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Specification for

Colours of light signals

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Cooperating organizations

The Illumination Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

Association of Public Lighting Engineers
British Glass Industry Research Association
Building Research Station (Department of the Environment)
Civil Aviation Authority*
Council of British Manufacturers of Petroleum Equipment
Department of Employment (HM Factory Inspectorate)
Department of the Environment*
Department of Trade and Industry*
Electricity Supply Industry in England and Wales
Engineering Equipment Users' Association
Glass Manufacturers' Federation*
Illuminating Engineering Society
Institution of Electrical & Electronics Technician Engineers
Institution of Electrical Engineers
Institution of Municipal Engineers
Lighting Industry Federation*
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Ministry of Defence (Navy Department)
National Physical Laboratory (Department of Trade and Industry)
Royal Institute of British Architects
Society of British Gas Industries
Society of Glass Technology

The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

British Plastics Federation
British Railways Board
Colour Group (Great Britain)
Ministry of Defence Procurement Executive
Transport and Roads Research Laboratory (Department of the Environment)
Trinity House
Vehicle Actuated Road Signal Development Association

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Contents

Foreword

This British Standard has been prepared under the authority of the Illumination Industry Standards Committee.

This revision has been undertaken to lay down performance requirements for plastics filters which are now in common use and to make those alterations that are necessary because of the changing availability of coloured glass.

This standard specifies the colour of light emitted by signalling equipment, though it also defines the colours of filters that may be used with various light sources to achieve these requirements. It also includes guidance on the stability of light sources and filters and photometric test requirements for both complete signals and for filters tested separately.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 36, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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Section 1. General

1 Scope

This British Standard specifies the colours of light signals for all purposes. While it has been based on requirements for transport signalling it is equally applicable to signal colours for other purposes, e.g. indicating lights.

Guidance on means of achieving these colours and of maintaining the performance of signals is also provided.

2 References

The titles of the British Standards referred to in this standard are listed on the inside back cover.

3 Definitions

For the purposes of this British Standard the definitions given in BS 4727-4 apply, together with the following.

3.1
signal

a) A message in coloured light which is conveyed to an observer.

b) A device which emits that light.

NOTE The applicable sense will be immediately apparent from the context in which the term appears.

3.2
chromaticity

throughout this standard, chromaticities are defined in terms of CIE[1] 1931 chromaticity co-ordinates *x*, *y* and *z*. The co-ordinate *x* is analogous to the proportion of red, *y* to the proportion of green and *z* to the proportion of blue

3.3
colour limits

limiting values of some or all of the three chromaticity co-ordinates *x*, *y* and *z*

3.4
filter

a device which modifies by transmission the spatial distribution or the colour, or both, of the light passing through it

3.5
plain filter

a filter of uniform thickness which effects no significant change in the direction of a beam of light normally incident upon it

3.6
colour filter

a selective filter that makes a significant change to the chromaticity of the light passing through it

3.7
lens

a filter, which may be a colour filter, used to modify the divergence of the light rays passing through it from a small source of light

3.8
diffuser

a filter used to increase the spatial distribution of a beam of light and depending essentially on the phenomenon of diffusion

3.9
spreader

a filter which increases the spatial distribution of a luminous flux in one plane only

3.10
chromaticity of a signal

the chromaticity co-ordinates of the light emitted by the signal when operated in the manner intended in service

3.11
chromaticity of a filter

the chromaticity co-ordinates of the light transmitted by the filter when light from a standard light source passes through it in the manner intended in service

NOTE For the purpose of this standard the standard source is the CIE Standard Illuminant A (a tungsten filament lamp operated at a correlated colour temperature of 2856 K).

3.12
transmittancy of a colour filter

ratio of the luminous transmittance of the filter to that of a colourless filter of the same pattern and refractive index

preferred abbreviation: Tcy

3.13
magnesium oxide screen

a silvered plate on which pure magnesium oxide has been freshly deposited to a thickness of at least 1 mm and manifesting no discontinuity when examined with the naked eye, or a screen of compressed magnesium oxide or barium sulphate powder as described in BS 4432-1

NOTE The references in this standard to magnesium oxide screens can be related to other white reference materials which may be employed for the same use. However, where other materials are used, correction factors may be required for some tests.

[1] Commission Internationale de l'Eclairage

4 General introduction

Coloured light signals are means of conveying information or instructions. They are usually generated by a light source together with a plain colour filter, coloured lens or combination of a lens or mirror and a colour filter. Self-coloured lights such as discharge or fluorescent lamps are also used and signals in general may be continuous, intermittent or flashing.

Section 2 specifies the limiting chromaticity requirements of the various colour class ranges of red, yellow, green, blue and white light signals; it relates only to the colour of the light emitted by the signal and is in no way concerned with the method used to obtain this coloured light. Although the colours complying with the requirements of Section 2 are properly defined as signal red, signal green etc., the work "signal" has been omitted for ease of reading in much of the text of this standard.

Section 3 deals with light sources, filters and combinations of these which may be used to produce coloured light to the requirements of Section 2. Some general guidance relating to problems of the stability of the signals and colour filters is contained in Appendix A.

Section 4 deals with photometric procedures by which complete light signals and filters may be tested for compliance with this standard. A means of inspection, which may be convenient when dealing with large numbers of filters, is described in Appendix B.

Appendix D gives information on the requirements and recommendations of a number of international bodies for the colours of light signals.

It is normally sufficient for purchasers of complete light signal equipments to specify the required colour and class, in accordance with Section 2 and the intensity and distribution of the light output required. The inclusion in such specifications of additional requirements for specific light sources and filters may impose unnecessary restrictions on the design and method of manufacture and should be avoided if possible.

The content of Section 3 should not, therefore, normally form a part of the specification of a complete equipment but may be regarded as an indication of what can be achieved with various combinations of filters and light sources and as guidance to designers and manufacturers in meeting a particular requirement. However, Section 3 may be used as a specification for replacement light sources and filters and in those cases where a purchaser has a particular reason for including such detailed requirements in a specification for a complete item of equipment.

Section 2. Colours emitted by light signals

5 General

When coloured lights are fixated and only just visible they appear nearly colourless, with the exception of red. As they get brighter, green lights become recognizable, thus providing the common three colour system of red, green and an intermediate colour which, at still higher luminosities, becomes distinguishable into yellow, white or blue.

These considerations have dictated the choice of colours of signals that are frequently seen near the limits of visibility but in order to preserve the similarity of message that each colour conveys, the use of these colours has naturally spread to signals that are normally only seen at close range.

In multi-coloured signalling systems it is possible to improve the certainty of colour recognition by ensuring that any pair of colours which must be distinguished are as far apart as possible in chromaticity, consistent with their having adequate intensity. For this reason, this standard subdivides each of the main signal colours so that appropriate colour areas can be chosen where high differentiation is required.

The use of blue as a light signal colour must be treated with some caution. Confusion of blue with other colours may occur unless the illuminance produced by the light at the eye of the observer (the point brilliance) is substantially above threshold. Since the luminous efficacy of radiation in the blue region of the spectrum is low, it is difficult to ensure adequate illuminance except at short ranges. Furthermore, colour recognition is uncertain if the angular subtense of the light at the observer is too small, say less than about 10 minutes of arc. It should also be noted that, owing to a yellowing of the lens of the eye with age, older observers may have elevated thresholds for detection and recognition of blue light.

6 Ranges of colours

In this standard, a colour of class A has the widest range of chromaticities and embraces the more restricted ranges designated classes B and C. Where two coloured lights need to be distinguished with extra reliability by observers with normal colour vision they should be chosen from their respective restricted ranges so that they are separated as much as possible in the CIE chromaticity co-ordinate diagram (see Figure 1). For example, class C white and red lights are distinguished from a yellow light with more reliability than are the class B whites and reds which, in turn, are more readily distinguished from yellow than the whites and reds permitted by class A.

7 Limits of chromaticity of light signals

The colour of the light emitted by a signal, when tested in accordance with the requirements specified in Section 4, shall lie within the boundaries for the specified colour on the CIE (1931) chromaticity co-ordinate diagram (see Figure 1) defined by the equations in Table 1, together with the spectrum locus (except for white) and the purple boundary (for red classes A and C only).

The definitive requirements of this standard are in terms of the equations in Table 1 but the chromaticity diagrams of Figure 1, Figure 2 and Figure 3 have been included as illustrations of the various colour boundaries. Figure 1 is a plot of the chromaticity diagram showing all boundaries and Figure 2 and Figure 3 show in greater detail the boundaries for red and yellow respectively.

When it is required to plot the areas of acceptable chromaticity regions on a diagram, it is often easier and quicker to do this by joining points corresponding to the intersections of the boundaries than by drawing the boundaries from their specifying equations. The co-ordinates of these points are, therefore, given approximately in Table 1A.

8 Choice of restricted colour limits

In choosing the restricted class of coloured lights to be adopted in a multi-coloured signalling system, consideration should be given to the risks of confusion between the various pairs of colours, so that if there is a conflict between several needs that which is most serious can be given priority. Also, in certain circumstances it may be necessary to consider the needs of observers with abnormal colour vision.

In the majority of cases where the ability to interpret a light signal is important, the individuals concerned will have been selected so as to eliminate those with defective colour vision. Where no such selection is possible, as in the case of road traffic lights, the more prevalent classes of persons with abnormal colour vision i.e. those who confuse reds and greens, can be helped by a particular choice of these two signal colours. This choice would avoid yellow-greens and would select blue-greens rather than mid-greens and would also select reds with a substantial yellow component rather than darker reds. Thus, the use of a class B red together with a class C green would provide many such persons with a certain amount of colour distinction between these two signals, where they would otherwise have to rely for identification solely on the position of the light within the signal head.

For some purposes, the $y = 0.3$ dark limit of class B red may be irrelevant and the appropriate range of chromaticities may be specified as B + C.

Table 2 gives typical applications of colour classes of light signals to the various branches of transport.

9 Colour stability

Having decided upon the chromaticity limits for a particular light signal application, it is a normal requirement that the colour should remain within these limits throughout the working life of the signal and in all its anticipated conditions of usage. The colour of the light emitted depends upon the chromatic qualities of the light source or of the colour filter/light source combination and these qualities are in turn dependent upon a large number of factors which are fully discussed in Section 3 and Appendix A. It is important that these factors be fully appreciated by anyone designing or specifying a requirement for a light signal as they may impose limitations on what can actually be achieved in practice. A particular problem arises in connection with the dimming of signals, in which the colour temperature of the light source is lowered when the light output of the lamps is deliberately reduced (see clause **19**).

10 Effects of the atmosphere

When a signal is required for use at long distances in a wide variety of conditions, consideration should be given to the effect that the passage of light through the atmosphere may have on its apparent colour.

In clear atmospheres the only problem is faintness of the signal when seen at a great distance and this usually has the effect of making the colour difficult to recognize with precision. In some types of mist, haze or smoke the bluer fractions of the light emitted by the signal are scattered and lost to a greater extent than the red fractions so that a yellow will appear more orange and a green more yellow: this effect may be more pronounced for some types of discharge lamp than for continuous-spectrum signals. In tunnels containing diesel exhaust, there is a general darkening but no significant colour change.

In no case, however, is there a risk of a red (stop) or a yellow (caution) signal being incorrectly read as green (proceed) as the changes in appearance that occur all operate in the direction of greater safety.

11 Effect of temperature of operation

For signals which may be required to operate over a wide temperature range, it is important to recognize that when the temperature of a filter is raised or lowered its transmittancy and colour will vary. These changes can be quite large and are particularly significant for red and yellow signals, where the chromaticity may change with temperature to such an extent as to move the colour of the light emitted from one colour class into another. Reference should be made to **A.3** and **A.4** for guidance on this point.

Section 3. The production of coloured light

12 General

Section 2 specifies the chromaticity of light signals for various purposes but is not concerned with how the coloured light is obtained. This section of the standard deals with light sources, filters and combinations of these which may be used to produce this coloured light. The requirements for colour filters are equally applicable to coloured lenses.

13 Self-coloured light sources

A limited range of coloured lights which come within the compass of this standard can be produced directly from discharge tubes with suitable gases or vapours or from fluorescent lamps according to the combination of phosphors in these lamps. Other self-coloured light sources include incandescent lamps of which the chromaticity is controlled by their operating temperature. The approximate characteristics of the self-coloured light sources in most general use are given in Table 3.

While self-coloured light sources have advantages, their size, shape, occasional low light output and the requirement for control gear to operate discharge tubes and fluorescent lamps prevent them from being widely used as light signals.

13.1 Light emitting diodes. For the small indicator light type of signal increasing use is being made of the light emitting diode (LED), the most commonly used varieties of which radiate in the region of 650 nm (corresponding to class C red). Yellow LEDs at about 590 nm (corresponding to class A or B yellow) and yellow-green LEDs at about 560 nm (outside the boundaries of any of the greens covered by this standard) are also available but with lower intensities than red LEDs. However, considerable development work is in progress on these devices and it may be anticipated that other colours falling within the requirements of this standard will eventually become available.

Table 1 — Limits for signal colours. Boundary equations in terms of CIE (1931) chromaticity co-ordinates

Colour name	Colour class	Boundary towards blue	Boundary towards green	Boundary towards yellow	Boundary towards red	Boundary[a] towards purple	Boundary towards white
Signal red	A	—	—	$y = 0.335$	—	$y = 0.980 - x$	—
	B	—	—	$y = 0.320$	$y = 0.300$	$y = 0.990 - x$	—
	C	—	—	$y = 0.300$	—	$y = 0.995 - x$	—
Signal yellow	A	—	$y = x - 0.120$	—	$y = 0.382$	—	$y = 0.790 - 0.667x$
	B	—	$y = x - 0.120$	—	$y = x - 0.170$	—	$y = 0.790 - 0.667x$
	C	—	$y = x - 0.160$	—	$y = 0.382$	—	$y = 0.790 - 0.667x$
Signal green	A	$y = 0.390 - 0.171x$	—	$x = 0.390 - 0.171y$	—	—	$x = 0.650y$
	B	$y = 0.390 - 0.080x$	—	$x = 0.520 - 0.500y$	—	—	$x = 0.650y - 0.030$
	C	$y = 0.390 - 0.080x$	—	$y = 0.600 - 0.434x$	—	—	$x = 0.625y - 0.041$
Signal blue	A	—	$y = 0.065 + 0.805x$	—	—	$x = 0.133 + 0.600y$	$y = 0.400 - x$
Signal white[b]	A	$x = 0.285$ —	$y = 0.150 + 0.640x$ —	$y = 0.640 - 0.400x$ $x = 0.540$	$y = 0.390$ —	$y = 0.050 + 0.750x$ —	— —
	B	$x = 0.285$ —	$y = 0.150 + 0.640x$ —	$y = 0.640 - 0.400x$ $x = 0.500$	$y = 0.390$ —	$y = 0.050 + 0.750x$ —	— —
	C	$x = 0.285$	$y = 0.150 + 0.640x$	$x = 0.440$	—	$y = 0.050 + 0.750x$	—

NOTE The term "amber" still appears in parliamentary legislation, legal specifications etc., as a synonym for yellow but such usage is deprecated.

[a] Not to be confused with the "purple boundary" joining the extremes of the spectrum locus which is marked separately on Figure 1.

[b] There is a risk of yellowish whites being confused with a yellow signal. Whites with an x co-ordinate greater than 0.500 cannot be reliably recognized as white and their use is deprecated.

