109 0,087	R 0,173 0,160	S 0,208 0,125	T 0,149 0,025
Class B *When reliable recognition of blue is not so important*	 *x* *y*	Q 0,109 0,087	R' 0,204 0,196	S' 0,233 0,167	T 0,149 0,025

8. FIGURES

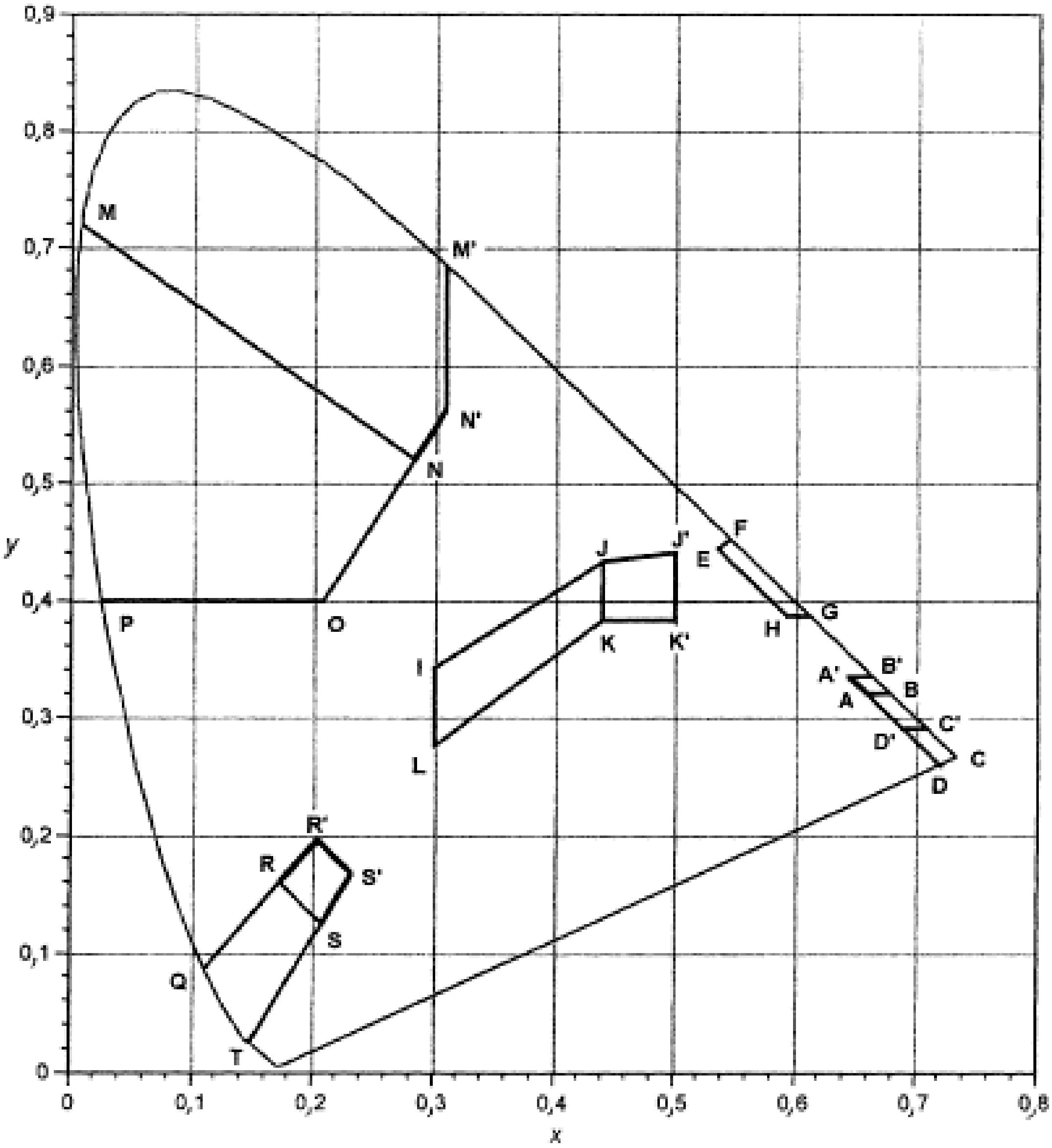

Figure 1 Allowed chromaticity areas for red, yellow, green, blue and white light signal colours plotted on the 1931 CIE chromaticity diagram.

