INTERNATIONAL STANDARD

ISO 3664

Third edition
2009-04-15

Graphic technology and photography — Viewing conditions

Technologie graphique et photographie — Conditions d'examen visuel

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Reference number
ISO 3664:2009(E)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 3664 was prepared by Technical Committee ISO/TC 42, *Photography*, in collaboration with Technical Committee ISO/TC 130, *Graphic technology*.

This third edition cancels and replaces the second edition (ISO 3664:2000), which has been technically revised by tightening the compliance tolerances on the ultraviolet portion of the D50 spectral power distribution, by adding additional optional illumination conditions, and by increasing the luminance levels of displays used for image appraisal.

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Introduction

While colour and density measurements play important roles in the control of colour reproduction, they cannot replace the human observer for final assessment of the quality of complex images. Colour reflection artwork, photographic transparencies, photographic prints, and photomechanical reproductions such as on-press and off-press proofs or press sheets, are commonly evaluated for their image and colour quality or compared critically with one another for fidelity of colour matching. Paper and other substrates contribute to the colour appearance, and controlling the colour of these is equally critical. However, it is noted that the paper industry has its own set of standards for unprinted paper, which differ in illumination conditions from those recommended in this International Standard.

There is no doubt that the best viewing condition for the visual assessment of colour is that in which the product will be finally seen. Where this is known and it is practical to do so, the various people in the production chain can sensibly agree to use this viewing condition for all evaluation and comparison. However, it is important that this be properly agreed upon in advance and that it be specified that such a viewing condition is not defined in this International Standard.

Unfortunately, such agreement is often not practical. Even if a particular end-use condition is known, it can be impractical to provide everybody in the production chain with sufficiently consistent viewing apparatus. Differences in illumination and viewing conditions can cause corresponding differences in the colour appearance of substrates, reproductions and artwork. Such differences are likely to cause misunderstandings about colour reproduction and processing. This International Standard provides specifications for illumination and viewing conditions that, when properly implemented, will reduce errors and misunderstandings caused by such deficiencies and inconsistencies.

The illumination used to view colour photographic prints, photomechanical reproductions and transparencies needs to provide adequate amounts of radiant power from all parts of the ultraviolet (UV) and visible spectrum to avoid distorting their appearance from that observed under commonly used sources of illumination, such as daylight. The UV content is important where fluorescent samples, which are excited in this region, are encountered – a phenomenon associated with many of the paper substrates on which images are reproduced, as well as with some of the dyes and pigments themselves.

To ensure consistency with previous editions of this International Standard, as well as with the majority of equipment in current use, the reference spectral power distribution specified in this International Standard is CIE illuminant D50. Many of the reasons for the selection of illuminant D50 in the first edition of this International Standard (ISO 3664:1975), as opposed to any other CIE daylight illuminant, are equally applicable today. In the development of the second edition of this International Standard (ISO 3664:2000), consideration was given to changing the reference illuminant to CIE F8, a 5 000 K illuminant more typical of fluorescent lamps. However, it was felt that this would provide only a minimal conformance advantage (as shown in Annex B), and the actual goal is for the illumination to simulate natural daylight.

Because it is very difficult to produce artificial sources of illumination that closely match the spectral power distribution of daylight, it is important that the tolerances specified within this International Standard provide a compromise between those required for lamp manufacturing purposes and those for consistent viewing. In this International Standard, three constraints apply which define the characteristics of the light falling on the viewing plane – one directly and two indirectly – and all three need to be met simultaneously if a viewing apparatus is to be in compliance.

The chromaticity, which directly defines the colour of the illumination at the viewing surface, is specified as that for illuminant D50, and the tolerance by a circle in the CIE 1976 Uniform Chromaticity Scale (UCS) diagram having a specified radius around that value. To establish the compliance of the spectral power distribution of the illumination to that of illuminant D50, the methods defined in CIE 13.3-1995 and ISO/CIE 23603 are both specified. One defines the colour rendering quality of a lamp and the other defines its ability to correctly predict metamers. Both requirements are important to the graphic technology and photographic industries. The virtual metamers for CIE illuminant D50 from ISO/CIE 23603 are used. In

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addition, based on experimental work described in Annex B, a practical tolerance of acceptability has been defined, alongside a Colour Rendering Index requirement.

The perceived tonal scale and colours of a print or transparency can be significantly influenced by the chromaticity and luminance of other objects and surfaces in the field of view. For this reason, ambient conditions, which will possibly affect the state of visual adaptation, need to be designed to avoid any significant effects on the perception of colour and tone, and immediate surround conditions also need to be specified. Such specifications are provided in this International Standard.