Table 1A — Approximate limits for signal colours in terms of the chromaticity co-ordinates of the intersections of their boundaries

Colour name	Colour class	*x*	*y*	*x*	*y*	*x*	*y*	*x*	*y*	*x*	*y*	*x*	*y*
Signal red	A	0.645	0.335	0.665	0.335	0.735	0.265	0.721	0.259	—		—	
	B	0.670	0.320	0.680	0.320	0.700	0.300	0.690	0.300	—		—	
	C	0.695	0.300	0.700	0.300	0.735	0.265	0.731	0.264	—		—	
Signal yellow	A	0.546	0.426	0.560	0.440	0.617	0.382	0.612	0.382	—		—	
	B	0.546	0.426	0.560	0.440	0.585	0.415	0.576	0.406	—		—	
	C	0.570	0.410	0.580	0.420	0.617	0.382	0.612	0.382	—		—	
Signal green	A	0.266	0.724	0.309	0.475	0.228	0.351	0.028	0.385	—		—	
	B	0.105	0.829	0.281	0.478	0.212	0.373	0.027	0.388	—		—	
	C	0.004	0.598	0.263	0.486	0.193	0.375	0.027	0.388	—		—	
Signal blue	A	0.090	0.137	0.186	0.214	0.233	0.167	0.148	0.025	—		—	
Signal white	A	0.285	0.332	0.471	0.452	0.540	0.424	0.540	0.390	0.453	0.390	0.285	0.264
	B	0.285	0.332	0.471	0.452	0.500	0.440	0.500	0.390	0.453	0.390	0.285	0.264
	C	0.285	0.332	0.440	0.432	0.440	0.380	0.285	0.264	—		—	

Table 2 — Typical applications of colour classes for light signals

Colour	Red	Yellow	Green	Blue	White
Application			**Class**		
Aircraft	A	B	A	A	B
Airfields (general)	A	B	A	A	B
Airfields (high recognition)	C	B	B	A	B
Lighthouses	A	A	A	A	A[a]
Railway signals (day colour lights)	C[b]	B	C	—	C[c]
Railway signals (semaphore)	C	C	C	—	—
Road traffic lights	B	A	C	—	
Ship's lights	B + C	—	B	—	A[a]

[a] The acceptable area for white lights of class A extends appreciably towards the yellow boundary of the CIE chromaticity diagram in order to include the light from oil lamps as these are still used in some signalling systems, and thus also includes light from high pressure sodium sources. The colour of both these lights is, however, undesirably yellow for signalling purposes because there is a risk of its being confused with a true yellow light. Accordingly, it is recommended that wherever possible a white light which is as yellowish as this should be avoided and that a class B white light should be employed instead.

[b] Restricted to y not greater than 0.295 for high intensity red signals.

[c] Restricted to between x = 0.330 and 0.420 and known as "lunar white".

Table 3 — Self-coloured light sources

Source	Approximate chromaticity		Colour class
	x	y	
Neon discharge (hot cathode)	0.67 to 0.68	0.32 to 0.33	Red A
Neon discharge (cold cathode)	0.69	0.31	Red B
Neon discharge (high intensity)	0.70	0.30	Red B
Red fluorescent	0.69	0.31	Red B
Sodium vapour discharge (low pressure)	0.58	0.42	Yellow B
Green fluorescent	0.23 to 0.25	0.61	Green A
Green mercury halide	0.28	0.60	Green A
Blue fluorescent	0.19	0.16	Blue A
Blue mercury halide	0.22	0.18	Blue A (Borderline)
Oil flame	0.53	0.41	White A
Sodium vapour discharge (high pressure)	0.52	0.43	White A
Acetylene flame	0.48	0.41	White B
Xenon discharge (continuous)	0.31 to 0.32	0.30 to 0.33	White C
Xenon discharge (flashing)	0.30 to 0.34	0.30 to 0.35	White C
"Northlight" fluorescent	0.31 to 0.32	0.32 to 0.34	White C
"Daylight" fluorescent	0.36 to 0.38	0.36 to 0.39	White C
White mercury halide	0.32 to 0.43	0.35 to 0.40	White C
Tungsten filament:[a]			
a) at rated conditions (100 % light output)	0.44 to 0.48	0.40 to 0.41	White B
b) at 10 % light output	0.48 to 0.54	0.41 to 0.42	White A or B
c) at 1% light output	0.52 to 0.58	0.39 to 0.41	White A

[a] This information is generally applicable to gas filled lamps. For tungsten halogen lamps insufficient data is available at present to make positive pronouncements concerning lamp performance.

13.2 Electroluminescent panels. Electroluminescent panels, comprising areas (usually plane) or phosphors excited by an electric field to uniform luminance, may be used for indicators where ambient illumination is low, for example in signs giving information in words or digits, or for indicating obstacles. At present there is no application for distant signals in view of the low intrinsic luminance of the panels, while the available range of somewhat unsaturated colours would make the colour coding unsatisfactory.

14 White light sources with colour filters

The majority of coloured light signals are produced by passing light from a nominally white source through a colour filter of glass or plastics. The white light source is usually an incandescent filament lamp whose colour lies on or near the Planckian locus between the colour temperatures of about 2 000 K and 3 300 K and its appearance ranges from the yellowish white of an oil flame to the purer white of a tungsten halogen lamp. Other white light sources of correlated colour temperatures up to 8 000 K may be used for special signals.

The filter which is placed in front of the light source transmits only selected wavelength bands from the total light emitted from the source. It is therefore necessary to consider the filter/source combination as a whole when designing a signal within specified colour limits because a variation in the characteristics of either filter or source can have a marked effect on the chromaticity of the resulting light emitted from the signal.

White light sources of low colour temperature have emissions which are rich in orange and red light, while those of high colour temperature such as a xenon arc show a preponderance of green and blue. Thus when a light signal of a specified colour is needed, the absorption characteristics of the filter must compensate for the characteristics of the light source and the two must always be used in conjunction with one another. A change of light source to one of increased colour temperature would make the light through a red filter appear less red, that through a yellow filter appear more green, and that through a green, white or blue filter more blue.

The possibility of employing a self-coloured light source whose chromaticity is close to but outside the required limits, combined with a very pale colour filter to bring the emitted light within the required colour class is sometimes worth considering. For example, it is possible to obtain a high intensity blue signal by the combination of an xenon discharge lamp and an appropriate pale blue filter.

15 White light sources

The most commonly used white light sources and their approximate colour temperatures are given in Table 4.

Table 4 does not include mercury discharge and fluorescent lamps because their correlated colour temperature figures would be of little value as part of this standard.

For practical convenience, the light sources considered in this standard are assumed to be Planckian.

The range of light source colour temperatures is sufficiently large to justify the use of different sets of chromaticity limits for colour filters required to be combined with these sources and to produce coloured light within a colour class as specified in Table 1.

16 Colour filters for general purposes

The chromaticity co-ordinates of the different colour filters suitable for use with light sources ranging in colour temperature from 1 900 K to 3 300 K are set out in Figure 4–Figure 15 for the more important colour classes of Table 1. Figures have not been included for xenon light sources or for blue filters because their use is at present very specialized and it is considered that designers of signals using xenon sources or blue filters will be competent to determine for themselves the required filter characteristics. White signals (except for "lunar white" — see clause **17**) normally employ self-coloured light sources without filters. With the exception of green, the figures apply to both glass and plastics filters; separate figures for green glass and green plastics are included because the wider variety of characteristics between different types of plastics in the green area necessitates narrower limits than for similar glass filters.

By reference to Figure 4 – Figure 15, as explained in **16.1**, it is possible to determine the boundaries within which the chromaticity co-ordinates of glass and plastics filters shall lie, when measured with Standard Illuminant A, in order to produce light of any specified colour class when combined with a light source of any specified colour temperature (or range). For some purposes, however, it may be agreed between the manufacturer and the user to adopt more restricted chromaticity limits for colour filters which may be required for use with more than one category of light source, as for example in the case of some railway signals (see clause **17**).

Table 4 — White light sources

Source	Approximate colour temperature (K)
Oil flame	1 900 — 2 100
Acetylene flame	2 350 — 2 600
Tungsten filament vacuum lamp	2 300 — 2 500
Tungsten filament gas filled lamps	
(a) At rated conditions (100 % light output)	2 500 — 3 000
(b) At 10 % light output	1 900 — 2 400
(c) At 1 % light output	1 500 — 2 000
Incandescent gas mantle	2 650 — 2 850
Tungsten halogen lamp (at rated conditions)[a]	3 000 — 3 300
Xenon discharge lamp (continuous)	6 000 — 6 600
Xenon discharge lamp (flashing)	5 000 — 7 000 or higher

[a] See note to Table 3.

16.1 Use of Figure 4 to Figure 15. As explained in clause **14**, colour filters for use in signals have to be selected with reference to the colour of the light required from the signal and to the type of light source to be employed in the signal. When the colour temperature of the light source can be restricted to a very narrow tolerance the chromaticity of the filter can be allowed the maximum range, but where a signal may be run with light sources covering a range of colour temperatures, or for signals designed for dimming (see clause **19**), the chromaticity of the filter must be appropriately restricted so as to keep the colour of the emitted light within the required colour class under all conditions of operation.

Each of the figures defines the chromaticity co-ordinate boundaries for a particular colour and colour class given in Table 1. These boundaries are shown by full lines for signal light sources of colour temperature 1 900 K, 2 200 K, 2 500 K, and 3 200 K and calibration marks indicate intermediate colour temperatures from which it is easily possible to interpolate any additional boundaries required with sufficient accuracy for most practical applications. The figures cover the following types of colour filters.

Figure 4, Figure 5 and Figure 6. Glass and plastics filters for signal red, classes A, B and C respectively.

Figure 7, Figure 8 and Figure 9. Glass and plastics filters for signal yellow classes A, B and C respectively.

Figure 10, Figure 11 and Figure 12. Glass filters for signal green, classes A, B and C respectively.

Figure 13, Figure 14 and Figure 15. Plastics filters for signal green, classes A, B and C respectively.

The required chromaticity co-ordinate boundaries for filters for use with light sources of constant colour temperature may be read directly from the figures, interpolating between the full lines if necessary. For example, the chromaticity co-ordinates for a filter required for use with a tungsten halogen lamp of colour temperature 3 200 K to produce class B signal red light, when measured with Standard Illuminant A, must lie within the boundaries marked EFGH on Figure 5.

When a filter is required for use with more than one light source, or with the same light source operating over a range of colour temperature its chromaticity co-ordinates must lie within that area on the appropriate figure which is common to the two extremes of source colour temperature. For example, the chromaticity co-ordinates of a filter required for use with either an oil lamp of colour temperature 1 900 K or a tungsten filament vacuum lamp of colour temperature 2 500 K to produce signal red class B light must lie within the boundaries marked KLMN on Figure 5, when measured with Standard Illuminant A. The boundaries for filters covering the same range of source colour temperatures for signal yellow, classes A and C and for signal green, classes A, B and C are also marked KLMN on the appropriate figures as further illustrations of this principle. However, a study of Figure 8 for signal yellow class B shows that no practical filter exists which can accommodate as wide a range of source colour temperature as this and it will be further seen from Figure 4 and Figure 6 that it is only the highest source colour temperature which is significant in the case of signal red, classes A and C.

The boundaries in Figure 4–Figure 15 have been fixed on the assumption that the filters to be employed will have typical light transmission characteristics for glass or plastics. To avoid errors arising from the accidental employment of materials of unusual characteristics, it is a wise precaution to work as near as possible to the centre of the permitted colour area. Where, however, it is necessary to select filters which are close to the boundaries, care should be exercised in the choice of materials and a check should be made by spectrophotometry and computation, or by direct colour measurement of the signal, that the intended result is being achieved.

Reference should also be made to Appendix C.

17 Colour filters for specific purposes

Although the variation in the observed colour of signals is sufficiently controlled for recognition and for most other purposes within the chromaticity limits given in Table 1, it is recognized that there may be some special requirements for a more closely controlled variation to achieve a reasonable match in colour appearance and luminosity for certain applications. Similarly, a batch of colour filters may be used in different signalling equipments in which the colour temperature of the light sources or operating thermal temperatures of the filters may vary to a significant extent. It may then be expedient and perhaps economic to control the variation of the colour properties of the filters to closer limits appropriate to these varying factors rather than to have different and perhaps small batches of filters for the various different conditions.

For these special purposes users may restrict the purchasing specification by agreement with the supplier. If this practice is adopted, such specific requirements should, for compliance with this standard, confine signal chromaticities to within the appropriate ranges stated in Table 1.

As an example of the application of this principle, the established practice for British railway signalling which has developed from the use of BS 623:1940 (superseded by this revision of BS 1376) has shown the desirability of restricting the range of colour properties of certain filters and lenses for several reasons. These include the need for high intensity (high luminance) red signals to be somewhat deeper than other red signals and the need for white signals to be restricted to a part of the range shown in Table 1 so that they have consistent colour appearance. These considerations lead to restrictions for filter chromaticities for railway use namely, a limiting chromaticity of $y = 0.295$ for use in high intensity red signals and limiting chromaticities of $x = 0.330$ and $x = 0.380$ for use in "lunar white" signals.

18 Choice of filter materials

The commonly used materials for colour filters in signals are glass and plastics, both of which may be coloured to a wide range of hues and saturations. In addition, interference filters or liquid filters could be used where appropriate but because of their very specialized properties it has not been possible to cover them in this standard.

Glass has the outstanding advantage of permanence of colour and the ability to withstand high operating temperatures without distortion, but it is not easy to produce with precise colours. Plastics have the advantages that they can be produced with precision of colour and surface finish; the ease with which they can be moulded into accurate and reproducible coloured lenses favours their use in signals of high optical accuracy. Also, they have the advantage of robustness to sudden shock and certain plastics are able to show advantages over glass where flying stones or vandalism would otherwise necessitate frequent replacement. However, plastics are generally inferior to glass in relation to their heat stability, weathering characteristics and resistance to abrasion which impose limitations on their use. Reference should be made to Appendix A for detailed information on the stability problems associated with both glass and plastics filters and for details of weathering tests for plastics filters.

19 Dimming of light sources

The use of incandescent light sources whose output is varied, either continuously or in two or more discrete steps, to economize in power or to provide a strength of signal which is appropriate to the conditions of observation (such as signals which are reduced in strength for use after dark), creates the special problem that the colour temperature of the source may be lowered as the light output of the lamps is reduced. Accordingly, for such a signal to remain within its specified colour class at all intensities, special care is required in selecting a filter which will achieve this over the range of source colour temperatures involved.

Consider, for example, the filter requirements of a signal with a gas filled tungsten filament lamp whose light output is required to stay within the limits of signal green, class C, over a dimming range of between 10 % and 100 % of its normal output when operating under rated conditions. Assume further that the correlated colour temperature of the source at 100 % light output is about 3 000 K, falling to about 2 400 K at 10 % light output. It will be immediately evident from a study of Figure 12 and Figure 15 that the chromaticity co-ordinates of a suitable green filter must lie within the restricted boundary indicated by PQRS on these figures if the light output of the complete signal is to fulfil the stated requirements.

Additionally, if the filter in the above example were to be mounted so close to the light source as to undergo a significant temperature change between the two extremes of light output, this would introduce a further restriction in its permissible chromaticity co-ordinate boundaries because of the temperature effect mentioned in clause **11** and further discussed in Appendix A. In fact, this effect would be insignificant in the case of a green filter but might well need to be taken into account for a red or yellow one.