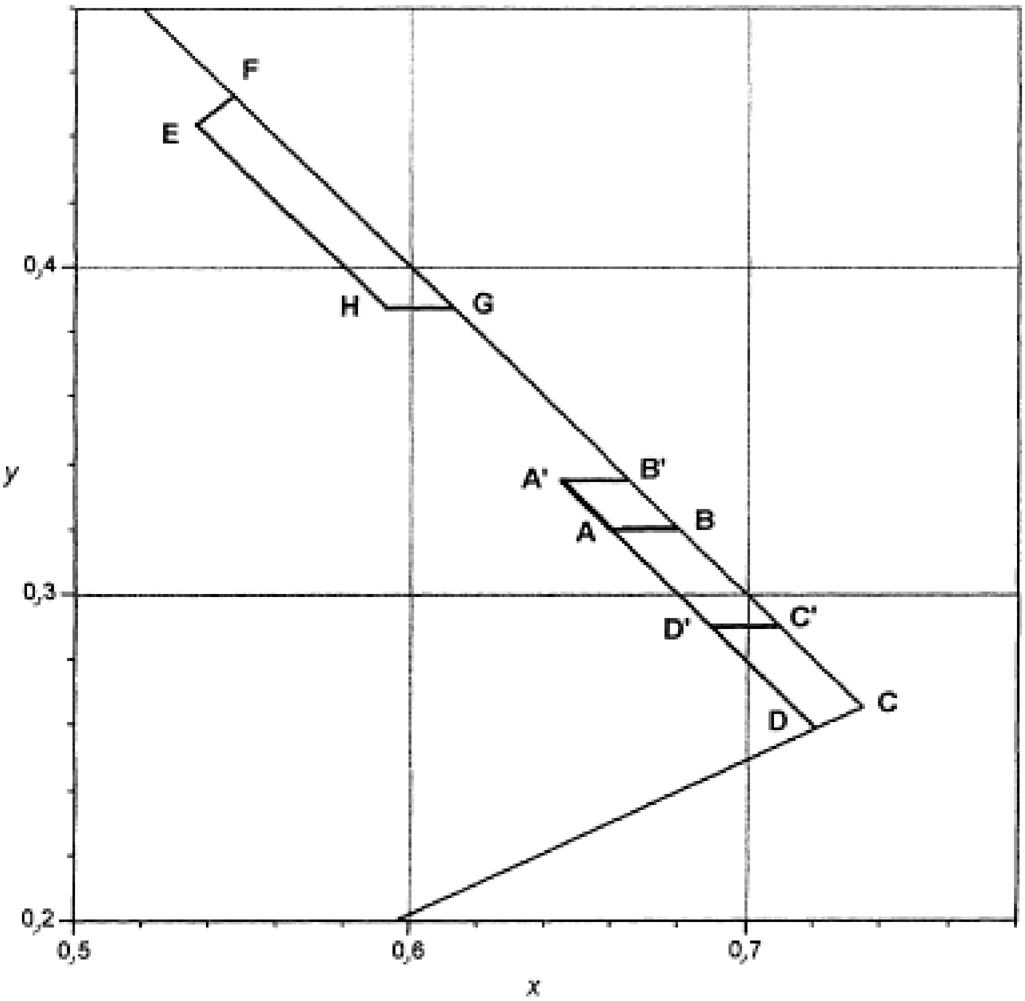

Figure 2 Allowed chromaticity areas for red and yellow light signal colours plotted on the 1931 CIE chromaticity diagram.

RED

Class A	ABCD	Red light signal colours.
Class A1	ABC'D'	Red for use when there are colour defective persons in the user population.
Class B	A'B'C'D'	Red for use only when reliable recognition of red is not so important.

YELLOW EFGH Yellow light signal colours.