Experience in the industries covered by this International Standard has revealed the need for two levels of illumination:

— a high level for critical evaluation and comparison, and

— a lower level for appraising the tone scale of an individual image under illumination levels similar to those under which it will be finally viewed.

This International Standard specifies these two levels of illumination.

The higher level is essential to graphic technology where comparison is being made, such as between original artwork and proof, or to evaluate small colour differences between proof and press sheet in order to control a printing operation. It is effective in these situations because it enhances the visibility of any differences. The high level of illumination is also appropriate in photography when comparing two or more transparencies or when critically evaluating a single image to assess the darkest tones that can be printed.

Since, despite adaptation, the level of illumination has quite a significant effect on the appearance of an image, the lower level is required in order to appraise the image at a level more similar to that in which it will be finally viewed. Although it is recognized that quite a wide range of illumination levels can be encountered in practical viewing situations, the lower level chosen is considered to be fairly representative of the range encountered. For this reason, it is applicable to aesthetic appraisal, including the conditions for routine inspection of prints.

The viewing of transparencies is specified both for direct viewing and by projection. Additional conditions are also specified for those situations where transparencies are to be compared to a print. The particular surround specified for transparencies recognizes the way that a transparency needs to be viewed for optimum visibility of the dark tones, but acknowledges that practical viewing equipment is likely to have ambient conditions that introduce some viewing flare. The combination of surround and flare produce an appearance that is fairly representative of how the transparency will look in a typically lighted room.

Small transparencies are commonly evaluated in graphic technology by direct viewing. When it is necessary to view transparencies directly, these need to be viewed in accordance with the conditions specified for the particular situation. However, for some purposes, smaller transparencies are not viewed directly because the viewing distance for correct perspective and perception of detail is too small for visual comfort. Furthermore, when small transparencies are reproduced for publication or other purposes, they are usually enlarged. To make comparison easier, it is helpful to enlarge the transparency image when comparing it to the print. For these reasons, a viewing condition can be required that provides a magnified image when viewed at an appropriate distance.

Colour monitors are being used increasingly to display and view digital images in graphic technology and photography. In order to ensure consistency of assessment in this situation, it is important that the viewing conditions in which the monitors are placed be reasonably well specified. However, it is important to note that adherence to these specifications does not ensure that the monitor will match the hardcopy without provision of a defined colour transformation to the displayed image or use of proper colour management. This aspect of matching is outside the scope of this International Standard.

The specifications provided in this International Standard for images viewed on colour monitors are for images viewed independently of any form of hardcopy. Conditions for direct comparisons between hardcopy and softcopy (even where a suitable colour transformation has been applied) are outside the scope of this International Standard, which can be seen as being primarily relevant where successive viewing of hardcopy and softcopy takes place. ISO 12646 provides more detailed recommendations where direct comparison is

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required. When making such comparisons, it is generally desirable to view the colour monitor under the lower levels of ambient illumination specified in this International Standard and with the maximum level of luminance achievable and the hardcopy sample at the lower levels of illumination specified for printed matter in this International Standard (and their equivalent for transparencies). However, this will in turn affect the perceived tone and colourfulness of the hardcopy.

This International Standard meets the current needs of the graphic technology and photographic industries and minimizes differences between viewing equipment. It contains multiple specifications, each of which is appropriate to specific requirements. It is important that users ensure they employ the specification that is appropriate to their application.

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Graphic technology and photography — Viewing conditions

1 Scope

This International Standard specifies viewing conditions for images on both reflective and transmissive media, such as prints (both photographic and photomechanical) and transparencies, as well as images displayed in isolation on colour monitors.

This International Standard applies in particular to:

— critical comparison between transparencies, reflection photographic or photomechanical prints and/or other objects or images;

— appraisal of the tone reproduction and colourfulness of prints and transparencies at illumination levels similar to those for practical use, including routine inspection;

— critical appraisal of transparencies that are viewed by projection, for comparison with prints, objects or other reproductions; and

— appraisal of images on colour monitors that are not viewed in comparison to any form of hardcopy.

This International Standard is not applicable to unprinted papers.