20 Transmittancy of colour filters

Table 5 shows the minimum transmittancy normally acceptable for the colour filters covered by Figure 4–Figure 15 when measured with Standard Illuminant A.

The minimum transmittancy of yellow filters depends to a significant extent upon the colour temperature of the source with which they are intended to be used; for red and green filters this effect is much less marked and for convenience the same minimum figures have been given in Table 5.

Applications exist for filters to give a reasonable probability of recognition (class A) combined with a high light output (high transmittancy). These filters have been designated class A/HT; their chromaticity characteristics are the same as class A and the minimum transmittancy values normally acceptable are given in Table 5.

It is stressed that the values given in Table 5 are minima and that filters having these minimum transmittancies may not necessarily be good enough for a practical signal. The user should check what transmittancy is actually required for the signal equipment concerned and specify this value as a minimum when ordering.

Table 6 gives the approximate range of transmittancy for typical filters when used in conjunction with the light source for which they have been designed, at their operating temperature in normal service.

Table 5 and Table 6 are intended for guidance only.

Section 4. Photometric and colorimetric measurement

21 General

The measurements of colour and transmittancy which are required by this standard may be made by any method which gives results of the required accuracy. Colour measurements shall be in terms of the chromaticity co-ordinates x, y and z of the CIE 1931 Standard colorimetric system.

Table 5 — Minimum filter transmittancy when measured with Standard Illuminant A

Colour name	Colour class	Colour temperature range of design light source		
		1 900 K – 2 200 K	2 200 K – 2 500 K	2 500 K – 3 300 K
		%	%	%
Signal red	A	7	7	7
	A/HT	18	18	18
	B	10	10	10
	C	7	7	7
Signal yellow	A	45	40	30
	A/HT	65	60	50
	B	65	60	50
	C	45	40	30
Signal green	A	9	9	9
	A/HT	15	20	20
	B	9	9	9
	C	9	9	9
Signal white	C (restricted)[a]	25	25	25

[a] "lunar white" for railway use (see clause **17**)

Table 6 — Approximate range of transmittancies (%) shown by typical filters when used in a signal with the light source for which they are designed

Colour name	Filter material	Colour class	Colour temperature of signal light source			
			1 900 K	2 200 K	2 500 K	3 200 K
Signal red	Glass	A	11–37	9–32	8–28	6–23
		A/HT	25–37	22–32	20–28	17–23
		B	15–30	13–26	11–22	9–18
		C	11–20	9–16	8–15	6–12
Signal red	Plastics	A	11–49	9–42	8–37	6–30
		A/HT	25–49	22–42	20–37	17–30
		B	23–39	19–33	17–29	13–23
		C	11–26	9–21	8–18	6–14
Signal yellow	Glass	A	60–85	50–80	40–75	30–70
		A/HT	70–85	60–80	50–75	40–70
		B	75–85	65–80	60–75	50–70
		C	60–75	50–70	40–65	30–60
Signal yellow	Plastics	A	69–88	58–87	51–85	38–73
		A/HT	74–88	65–87	58–85	47–73
		B	85–88	80–87	73–85	60–73
		C	69–84	58–81	51–75	38–63
Signal green	Glass	A	6–16	7–23	8–27	10–34
		A/HT	11–16	17–23	19–27	21–34
		B	6–14	7–18	8–21	10–25
		C	6–12	7–15	8–17	10–19
Signal green	Plastics	A	6–26	7–38	8–47	10–57
		A/HT	11–26	17–38	19–47	21–57
		B	6–20	7–30	8–39	10–52
		C	6–14	7–23	8–32	10–48

The complete signal equipment, or a self-coloured light source, may be tested for compliance with the chromaticity requirements specified in Section 2 or the colour filter or coloured lens used in the signal equipment may be tested for compliance with the chromaticity and transmittancy requirements of Section 3. Appendix B describes an inspection method for use when large numbers of filters have to be tested and when a lower order of accuracy can be accepted.

Care should always be taken to ensure that only the chromaticity of the coloured light emitted by the signal equipment, or transmitted by the colour filter, is measured and that adequate precautions are taken to eliminate stray light from all other sources.

The method of measurement should always be agreed between the purchaser and the manufacturer, with due regard to the conditions under which the equipment will operate in service. It is emphasized that the choice of the correct method is important.

22 Complete signal equipments

The signal equipment shall be operated under the conditions stipulated by the manufacturer and, unless otherwise stated, in an ambient temperature between 20 °C and 25 °C.

To determine the chromaticity of the signal, light from the equipment may be received directly by the measuring instrument or by a white diffusing screen, care being taken to ensure that the light is received in a suitable direction from the signal and that the part of the beam of light which enters the instrument is representative of the light issuing in other directions which may be effective in service.

If the signal equipment produces a beam which is not reasonably homogeneous in luminance or colour, some selection of the preferred direction or some integration of the light in the beam is required.

For measurement in a particular direction from the signal equipment a white diffusing screen is placed to receive the light normally at a sufficient distance to ensure that the apparent colour of the screen is uniform and that it is receiving light substantially equally from all parts of the light emitting aperture of the equipment. The measuring instrument is set to receive light reflected from the screen at an angle of 45° (0°/45° method). The screen may be coated with any recognized standard reflecting material, preferably smoked magnesium oxide. If there is any slight coloration in the "white" screen or if its spectral reflectance is significantly non-uniform, a small correction will be required to the measured colour of the light reflected from it. This correction is particularly important where the light has a wide spectral distribution, i.e. white light. It is usual to assume that smoked magnesium oxide has a uniform spectral reflectance.

If the signal equipment provides a light beam with a well-defined axis, this is normally to be used as the direction in which light is received by the screen but other directions of viewing the signal may be important in service. In such circumstances the white screen should therefore be located additionally in suitable non-axial positions, at the same distance from the source as was adopted for the axial measurements and turned so as to receive the light normally.

It is possible to illuminate the white screen at 45° and to view it normally (45°/0° method) if these conditions are more convenient than those described above (0°/45° method). The results should be equally accurate by either method.

If the beam of light from the signal equipment cannot be properly represented by measurement in a particular direction or in several chosen directions, the average chromaticity of the beam may be determined by receiving the light in a photometric integrator. The signal equipment may be mounted wholly within the integrator, or with the emitting area inserted into the integrator, or the equipment may be entirely outside so that desired parts of the emission may be collected and passed into the integrator.

When a signal equipment is operated within an integrator its temperature may rise above that at which it would operate in free air, with a consequent change in the chromaticity of the light emitted. An appropriate correction for this effect may be required. A more important correction is for the marked colour distortion which is likely to arise from multiple reflection of the light from the integrator wall. As in the case of the flat white screen the spectral reflectance of the wall coating (usually a barium sulphate paint) must be known, also the spectral power distribution of the signal, in order to assess the colour distortion, which is much greater in general than that resulting from a single reflection from a flat screen. A signal equipment inside an integrator can also affect the measured chromaticity by its own absorption of light, and another correction may be needed on this account.

Measurements made by the integrator method are more difficult than those using a flat screen and it is important that they should be made only by a skilled photometrician using measuring equipment with which he is familiar.

When the signal equipment cannot be tested as a whole by one of the methods described above, the colour of the signal may be taken as being the same as that of the light transmitted by the actual colour filter used in the signal, when maintained at the same thermal temperature as that which it would reach in normal use in the complete signal and when illuminated by a light source of the same colour temperature as the source used in the signal.

For a field test, it may be required to compare the colour of the signal with that of a calibrated light signal which may, for example, be set on or near one of the chromaticity limits. Such tests should be made from a sufficient distance to ensure that both signals are seen as distinctly separate but not more than 2° apart; the two signals should appear to be of substantially equal intensity and size.

23 Colour filters

Measurements of colour filters alone may be made by any of the methods described in clause **22** as appropriate.

23.1 Light source. For measurements of the chromaticity and transmittance of lenses, diffusers and spreaders, the light source shall be a suitably aged tungsten filament lamp, either screened by an opal (white) translucent filter or illuminating a reflecting magnesium oxide screen. The screen shall be regarded as the light source, and the lamp shall be operated such that the colour temperature of the light emitted from the screen is 2 856 K. For measurements on plain filters the screen may be omitted and the lamp itself operated at a colour temperature of 2 856 K.

Alternatively, measurements may be made using an integrating sphere. The light source in this case shall be operated at 2 856 K as in the directional method but no translucent screen is required.

23.2 Temperature of test. Unless otherwise specified, all measurements shall be made with the filter under test at the same thermal temperature as that which it would normally reach when used in the equipment for which it has been designed. It should be noted that the effect of temperature on chromaticity and transmittancy of red and yellow filters may be considerable (see Appendix A).

Quoted characteristics for filters of unknown application shall clearly state the temperature at which the measurements were made if other than between 20 °C and 25 °C.

23.3 Measurement of chromaticity. Care should always be taken to ensure that only the chromaticity of the light transmitted by the filter under test is measured and that adequate precautions are taken to eliminate stray light from all other sources. When the effective area of a filter is less than its whole area this should be indicated by the user and measurements should then be made with a mask suitably shaped so that the light measured has passed through the effective area only. Any type of appropriate measuring instrument may be used which is capable of producing results to the required order of accuracy.

Where the filter under test is of uniform colour and thickness, it is sufficient to test any part to judge its conformity with this standard. Where thickness variations result in colour differences across the face of the filter, light from the whole area shall be integrated and a determination made of the average colour. The filter shall be judged to meet the requirements of this standard provided that the total of any usable areas which have a chromaticity outside the applicable limits does not exceed 5 % of the total usable area of the filter and in addition that the average colour is within the limits.

23.3.1 When making measurements on a plain colour filter the incident light shall fall on its surface at the same angle as light from the source would be incident upon it in the complete signal equipment for which it has been designed. Colour filters of unknown application shall be tested with the light passing normally through them.

23.3.2 Measurements on coloured lenses shall be of the chromaticity of the light reflected at 45° from a screen of magnesium oxide or other recognized white diffusing material placed normal to the optical axis of the lens at a distance of not less than five times the diameter of the lens. A light source as defined in **23.1** shall be placed at the point on the axis of the lens conjugate to the screen, which shall receive light from the whole effective area of the lens. The effective diameter of the light source shall be not less than one quarter the focal length of the lens.

An alternative method of measurement, using an integrating sphere, is to mount the lens in one face of a light tight box containing a light source operating at 2 856 K and placed at the standard focus of the lens, and to measure the chromaticity of this assembly as if it were a complete signal, by one of the methods described in clause **22**.

23.3.3 Measurements on a diffuser are made by placing it in close proximity to a colourless condensing lens which shall be set up in relation to the light source and reflecting screen as described in **23.3.2**. The diameter of the lens shall be not less than that of the diffuser and care shall be taken that no direct light from the lens reaches the screen. If the lens used is not colourless, correction may be made by adjusting the light source so that the light from the lens has a colour temperature of 2 856 K. Alternatively, the measurements may be made using an integrating sphere as described in **23.3.2**.

23.3.4 Measurements on spreaders are made in the same way as for diffusers. Unless otherwise specified such measurements shall be made on the axis of the spreader and in the direction of the one-tenth peak divergence.

24 Transmittany

The recommended method of measurement is that in which the transmission of the combination of the colour filter under test with a colourless flat plain filter is compared by a substitution method with the transmission of the combination of a colourless filter of the same pattern as the colour filter under test with a calibrated flat colour filter of known transmittancy. For measurement of a plain colour filter, direct comparison with a calibrated plain colour filter is sufficient.

The arrangement for illuminating the combinations of filters and for observing the light transmitted by them shall be as given in **23.1**, **23.2** and the first paragraph of **23.3.2**, except that in this case the measurement is of the luminance of the screen rather than of its chromaticity. The transmittancy of diffusers and spreaders shall be measured for the light emitted in the direction of the optical axis. The colourless flat plain filter and the flat colour filter of known transmittancy shall be mounted close to the aperture of the photometer or colorimeter.

The ratio of the luminance of the magnesium oxide screen when the colour filter under test and the colourless flat plain filter are in position, to the luminance when the colourless filter of the same pattern as the filter under test and the flat colour filter of known transmittancy are in position, is equal to the ratio of the transmittancy of the colour filter under test to the transmittancy of the calibrated colour filter, provided that the absorption in the colourless filter substituted for the filter under test is equal to that of the flat plain filter. If these absorptions differ a correction will be required.

The transmittancy of the calibrated colour filter required for the above test may be measured with a colorimeter or calculated from its spectral absorption curve. In materials of refractive index between 1.49 and 1.52, the ratio of transmittancy to transmittance of a plain colour filter is 1.08.

If the transmittancy measurements are made with a visual photometer, a flat colour filter with properties similar to those of the calibrated colour filter should be mounted on the comparison side of the photometer to eliminate the difficulties of hetrochromatic photometry, but the properties of this filter need not be known.

If a photoelectric photometer is used for the transmittancy measurements, it is important to ensure that its calibration is frequently checked against known standards.

It may be noted that the numerical value of the transmittancy of a colour filter, which is always greater than the transmittance because it is independent of reflection losses, is determined solely by the absorption of the light within the filter.

Appendix A Stability

A.1 Light signals

Light signals are required to produce light within their specified intensity and chromaticity limits in the environment to which they are normally subjected and over the whole of their service life. The major factors which determine the output of a light signal are the colour temperature or colour properties and the flux output of the light source and, except for signals which contain only a self-coloured light source, the chromaticity and transmittancy of the colour filter used. It is important, therefore, that the stability of light sources and of light source/colour filter combinations used for light signals is such that the intensity and chromaticity of the light from the signal will remain within tolerance throughout its life.

This appendix draws attention to the more important factors likely to influence the stability of light sources and colour filters. Reference should also be made to manufacturers for detailed information concerning lamps and colour filter materials.

Although not strictly speaking a matter of stability, a further effect which can give rise to apparent colour changes due to variations in luminance should be mentioned. This is known as the Bezold-Brücke effect which, at unusually high luminance levels, results in red and yellow-green colours tending to appear somewhat more yellow, and in violet and blue-green colours tending to appear somewhat more blue. The effect may be significant where very high luminance signals may be fixated over long periods, e.g. a long range signal viewed at a short distance by a stationary observer. This is not the same effect as the complementary after-image effect which may occur if a white surface is viewed after fixation on a colour signal.

A.2 Light sources. When selecting an electric light source for a signal it is advisable to consider to what extent, if any, the colour, the luminous efficacy, the burning position, the run-up time, the restriking time and the lamp life may be affected during the working life of the lamp by variations in voltage, ambient temperature and the changes in gas/vapour pressure and by operation in a flashing mode

Most light signals operate with tungsten filament lamps although signals using oil (kerosene) and acetylene flames and incandescent mantles may still be found. Some gaseous discharge lamps offer the possibility of obtaining signal colours without the use of colour filters, although such lamps may be used with filters to bring their chromaticities within the required limits, as discussed in clause **14**.