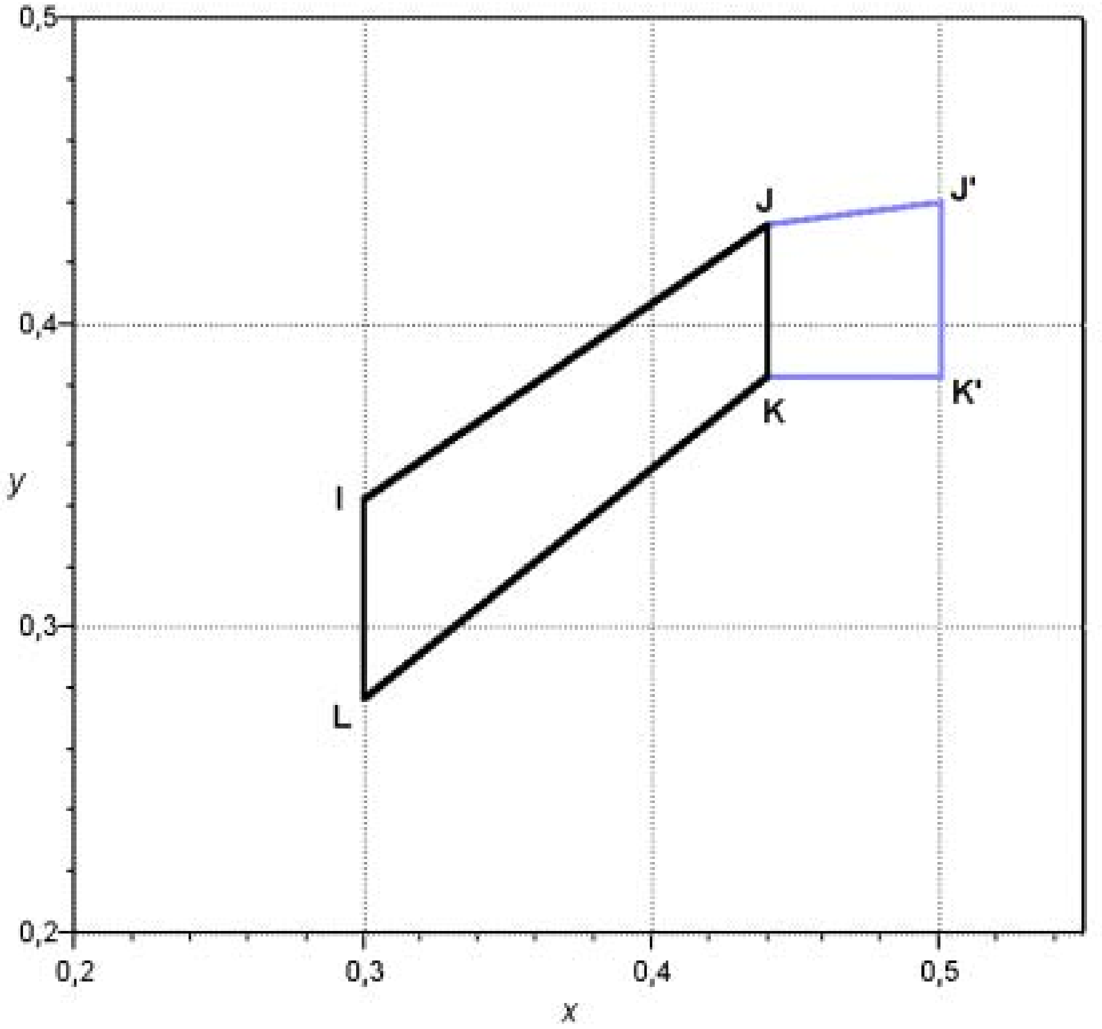

Figure 3 Allowed chromaticity areas for white light signal colours plotted on the 1931 CIE chromaticity diagram.

Class A	IJKL	White light signal colours.
Class B	IJJ'K'KL	When yellow signals are not included in the signal code, there is no risk of confusion with extraneous background lights and there is no likelihood of significant atmospheric attenuation.