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2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5-2, *Photography — Density measurements — Part 2: Geometric conditions for transmission density*

ISO 5-3, *Photography — Density measurements — Part 3: Spectral conditions*

ISO 13655, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*

ISO/CIE 23603:2005, *Standard method of assessing the spectral quality of daylight simulators for visual appraisal and measurement of colour*

CIE 13.3-1995, *Method of measuring and specifying colour rendering properties of light sources*

CIE 15-2004, *Colorimetry*

CIE 69-1987, *Methods of characterizing illuminance meters and luminance meters — Performance, characteristics and specifications*

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3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
chromaticity
property of a colour stimulus defined by its chromaticity co-ordinates, or by its dominant or complementary wavelength and purity taken together

[CIE 17.4-1987, 845-03-34]

3.2
colour rendering index
measure of the degree to which the psychophysical colour of an object illuminated by a test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation

[CIE 17.4-1987, 845-02-61]

3.3
correlated colour temperature
temperature of the Planckian radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions

[CIE 17.4-1987, 845-03-50]

3.4
hardcopy
representation of an image on a substrate which is self-sustaining and reasonably permanent

EXAMPLE Prints, transparencies.

3.5
illuminance
⟨at a point of a surface⟩ quotient of the luminous flux incident on an element of the surface containing the point by the area of that element

[CIE 17.4-1987, 845-01-38]

3.6
illuminant
radiation with a relative spectral power distribution defined over the wavelength range that influences object-colour perception

[CIE 17.4-1987, 845-03-10]

3.7
luminance
L_v
⟨in a given direction, at a given point of a real or imaginary surface⟩ quantity defined by the formula

$$L_v = \frac{\mathrm{d}^2 \phi_v}{\mathrm{d}A \times \cos\theta \times \mathrm{d}\Omega}$$

where

$\mathrm{d}^2\phi_v$ is the luminous flux transmitted by an elementary beam passing through the given point and propagating in the solid angle $\mathrm{d}\Omega$ containing the given direction;

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dA is the area of a section of that beam containing the given point;

θ is the angle between the normal to that section and the direction of the beam

[CIE 17.4-1987, 845-01-35]

3.8
luminous reflectance
ratio of the luminous flux reflected from a surface to the luminous flux incident on the surface

3.9
off-press proof
print produced by a method other than press printing, whose purpose is to show the results of the colour separation process in a way that closely simulates the results on a production press

3.10
on-press proof
print produced by press printing, using either a proof press or a production press, whose purpose is to show the results of the colour separation process in a way that closely simulates the results on a production press

3.11
original
scene or hardcopy from which image information is obtained using an image capture device in a reproduction process

NOTE As used in graphic technology, the original is typically a print or transparency and the capture device is usually an input scanner or, occasionally, a process camera. In photography, the term "original scene" is sometimes used.

3.12
print
two-dimensional hardcopy form of an image intended for viewing

NOTE In still photography and graphic technology, the term "print" is reserved for reflection hardcopy, a medium designed to be viewed by reflected light.

3.13
relative spectral power distribution
ratio of the spectral power distribution of a source or illuminant to a fixed reference value

NOTE The fixed reference value can be an average value, a maximum value or an arbitrarily chosen value of this distribution

3.14
softcopy
representation of an image produced using a device capable of directly representing different digital images in succession and in a non-permanent form

NOTE The most common example is a monitor.

3.15
source
primary emitter of electromagnetic radiation

3.16
surround
area adjacent to the border of an image which, upon viewing the image, can affect the local state of adaptation of the eye

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NOTE The surround, which can have a significant effect on the perceived tone and colour reproduction of an image, is not to be confused with any border immediately surrounding the image, such as any unprinted white substrate for reflection copy or the unexposed border present on many transparencies. For a colour monitor, the border will normally be dark grey or black, and hence the same as the surround. However, when simulating hardcopy, it will be similar to that hardcopy, both in terms of lightness and width.

3.17
transparency
two-dimensional hardcopy form of an image designed to be viewed by transmitted light

3.18
transparency illuminator
apparatus used for back illumination of a transparency

3.19
veiling flare
relatively uniform but unwanted irradiation in the image plane of an optical system, caused by the scattering and reflection of a proportion of the radiation which enters the system through its normal entrance aperture, where the radiation can be from inside or outside the field of view of the system

NOTE Light leaks in an optical system housing can cause additional unwanted irradiation of the image plane. This irradiation can resemble veiling flare.

3.20
veiling glare
light, reflected from an imaging medium, that has not been modulated by the means used to produce the image

NOTE 1 Veiling glare lightens and reduces the contrast of the darker parts of an image.