A.2.1 Electric (tungsten) filament lamps. The colour temperature of a tungsten filament lamp is dependent upon the operating temperature of the filament. The difference in normal operating temperatures of these lamps arises partly from differences in lamp design and partly from variations in operating voltage. When the voltage applied to a lamp is reduced below its normal rated value, the colour temperature decreases and the colour appearance moves towards the red end of the visible spectrum. Ageing also leads to changes in intensity and to a lesser extent in chromaticity due to deposition of filament material on the bulb and to slightly increased electrical resistance of the filament. Care should therefore be taken to minimize variations in the supply voltage of the lamp and lamps should be renewed on a regular maintenance cycle before they have deteriorated significantly.

The lives of tungsten lamps may be considerably increased if the lamps are operated at 5 % or more below their normal rated voltage although this will be at the expense of their luminous efficacy and will result in a slight shift in their colour temperature. Some signals may be required to operate in a "flashing" mode by alternately applying and removing a voltage to the lamp. For such methods of operation care should be taken to ensure that the lamp selected is suitable for such requirements as it may never fully attain its specified colour temperature if voltage is only applied to it for very short periods.

A.2.2 Electric (gaseous) discharge lamps. The nature of the gas or vapour, the temperature, the pressure developed and the current density are the main factors which determine the characteristic colour of a gaseous discharge lamp. Also both the luminance and the chromaticity of metal halide lamps are to some extent dependent upon their burning position.

Discharge lamps generally emit radiation at discrete wavelengths as opposed to incandescent sources which emit radiation as a continuous spectrum. At very high gas pressures a more continuous spectrum will develop made up of a series of wide spectral bands. Hence the light emitted by such lamps may, with use, change both in intensity and chromaticity and their regular replacement is necessary.

With discharge lamps which contain mercury, there may be a change of chromaticity as the ambient temperature varies. At lower temperatures the vapour pressure of the mercury is reduced with consequent decrease in the intensity of the mercury spectrum although the spectral distribution of the light from the rare gases in the lamp is little affected by the temperature change.

Similar difficulties may be experienced with low pressure sodium lamps; at low temperatures the sodium is not fully volatilized and the neon gas which is used to start the discharge contributes most of the light so that the light is nearly red. When the lamp is fully heated to its stable operating temperature the colour is predominantly yellow.

The chromaticity of neon lamps varies with pressure. With use the pressure in the neon decreases and this may cause the colour to become less saturated i.e. an increase in the z co-ordinate.

Many electric discharge lamps require considerable time (15 minutes or more) to attain fully stabilized operating conditions and in the event of a lamp being extinguished by a momentary interruption of the supply voltage it will not restrike until the gas pressure has been reduced i.e. the lamp has cooled down. Such light sources are not usually appropriate for dimming or flashing applications.

Fluorescent lamps are seldom used as signal lamps because of their low luminance and of the large area of the light source.

The spectral energy distribution of a compact source xenon lamp in the visible spectrum is akin to sunlight and is achieved at reasonably high efficacies (20 lm/W to 50 lm/W) over a range of correlated colour temperatures depending on the gas pressure and the colour density. The disadvantages which have so far limited the more wide-spread use of xenon lamps are largely their cost and the complexity of their control gear.

A.3 Plastics filters

A.3.1 General. The limited resistance of plastics to heat, light and weathering needs to be considered whenever their use is contemplated. Heat distortion can be a problem where the temperature exceeds 60 °C; plastics are generally not suitable for operation at temperatures above 100 °C. The colouring materials used in plastics filters have been selected to have good stability to light (generally by exposure tests, see **A.3.2.2**) but the combination of heat and light received in a signal imposes more severe conditions than either heat or light alone and is a further reason why high operating temperatures need to be avoided.

Plastics are also less weather resistant than glass, though some are appreciably better than others. Where, therefore, the exterior lens of a signal is moulded from a plastics material, the weather resistance of that material must be considered, particularly if exposed to direct sunlight.

The colour may also be permanently affected by prolonged ultra-violet radiation, as from a discharge lamp, the effect occurring more rapidly if the filter is warm. While colours may fade as a result of this treatment, it is more usual for colorants to be selected so that darkening occurs and the colour then continues to remain within specification.

In common with glass filters (see **A.4**), plastics colour filters are subject to reversible changes in both chromaticity and transmittancy with changes of temperature. As yet there is little published data available concerning such temperature-dependent changes for plastics but as they are normally limited to an upper temperature of operation of about 100 °C, the problem is of less practical importance than for glass lenses which may operate at much higher temperatures. Changes due to temperature are therefore only likely to require consideration when plastics filters are to be used close to the limit of the chromaticity or transmittancy of a particular class of signal, and an expectation of the magnitude of the changes which may occur may be obtained from consideration of the changes with operating temperature of a glass filter of similar chromaticity and transmittancy.

Although plastics filters are not generally in contact with chemical substances when used in light signals, such occasions may occur during cleaning or assembly, and it should be noted that some types of plastics may be easily damaged by solvent attack. The advice of the plastics manufacturer should therefore be sought on the matter of cleaning fluids and greases that may be used.

A.3.2 Environmental tests. Before selecting a particular plastics material for use in a light signal it is advisable to ensure that the material has the necessary stability with respect to exposure to heat and light. The following tests, which have been found to produce generally satisfactory results, have been included in this appendix as an indication of what may be required.

A.3.2.1 Test specimens. The material to be tested should be in the form of plain, polished specimens, 75 mm squares or 75 mm diameter discs. Specimens of at least two thicknesses, chosen from the range given below, at which the colour meets the chromaticity requirements of the specification are required.

Thickness	Tolerance
1.5 mm	± 0.125 mm
3.0 mm	± 0.125 mm
6.0 mm	± 0.125 mm

At least one specimen of each chosen thickness should be tested and a corresponding control specimen retained for comparison.

The control specimen should be kept properly protected from influences which may change its appearance or properties.

A.3.2.2 Outdoor exposure test. The test should be carried out according to BS 4618-4.2 at not less than one temperate and one tropical test site for a minimum period of 2 years.

The mounting of the test specimen should be such that a minimum area of 30 cm^2 is exposed continuously.

The material is deemed to be satisfactory if the following conditions are met.

a) The transmittancy of the exposed specimen does not vary by more than 25 % of the transmittancy of the corresponding unexposed control specimen.

b) The chromaticity co-ordinates of the exposed specimen and the corresponding unexposed specimen are within the limits laid down in clause **16**.

c) The exposed specimens do not show undue surface deterioration, crazing, haze and dimensional changes when compared with the corresponding unexposed control specimen.

A.3.2.3 Heat test. The specimen should be supported in a vertical position by utilizing not more than the lower one third of its height.

The specimen should then be placed in an air circulating oven for 2 hours at a temperature appropriate to the material under test, with a tolerance of ± 2 °C.

The nominal temperature of the oven should be set at 5 °C below the heat distortion temperature of the material as determined by test method 102H of BS 2782.

The material is deemed to be satisfactory if after heat test and cooling to room temperature the specimens show no significant change in shape and general appearance when compared with the corresponding unexposed control specimens and the chromaticity co-ordinates are within the limits laid down in clause **16**.

A.3.2.4 Simulated weathering test. Artificial exposure tests to simulate outdoor tests are not, at the present time, sufficiently reliable to be used as an alternative to the test detailed in **A.3.2.2**.

A.4 Glass filters. When subjected to prolonged radiation from ultra-violet rich discharge lamps, glass colour filters may undergo a permanent change in transmission characteristics, particularly when hot. This change is generally marked by an increase in absorption mainly at the short wavelength end of the visible spectrum. Certain green glass filters can suffer permanent darkening after prolonged exposure to excessive temperature alone.

Both the chromaticity and the transmittancy of glass colour filters will vary to some extent with the thermal temperature of the glass. This is a reversible change and it is therefore important that for signals containing colour filters and for colour filters tested separately, measurements of chromaticity and transmittancy are made with the filter at the temperature at which it will operate in normal use. The effect is most significant for red and orange filters, where it operates to increase the redness and decrease the transmittance with increased temperature; it is insignificant for green filters. For typical glasses of the cadmium, selenium, sulphur type, a temperature change of 200 °C may change the *y*-co-ordinate by as much as 0.06 and the transmittancy by 15 percentage units. An "orange" filter in a signal might shift from the red end of the class A yellow range when cold to the yellow end of the class A red range when hot and might decrease in transmittancy from say 45 % when cold to 30 % when hot. Such changes are entirely reversible. Generally no permanent colour changes are caused by a high temperature unless it approaches the softening temperature of the glass.

Typical changes in chromaticity with temperature for red and yellow filters are illustrated in Figure 16 and Figure 17 based on data published by Werner and Wedding.

Appendix B Approximate inspection method for colour filters

B.1 General. This appendix describes a means of inspection which is convenient when dealing with large numbers of flat filters. It may, however, be used for shaped filters if the control limit filters are of the same form as the samples under test and can be calibrated with sufficient accuracy.

The method is to employ calibrated control limit filters having chromaticities and transmittancies adjacent to and within the relevant chromaticity and transmittancy limits of clauses **16** and **20** respectively with a light source at 2 856 K. One calibrated chromaticity limit is required for red classes A and C and two for red class B and all classes of yellows, greens and "lunar white". One calibrated transmittancy limit is required for each class and colour.

NOTE For green plastics filters it may be necessary to use three calibrated chromaticity limits (for blueness, yellowness and paleness) unless the limit filters have the same constitutents as the filters under test.

B.2 Calibrated control limit filters

B.2.1 Filter material. The calibrated limit filters for chromaticity and transmittancy tests should be made of the same type of material as the filters to be tested. The addition of a neutral filter is permissible with calibrated transmittancy limits.

B.2.2 Form. It is desirable for the calibrated limit filters to be transparent and approximately 60 mm × 60 mm with reasonably flat and parallel surfaces of such quality that the filters can be calibrated with a spectrophotometer or can be used in the substitution method described in clause **21**.

B.2.3 Identification. Each calibrated limit filter should be marked for identification.

B.2.4 Uniformity. The transmittance of each calibrated limit filter at each of the points midway between the centre and the corners should be between 0.95 and 1.05 times the central value.

B.2.5 Chromaticity. The chromaticities of calibrated limit filters for colour tests should be near to and within the appropriate limiting chromaticities specified in clause **16**.

The chromaticities of limit filters which are calibrated as transmittancy limits, when measured in accordance with clause **23**, should satisfy the chromaticity requirements of clause **16**.

B.2.6 Transmittancy. The transmittancies of calibrated limit filters for transmittancy tests should be between the minimum transmittancy requirements of clause **20** and these values multiplied by 1.05.

The transmittancies of calibrated limit filters for colour tests need not comply with the transmittancy requirements specified in clause **20**.

B.3 Inspection of colour filters by visual comparison. For this method of testing, the production filters should be compared visually with colours given by calibrated limit filters at the same brightness level. The method described in clause **23** may be used, the calibrated limit filter being employed on the comparison side of the photometer.

Acceptable production colour filters should meet the following requirements.

a) Red filters should not be visibly yellower nor less saturated than the calibrated yellow limit filter.

b) Yellow filters should not be visibly greener nor less saturated than the applicable calibrated green limit nor redder than the calibrated red limit filter.

c) Green and "lunar white" filters should not be visibly yellower nor paler than the applicable calibrated yellow limit nor bluer than the calibrated blue limit filter.

B.4 Inspection of transmittancy filters. Transmittancies of filters may be compared with those of calibrated limits by the method described in clause **24**, the calibrated limit being that employed on the comparison side of the photometer, or by any other convenient method. The transmittancies should be not less than those of the appropriate calibrated limit filter.