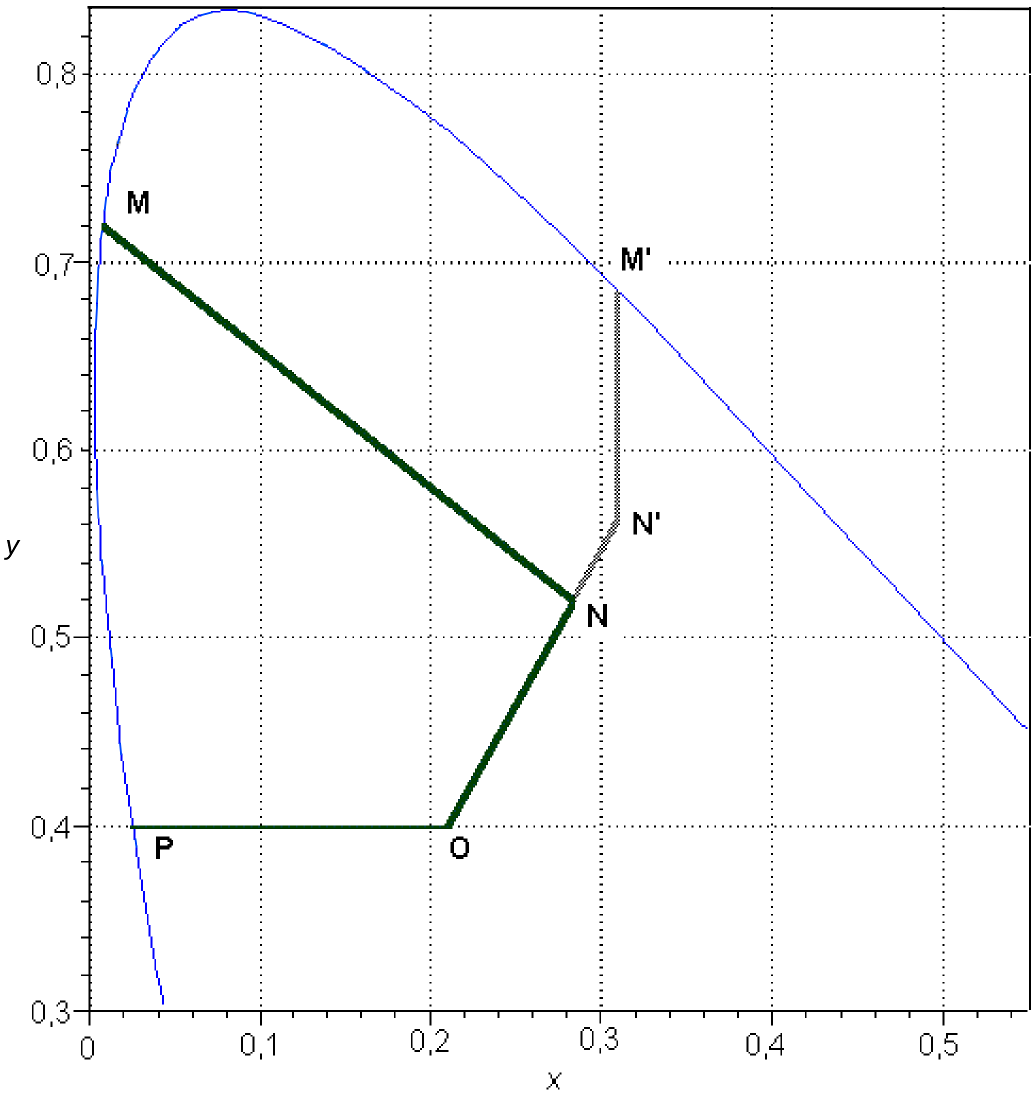

Figure 4 Allowed chromaticity areas for green light signal colours plotted on the 1931 CIE chromaticity diagram.

Class A	MNOP	Green light signal colours.
Class B	M'N'OP	Green for use only when persons with defective colour vision are not included in the user group.

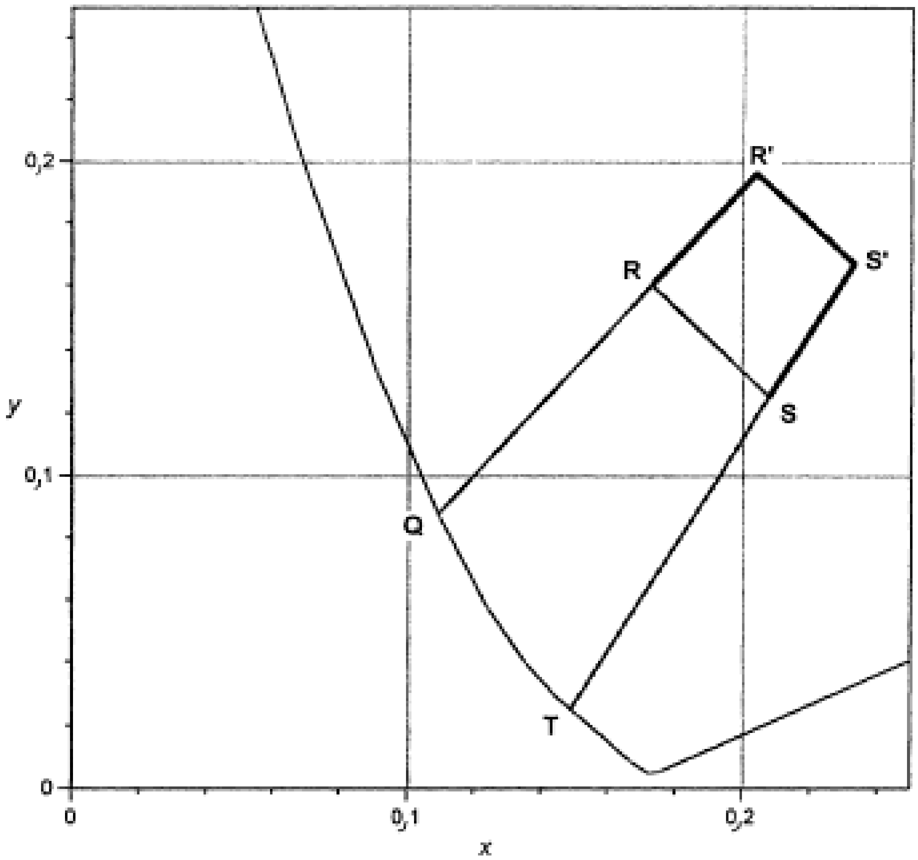

Figure 5 Allowed chromaticity areas for blue light signal colours plotted on the 1931 CIE chromaticity diagram.

Class A	QRST	Blue light signal colours.
Class B	QR'S'T	Blue for use when reliable recognition of blue is not so important.

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