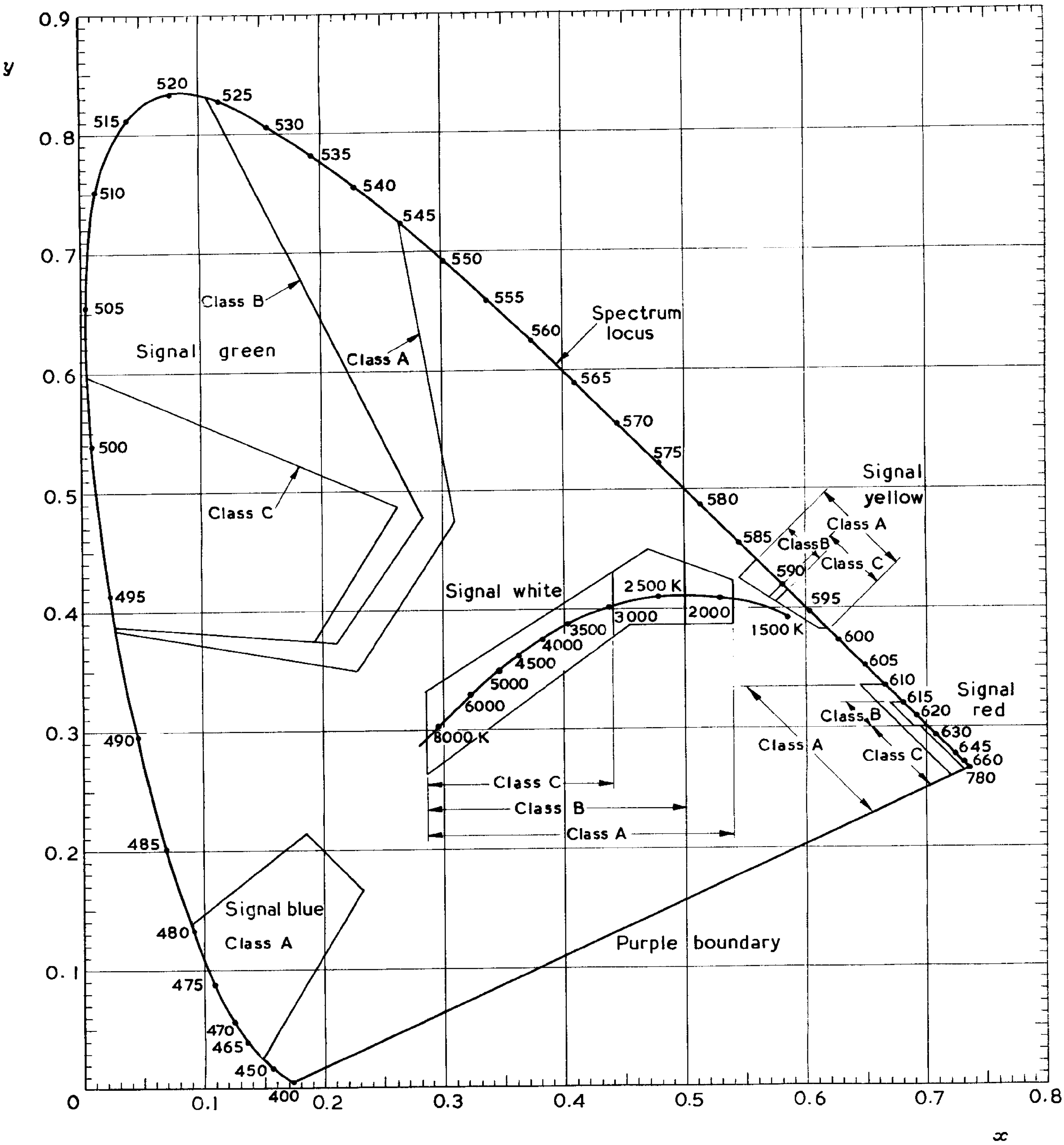


Figure 1 — Chromaticity limits for signal colours

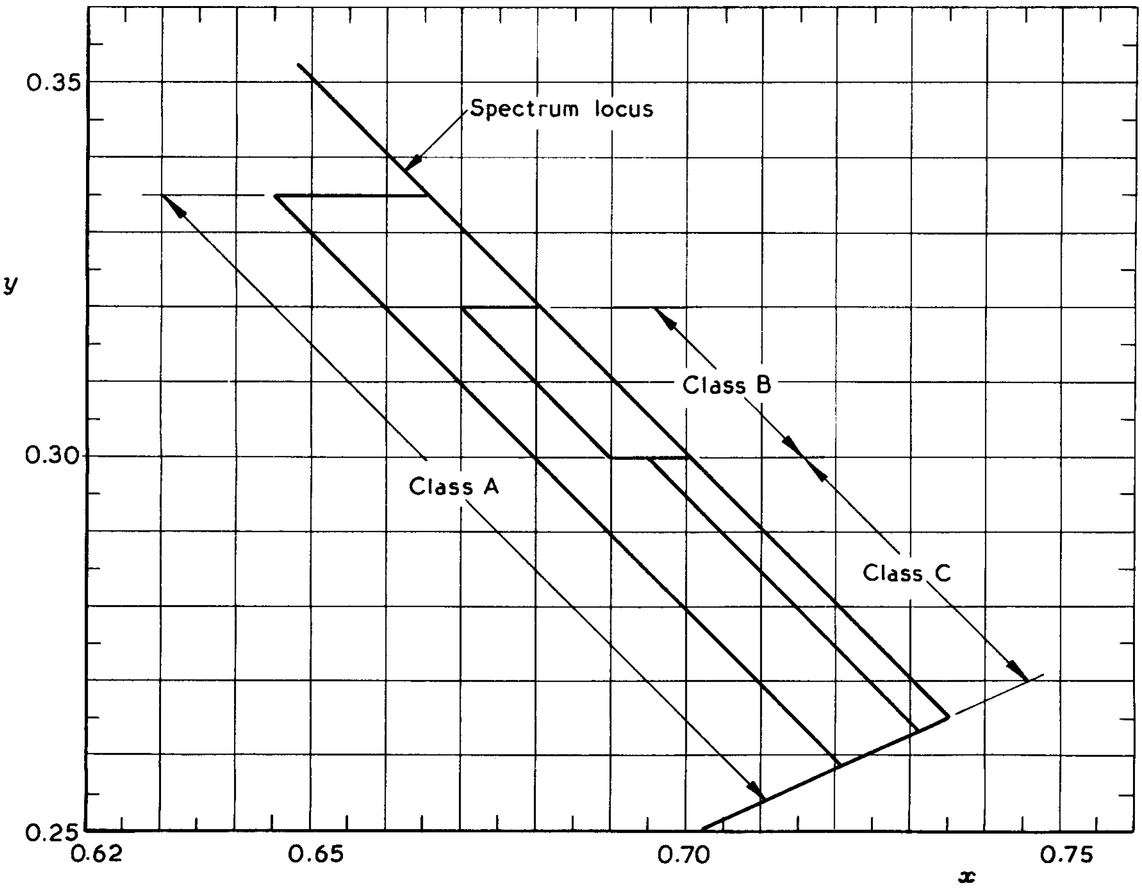


Figure 2 — Signal red

Appendix C Notes on Figure 4–Figure 15

Figure 4–Figure 15 specify the chromaticity co-ordinate boundaries, measured with Standard Illuminant A, within which the chromaticity co-ordinates of glass and plastics filters should fall, at their intended operating temperatures, if they are to emit light falling within the desired colour class when used in conjunction with any of the light sources for which these figures have been calibrated.

Boundaries for light source colour temperatures of 1 900 K, 2 200 K, 2 500 K, and 3 200 K are clearly indicated and calibration marks at intervals of 100 K allow interpolation between these values if necessary. These four colour temperatures are typical of oil flame, vacuum tungsten filament, gas-filled tungsten filament and tungsten halogen lamps respectively.

A complete explanation of the method of use of Figure 4–Figure 15 is given in **16.1**, together with a typical example, and a further example relating to light sources which may require to be dimmed is given in clause **19**.

As explained in the last paragraph of **16.1**, it must be emphasized that the figures have been calculated with relation to the characteristic of typical coloured glass and plastics filters and that exceptions may be found. To guard against these, users of this part of the standard should avoid the employment of filters which are near the boundaries of the permitted area, unless they have the facility to check the filters by measuring the chromaticity of the light emitted by the complete signal under its operating conditions.

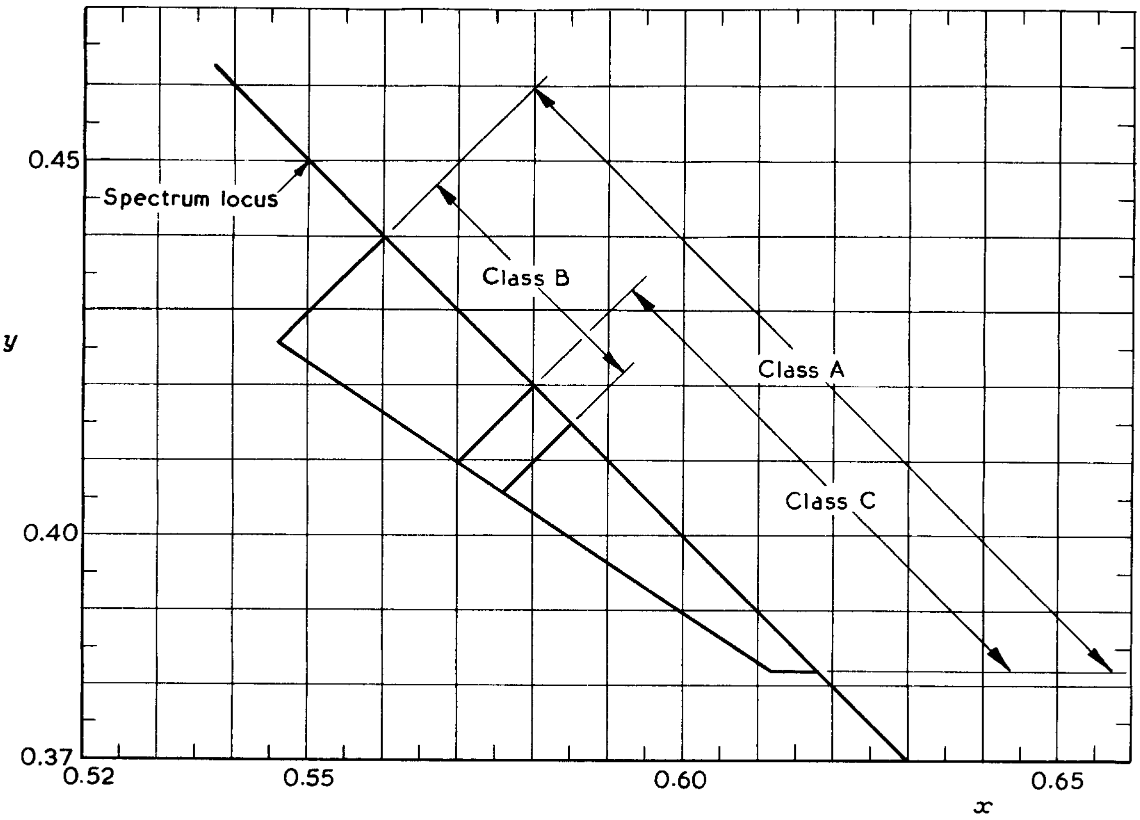


Figure 3 — Signal yellow

Where facilities for measuring chromaticity at elevated temperatures are not available, the appropriate allowance may be approximately estimated, for typical red and yellow filters, from Figure 16 and Figure 17 respectively. Here again, however, it must be appreciated that these figures also are based on typical filters and the results of such corrections should be treated with some reserve.

NOTE For an explanation of the letters KLMN on some of the figures, see **16.1**.

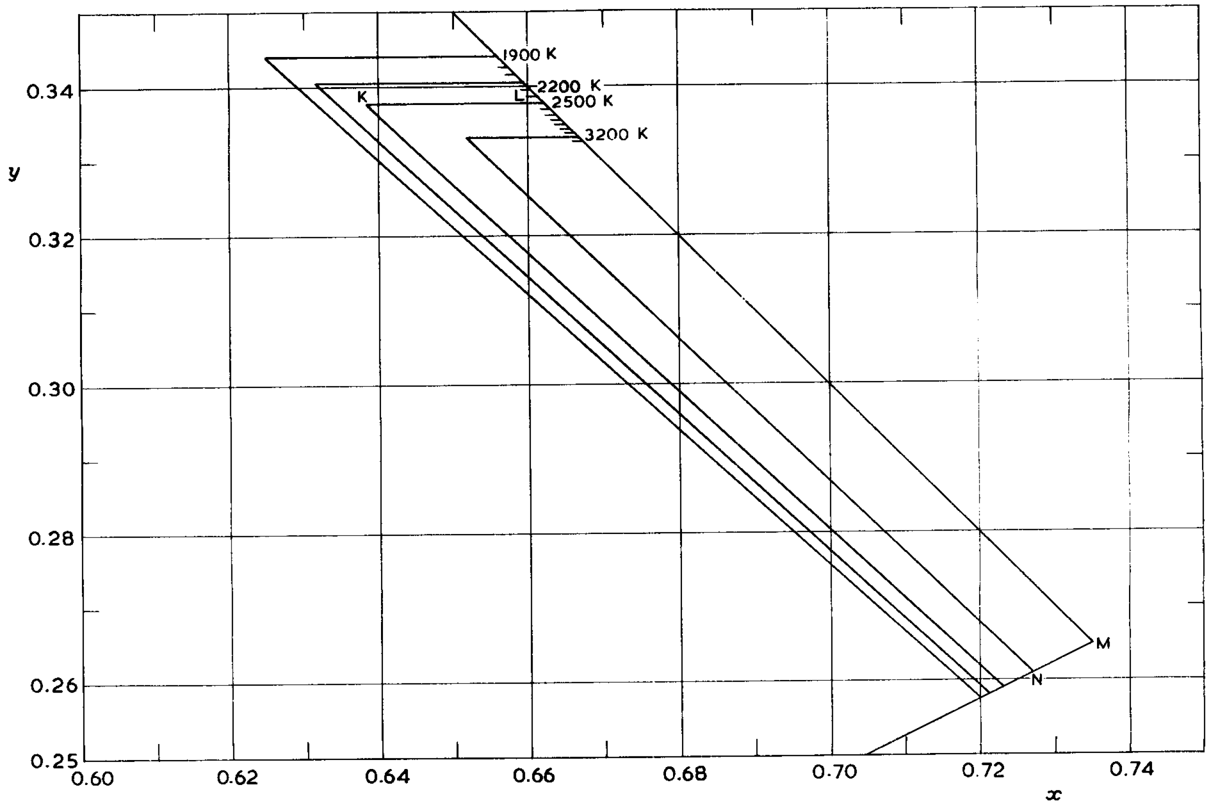
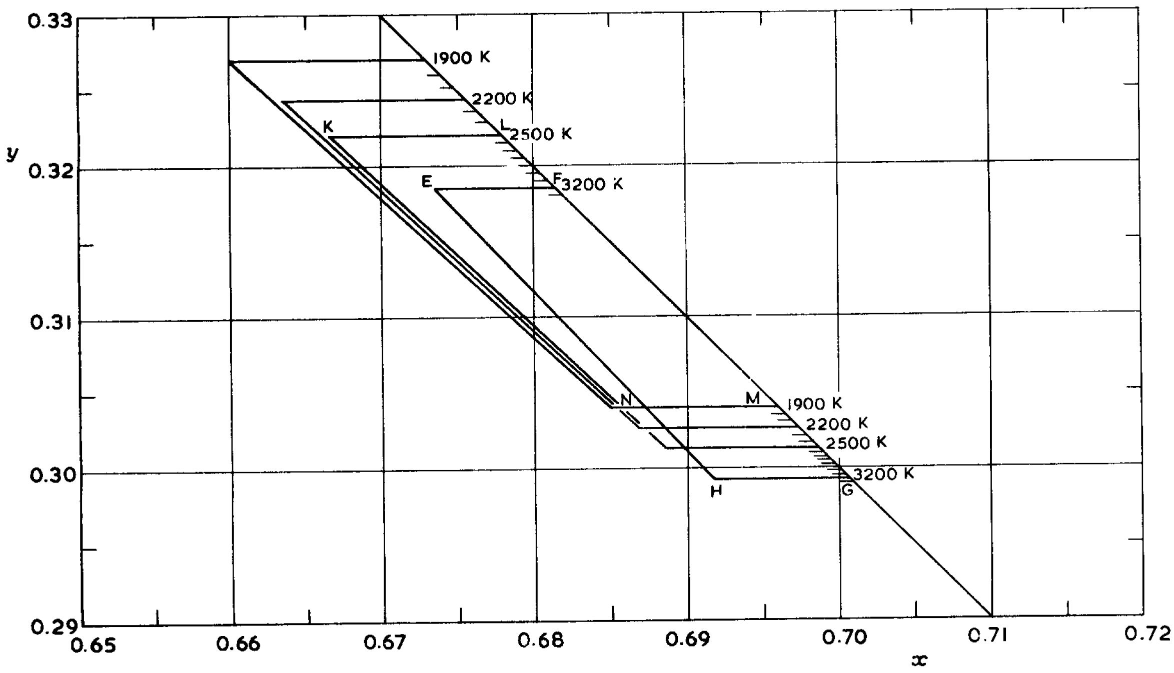


Figure 4 — Limits of class A red glass and plastics filters for particular light sources



NOTE For explanation of area EFGH, see **16.1**.

Figure 5 — Limits of class B red glass and plastics filters for particular light sources

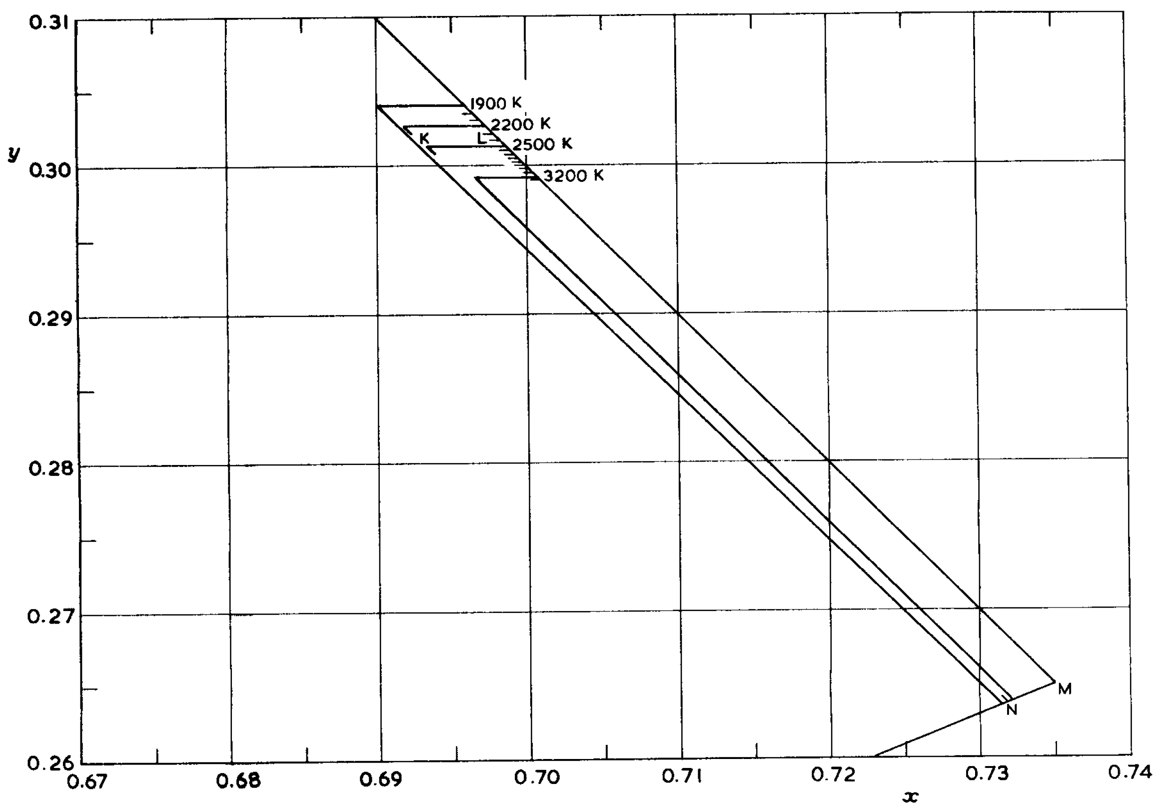


Figure 6 — Limits of class C red glass and plastics filters for particular light sources

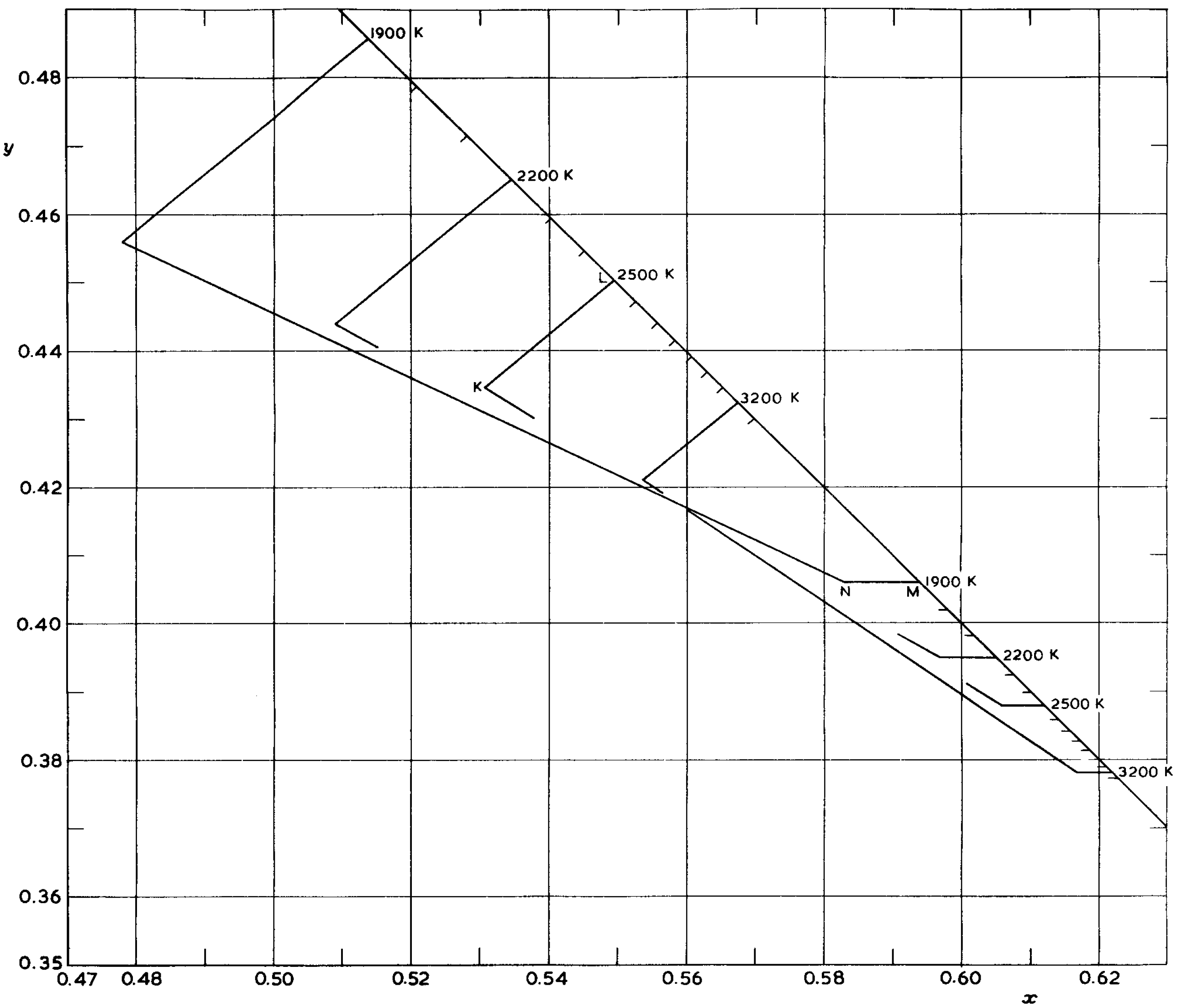


Figure 7 — Limits of class A yellow glass and plastics filters for particular light sources

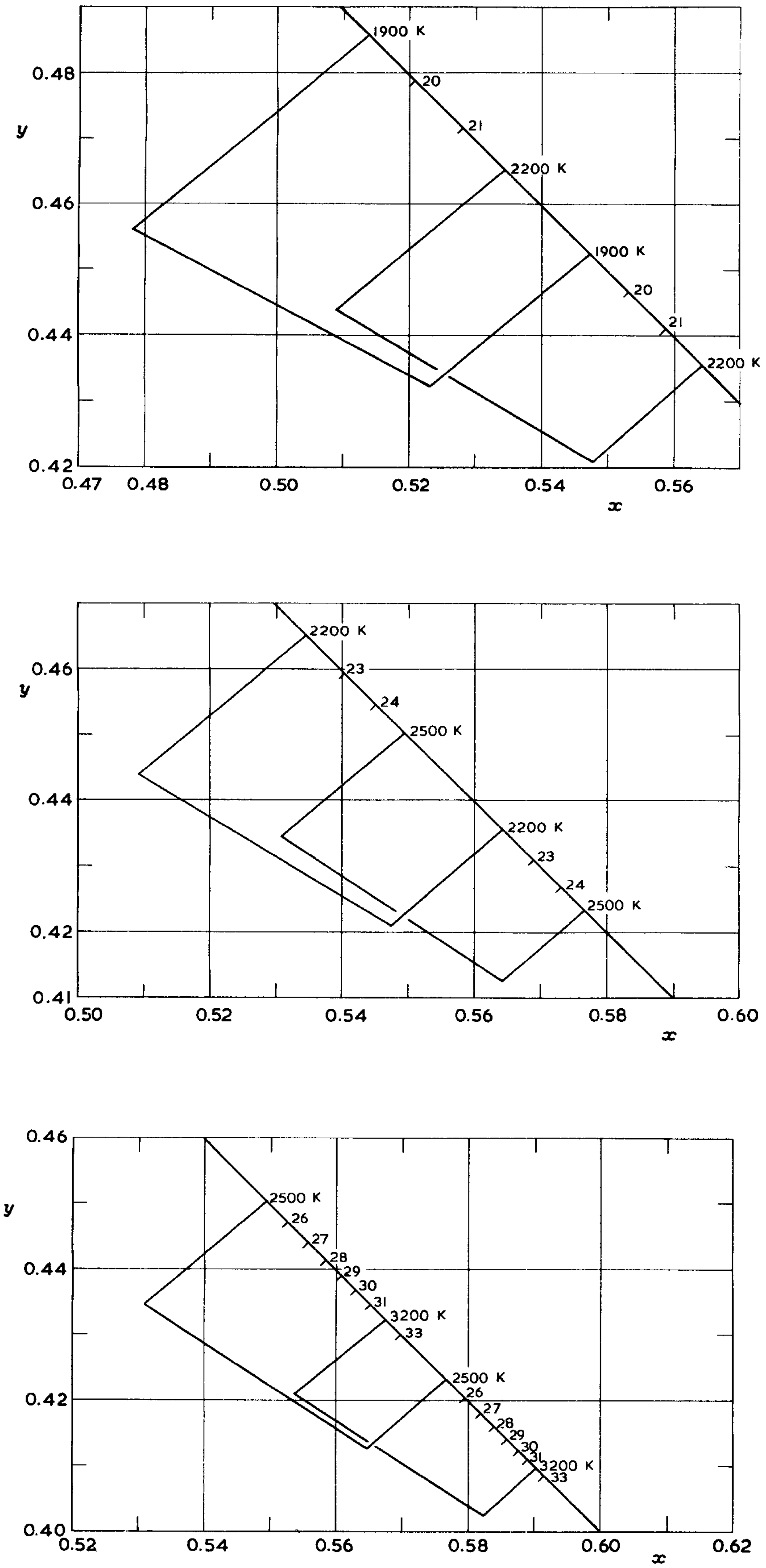


Figure 8 — Limits of class B yellow glass and plastics filters for particular light sources

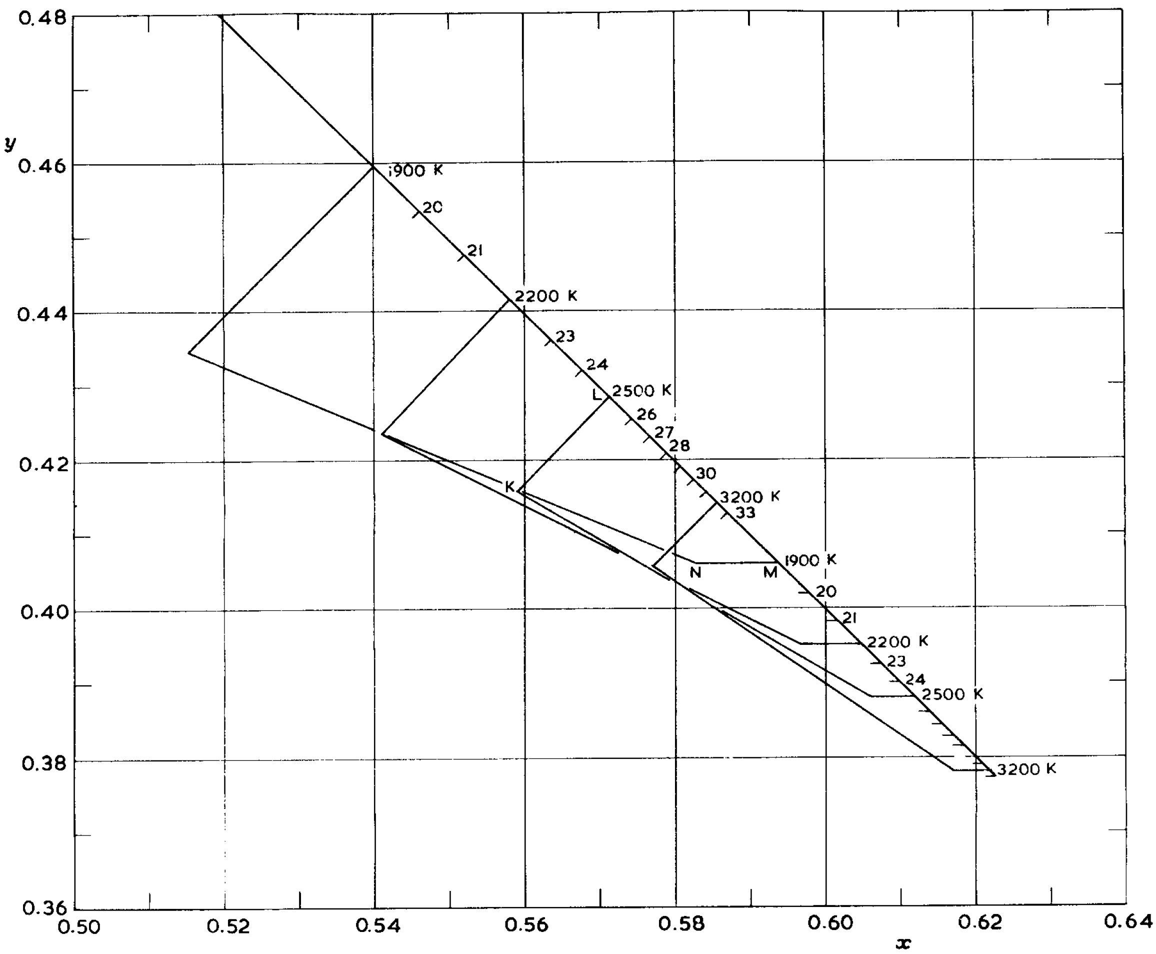


Figure 9 — Limits of class C yellow glass and plastics filters for particular light sources

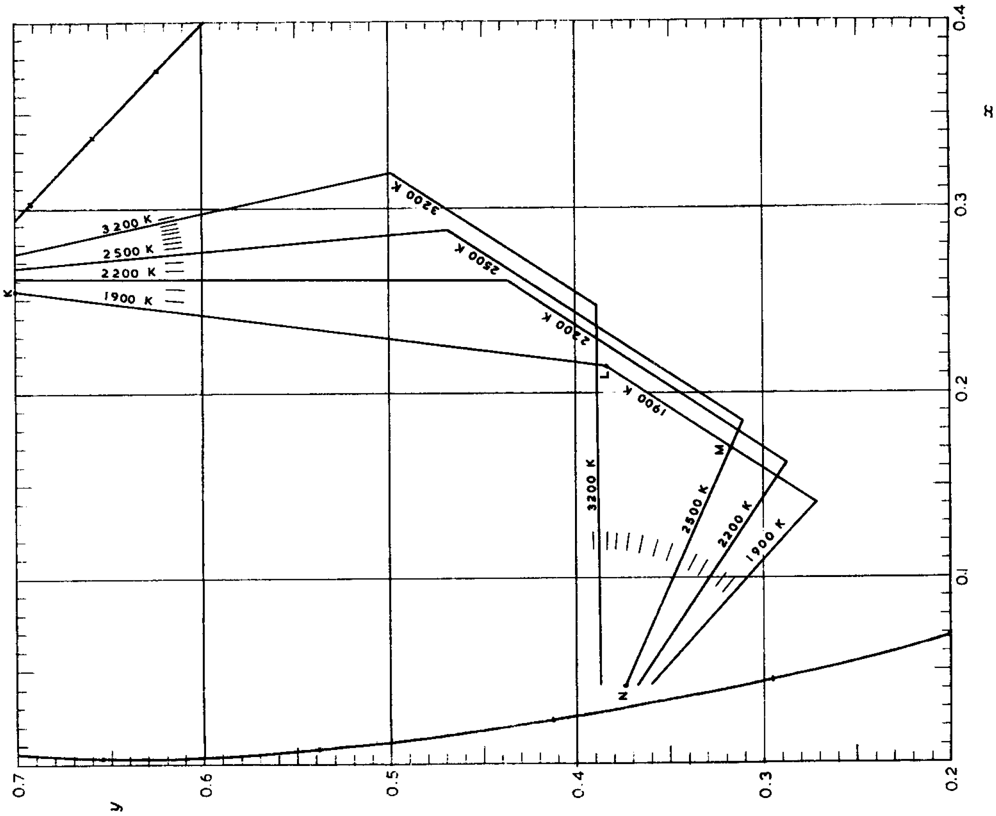


Figure 10 — Limits of class A green glass filters for particular light sources

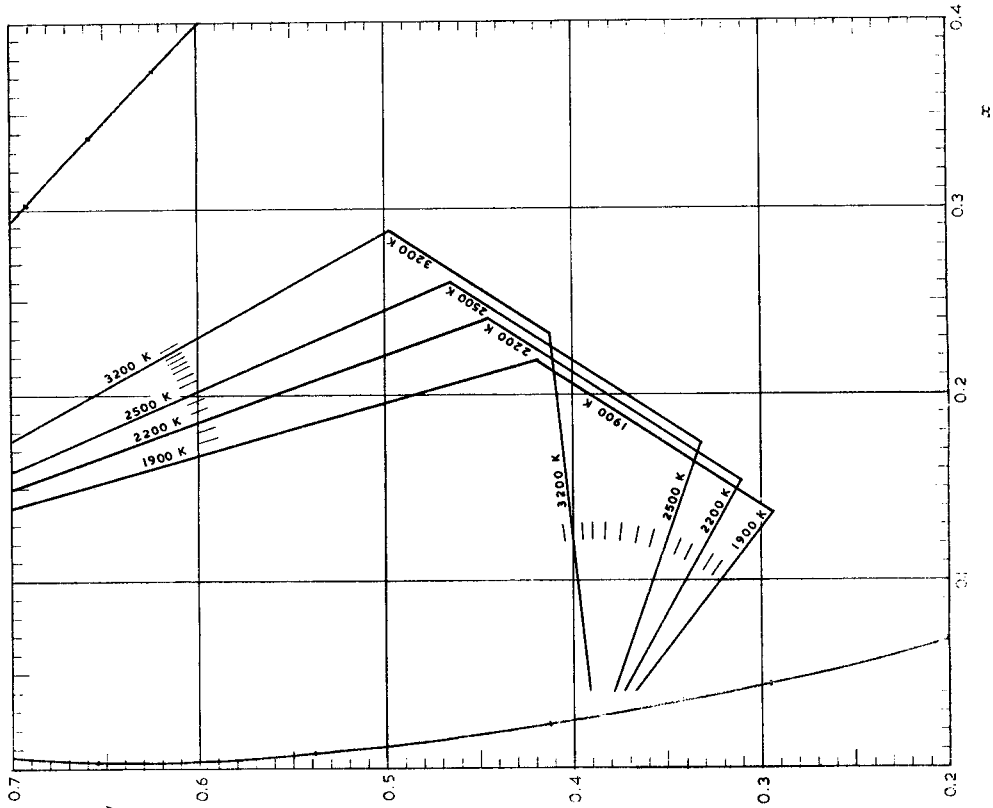
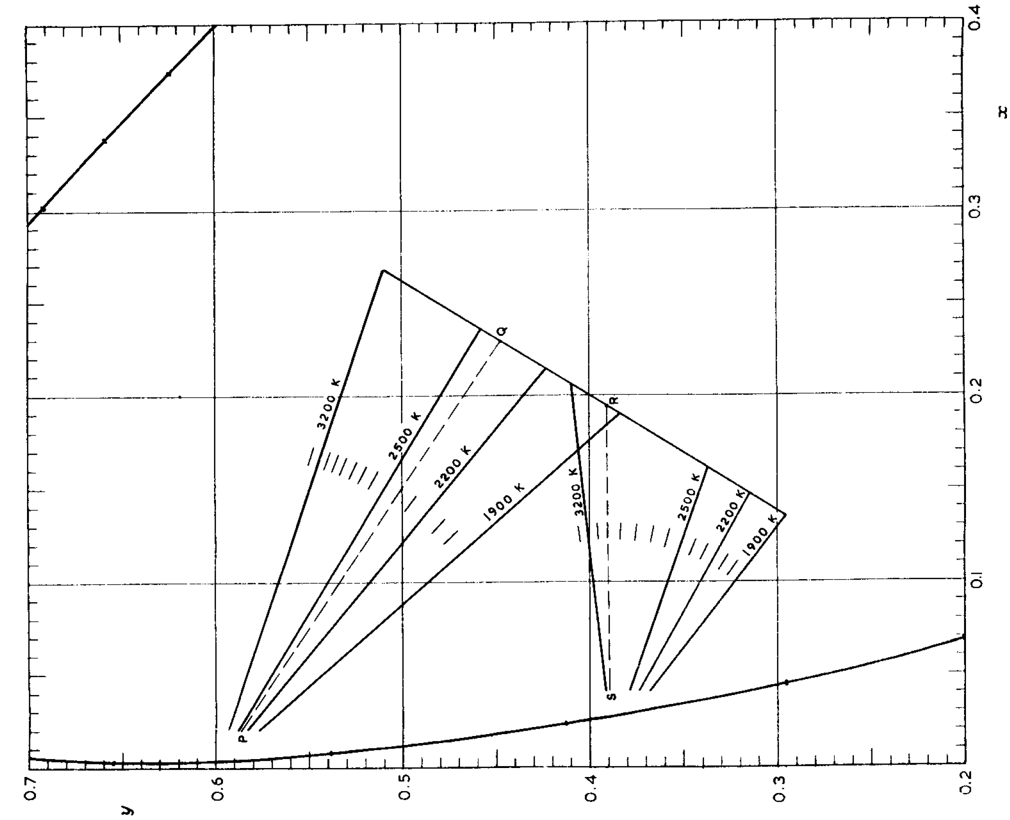


Figure 11 — Limits of class B green glass filters for particular light sources



NOTE For explanation of area PQRS see clause 19.

Figure 12 — Limits of class C green glass filters for particular light sources

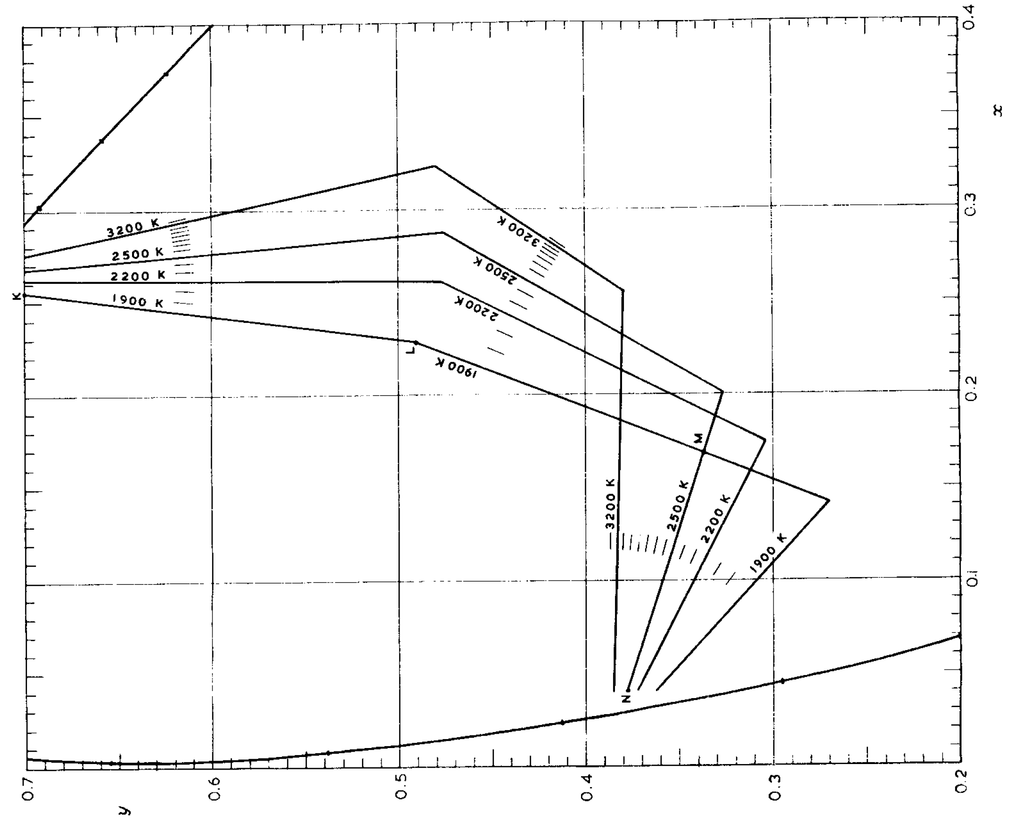


Figure 13 — Limits of class A green plastics filters for particular light sources

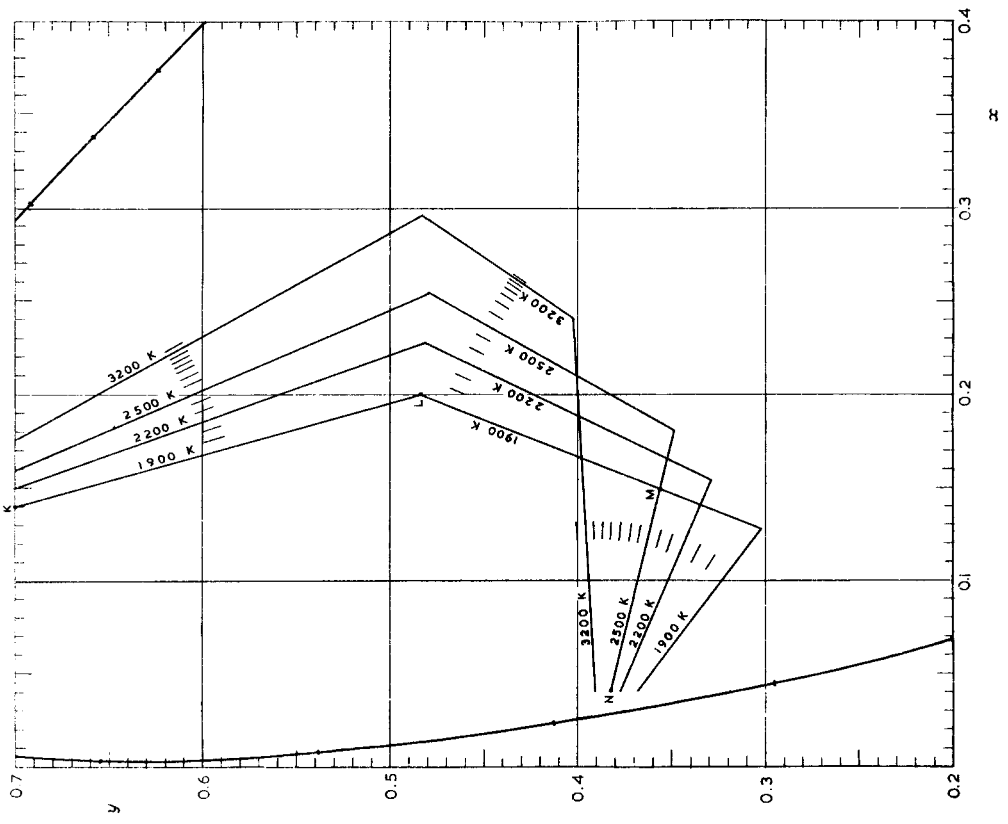
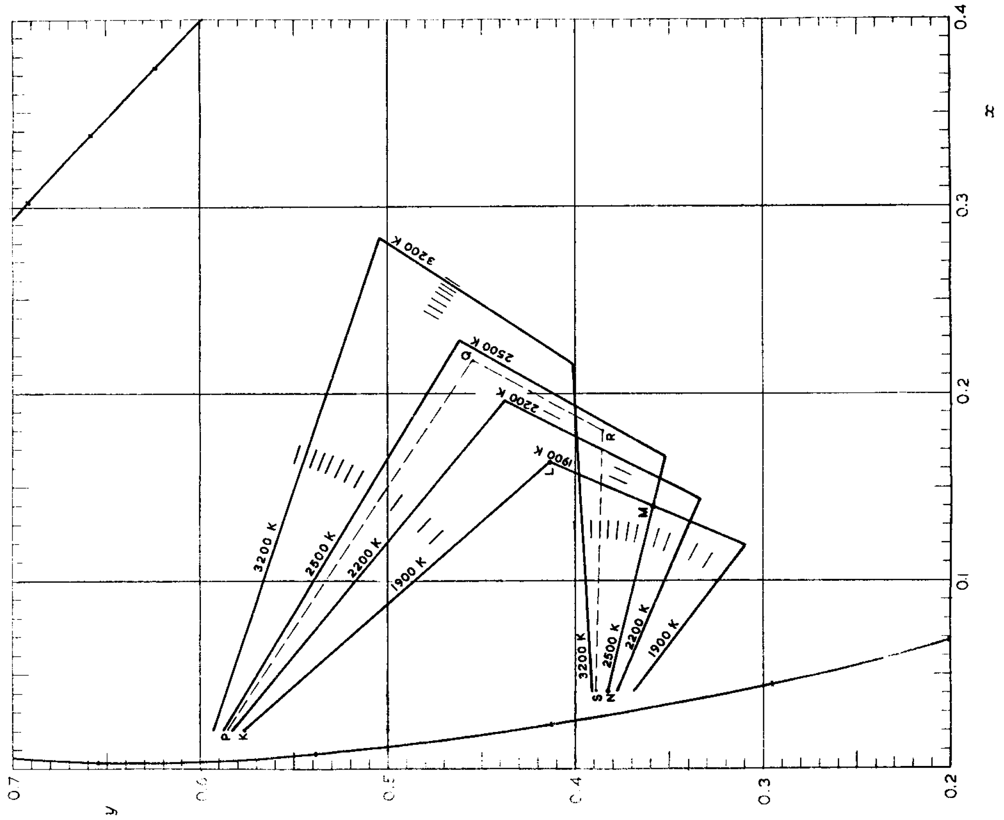


Figure 14 — Limits of class B green plastics filters for particular light sources



NOTE For explanation of area PQRS see clause 19.

Figure 15 — Limits of class C green plastics filters for particular light sources

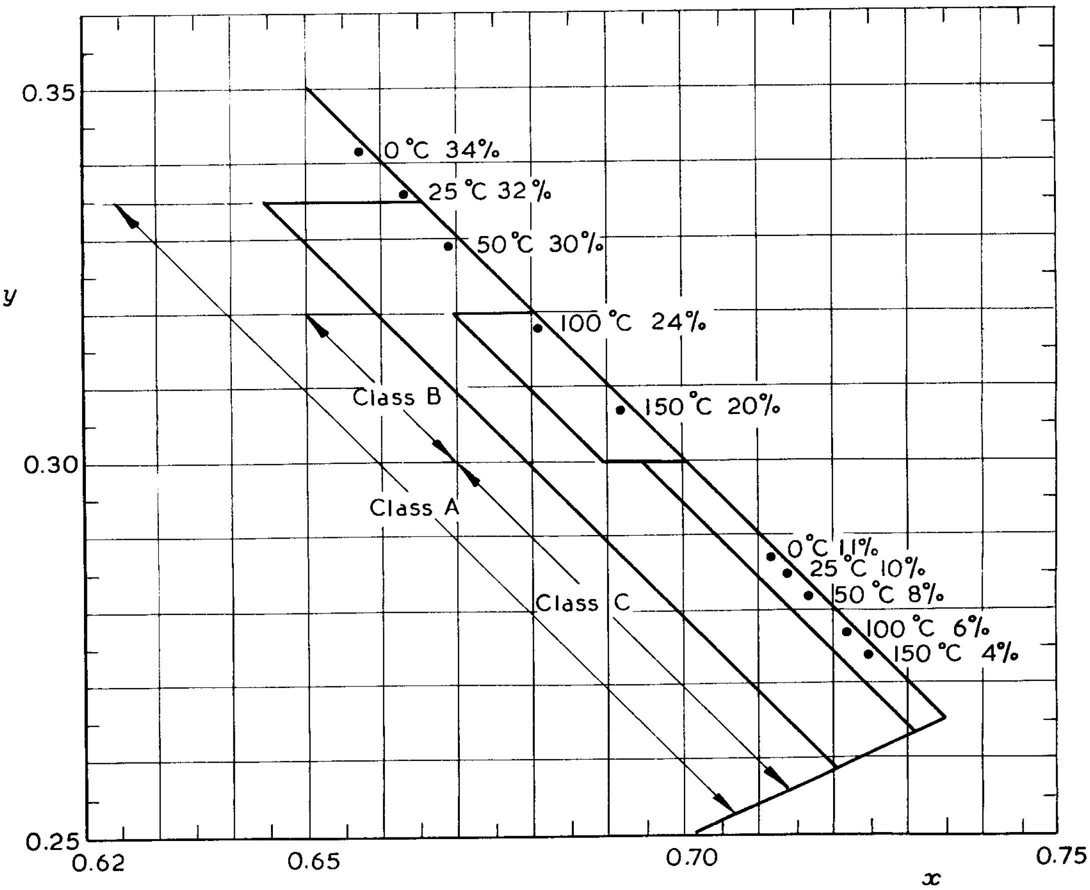


Figure 16 — Changes in colour and transmission of two typical red filters with change of thermal temperature

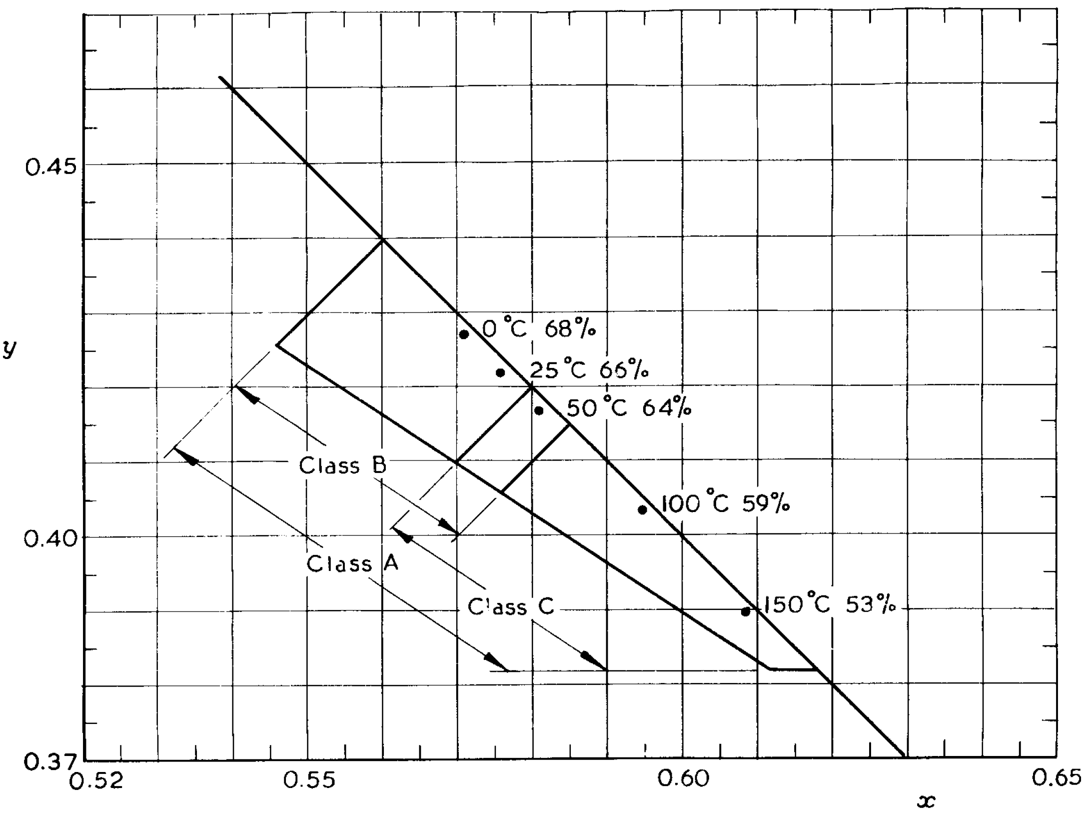


Figure 17 — Changes in colour and transmission of a typical yellow filter with change in thermal temperature

Appendix D Comparison with international standards

D.1 Introduction Since the second revision of this British Standard (September 1974), several international standards have been issued or revised. These differ in some respects from this British Standard, as indicated briefly in this appendix; reference should be made to the standards themselves for full information.

There may be particular recommendations regarding the circumstances in which the signal colours are to be recognized and which are not included in this comparison. Some of the standards that have the same range of chromaticities as those in the CIE Official Recommendations (1975) are not described in detail.

D.2 General recommendations of the Commission Internationale de l'Eclairage (CIE)

Red	
General:	class A
Restricted:	class C but extended slightly in saturation towards purple ($y = 0.990 - x$)
Restricted for protanomalous and protanopic observers:	class B but extended towards yellow and towards deep red ($y = 0.335$) ($y = 0.290$)
Yellow	
General:	class A
Restricted:	class A but restricted in saturation towards white ($y = 0.951 - 0.930x$)

Green

General:	class A but extended slightly towards yellow ($x = 0.360 - 0.080y$)
Restricted:	there are three optional boundaries: towards white: $x = 0.625y - 0.041$ (as class C) towards yellow: $y = 0.726 - 0.726x$ towards blue: $y = 0.500 - 0.500x$

Blue

General:	class A but the total red light (beyond 650 nm) should not exceed 1.5 % of the total light.

Violet

Introduced as a possible alternative to blue. Violet is light of which the component radiations are almost entirely within the range of wavelengths from 380 nm to about 455 nm.

Boundary towards purple: $x = 0.185 - 0.521y$

White

General:	class A but extended towards yellow to include 1 750 K ($y = 0.440$) ($y = 0.790 - 0.667x$) ($x = 0.255 + 0.750y$) and extended slightly towards purple ($y = 0.382$)
Restricted:	there are two optional boundaries: excluding 2 250 K: $x = 0.500$ (as class B) excluding 2 900 K: $x = 0.440$ (as class C)

D.3 Aircraft. The international Civil Aviation Organization (ICAO) makes the following recommendations for the international standardization of colours. The limits specified in the *British Civil Airworthiness Requirements* (BCAR Sections D, K and G covering aeroplanes and rotorcraft) and in the *(US) Federal Aviation Regulations* (FAR Parts 23, 25, 27 and 29 covering airplanes and rotorcraft) are mandatory in their respective countries and other countries that certificate aircraft to the same or similar standards.

The figures given below for ICAO are from Example 2, Chapter 1, Section 8 of the *Airworthiness Technical Manual* and are applicable to aeroplanes whose prototypes were submitted for certification on or after 1 January 1975. Before this date the tolerances recommended for green and white were slightly narrower.

Colour	ICAO	BCAR	FAR
Red	Class A	Class A	Class A but restricted in saturation towards purple ($y = 0.998 - x$)
Green	CIE General (similar to class A)	Class A	Class B but extended towards yellow ($x = 0.440 - 0.320y$) and altered towards white ($x = y - 0.170$)
White	CIE General (similar to class A)	Class A	Similar to class A but expressed differently and excluding 8 000 K

D.4 Aerodromes. The International Civil Aviation Organization (ICAO) specifies the colours to be used for aeronautical ground lights, and makes some recommendations for particular circumstances, as follows.

Colour	ICAO specification	ICAO recommendation
Red	Class A	
Yellow	Class A	See the recommendation for variable white
Green	CIE General (similar to class A)	Where dimming is not required or where observers may have defective colour vision, a restriction against yellow (as CIE) is recommended: ($y = 0.726 – 0.726x$) Where increased certainty of recognition is more important than the maximum visual range, class C is recommended but with extensions towards yellow and towards blue: ($y = 0.726 – 0.726x$) ($y = 0.390 – 0.171x$)
Blue	Class A	
White	CIE General but restricted to exclude 2 250 K ($x = 0.500$) (similar to class B)	
Variable white	CIE General (similar to class A)	To be used only for lights that are varied in intensity. If the colour Variable White is to be discriminated from yellow, the x co-ordinate of the yellow should exceed that of the white by 0.050 or more, and the yellow and white lights should be displayed simultaneously and in close proximity.

D.5 Lighthouses, beacons and buoys. The following recommended colours of light signals on aids to navigation were published by the International Association of Lighthouse Authorities (IALA) in December 1977.

Red

General: class A

Preferred: class B but extended in hue towards deep red ($y = 0.290$)

Yellow

General: class A but restricted in saturation towards white and also towards red ($y = 0.951 – 0.930x$) ($y = x – 0.200$)

Preferred: class B but restricted in saturation towards white ($y = 0.951 – 0.930x$)

Green

General: CIE general (similar to class A)

Preferred: based on all three CIE restrictions but altered towards yellow ($y = 0.800 – x$) ($x = 0.625y – 0.041$) ($y = 0.500 – 0.500x$)

White

General: CIE general but restricted to exclude 2 250 K ($x = 0.500$) (similar to class B)

Preferred: class C

D.6 Road vehicles. Recommendation 7 (Annex 5) of the Economic Commission for Europe (confirmed by the EEC Directives 76/759, 761 and 762, 77/538 and 539) states the ranges of red, amber (yellow) and white, and also "selective yellow" (for headlamps etc. as in Article 15, paragraph 2 of the 1949 Road Traffic Convention), in terms of the chromaticity limits when the light source is operated at 2 856 K, as follows.

Red

Class A but restricted in saturation towards purple

($y = 0.992 - x$)

Amber (yellow)

A restricted range entirely within class A

($y = 0.398$)

($y = 0.429$)

($y = 0.993 - x$)

White

Similar to CIE general but restricted to exclude 2 250 K and 6 750 K

($y = 0.050 + 0.750x$)

($x = 0.500$)

($x = 0.310$)

Selective yellow

A pale yellow range for which the boundaries are:

$y = 0.138 + 0.580x$

$y = 1.29\,x - 0.100$

$y = 0.966 - x$

$y = 0.992 - x$

Foglamp yellow

As Selective yellow but with the boundary ($y = 0.966 - x$) replaced by:

($y = 0.940 - x$)

($y = 0.440$)

Green

Class A but slightly extended towards yellow

($x = 0.360 - 0.080y$)

D.7 Vessels. For sea-going vessels, the Inter-Governmental Maritime Consultative Organization (IMCO) has published the *International regulations for preventing collisions at sea, 1972,* which specifies the following colours of navigation lights. For inland navigation, the Economic Commission for Europe (ECE) issued in 1968 a *European Code for Inland Waterways* (CEVNI), which recommends the following ranges of colours of light signals to be used on vessels on inland waterways.

Colour	IMCO specification	CEVNI recommendation
Red	Class A but restricted towards yellow ($y = 0.320$)	*General:* class A *Preferred:* class B but extended in saturation towards purple and extended in hue towards deep red ($y = 0.980 - x$) ($y = 0.290$)
Yellow	Class C but differently expressed towards green ($x = 0.575$)	*General:* class C but differently expressed towards green ($x = 0.575$)

Colour	IMCO specification			CEVNI recommendation
Green	Class B but extended towards blue and altered towards yellow and white.			*General:* CIE general (similar to class A)
	The co-ordinates of the intersections of the boundaries are:			*Preferred:* class C but extended towards yellow and towards blue
	x	**y**	**approximate equation**	($y = 0.623 - 0.408x$)
	0.009	0.723		($y = 0.390 - 0.171x$)
			($y = 0.729 - 0.729x$)	
	0.300	0.511		
			($x = 0.626y - 0.020$)	
	0.203	0.356		
			($y = 0.390 - 0.166x$)	
	0.028	0.385		
Blue				*General:* class A *Preferred:* considerably restricted within class A ($y = 0.833x + 0.020$) ($x = 0.360 - y$) ($x = 0.104 + 0.807y$)
White	CIE general but restricted to exclude 2 000 K ($x = 0.525$) and 6 750 K ($x = 0.310$)			*General:* CIE general but restricted to exclude 2 000 K ($x = 0.525$) and 6 750 K ($x = 0.310$)

D.8 Sources. The documents on which this appendix is based are as follows.

CIE	*Official Recommendations for colours of light signals.* Publication 2.2(TC – 1.6)1975, published by the CIE at 52 Boulevard Malesherbes, 75008 Paris, France. Obtainable from the National Illumination Committee of Great Britain (Hon. Librarian, Jules Thorn Laboratory, Great Cambridge Road, Enfield, Middlesex EN1 1UL.
ICAO	*Airworthiness Technical Manual* (Part III, Section 8, Chapter 1) *International Standards and Recommended Practices — Aerodromes,* Annex 14 to the Convention on International Civil Aviation, Montreal, 7th ed. 1976, Appendix I "Aeronautical ground light and surface marking colours" (as amended by Amendment 32, 1978). Obtainable from the Civil Aviation Authority, Printing and Publication Services, Greville House, 37 Gratton Road, Cheltenham, Gloucestershire GL50 2BN.
BCAR	BCAR Section D, *Aeroplanes* (and similar BCAR Sections K and G). Obtainable from the Civil Aviation Authority, Airworthiness Division, Brabazon House, Redhill, Surrey RH1 1SQ.
FAR	FAR Part 25, *Airworthiness Standards: Transport Category Airplanes* (and similar FAR Parts 23, 27 and 29). Obtainable from the Department of Transportation, Federal Aviation Administration, 800 Independence Avenue S W, Washington DC 20591, USA.
IALA	*Recommendations for the colours of light signals on aids to navigation,* December 1977. Obtainable from the International Association of Lighthouse Authorities, 13 rue Yvon Villarceau, 75116 Paris, France.
EEC	EEC Directives 76/759, 761 and 762, 77/538 and 539. EEC Directives appear in the *Official Journal* of the EEC, obtainable from HMSO. Further information is available from the European Economic Community in London, 20 Kensington Palace Gardens, London W8 4QQ.
IMCO	*Final Act of the International Conference on Revision of the International Regulations for Preventing Collisions at Sea,* 1972. Published by HMSO: Shipping, Miscellaneous No. 28 (1973).
ECE	*European Code for Inland Waterways* (CEVNI), 6th March 1968. Obtainable from the Economic Commission for Europe, Palais des Nations, 1211 Geneva 10, Switzerland.

Publications referred to in this standard

This standard makes reference to the following British Standards:

BS 2782, *Methods of testing plastics.*

BS 4432, *Methods for determining optical properties of pulp, paper and board.*

BS 4432-1, *Determination of diffuse ISO reflectance factor of pulp, paper and board.*

BS 4618, *Recommendations for the presentation of plastics design data.*

BS 4618-4.2, *Resistance to natural weathering.*

BS 4727, *Glossary of electrotechnical, power, telecommunications, electronics, lighting and colour terms.*

BS 4727-4, *Terms particular to lighting and colour.*

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