NOTE 2 In CIE 122-1996, the veiling glare of a cathode ray tube (CRT) display is referred to as ambient flare.

3.21
viewing flare
veiling glare that is observed in a viewing environment, but not accounted for in radiometric measurements made using a prescribed measurement geometry

NOTE The viewing flare is expressed as a percentage of the luminance of the adopted white.

3.22
virtual metamer
set of spectral radiance factors, not based on physical samples, which provide metameric matches for specific standard daylight illuminants

NOTE Virtual metamers are used to test and classify illumination sources which simulate daylight in accordance with the method provided in ISO/CIE 23603. This classification is accomplished by calculating the average of the colour differences obtained for these metamers between the illumination source in question and a CIE standard illuminant. Although it can be possible to construct physical realizations of some virtual metamers, the fact that they are not required to be real allows greater flexibility in their design.

4 Viewing condition requirements

4.1 General requirements

4.1.1 Applicability

Although 4.2 to 4.5 contain additional requirements specific to a variety of viewing applications, the requirements in this clause are general and apply to all viewing applications.

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The specific viewing applications are:

- conditions for critical comparison;
- conditions for practical appraisal of prints;
- conditions for viewing small transparencies by projection;
- conditions for appraisal of images displayed on colour monitors.

NOTE For ease of reference, each viewing condition described in this International Standard has been given an alphanumeric designation. This can be useful in describing or specifying conditions, e.g. "ISO 3664 viewing condition P2".

4.1.2 Viewing apparatus

To comply with this International Standard, the values specified shall be achieved at the surface of viewing. The specified relative spectral power distribution applies to the illuminated surface rather than to the source (or lamp) because the light from the source may be modified by reflecting and transmitting components of the apparatus, and the required relative spectral power distribution may be obtained from a mixture of light from different sources.

The source, image being viewed, and observer's eyes shall be positioned to minimize the amount of light specularly reflected toward the eyes of an observer on or near the normal to the centre of the viewing surface.

The surround of a print shall have a diffuse reflecting surface and shall have a CIELAB [1)] chroma value no greater than 2 relative to a perfect reflecting diffuser at the viewing surface, i.e. it shall appear neutral.

The surround of a transparency shall have a CIELAB chroma value no greater than 2 relative to the illuminating surface.

4.1.3 Spectral conditions for the reference illuminant

The relative spectral power distribution of the reference illuminant for both prints and transparencies shall be CIE illuminant D50, as defined in CIE 15-2004, Table T.1. This represents a phase of natural daylight having a correlated colour temperature of approximately 5 000 K. The chromaticity coordinates of illuminant D50 are $x_{10} = 0{,}347\ 8$ and $y_{10} = 0{,}359\ 5$ in the CIE chromaticity diagram, and $u'_{10} = 0{,}210\ 2$ and $v'_{10} = 0{,}488\ 9$ in the CIE 1976 Uniform Chromaticity Scale (UCS) diagram.

See Table 1.

NOTE 1 Chromaticity is specified for the CIE 1964 standard colorimetric observer to ensure compatibility with the method specified in ISO/CIE 23603, which is used to define the degree of compliance of the illumination to the reference illuminant specified in 4.2.2.

NOTE 2 The spectral power distribution specified in this International Standard corresponds to the spectral power distribution of measurement condition M1 specified in ISO 13655. ISO 13655 also specifies a measurement condition, M2, which adds a requirement that the radiation illuminating the sample pass through a UV-cut filter, which suppresses the UV content of the source radiation below 400 nm. This minimizes the effect of optical brightening agents on measured results. Consequently, the measured results obtained using measurement condition M2 will not correlate exactly with the colour appearance observed when the sample is viewed under D50 illumination.

4.1.4 Colour rendering index

The CIE general colour rendering index of the viewing surface shall be measured as specified in CIE 13.3-1995 and shall have a value of 90 or higher. In addition, the separate special colour rendering indices for samples 1 to 8, as specified in CIE 13.3-1995, shall each have a value of 80 or higher.

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1) See CIE 15-2004.

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Table 1 — Relative spectral power of reference illuminant D50

Wavelength nm	Relative power for illuminant D50	Wavelength nm	Relative power for illuminant D50
300	0,02	550	102,32
305	1,03	555	101,16
310	2,05	560	100,00
315	4,91	565	98,87
320	7,78	570	97,74
325	11,26	575	98,33
330	14,75	580	98,92
335	16,35	585	96,21
340	17,95	590	93,50
345	19,48	595	95,59
350	21,01	600	97,69
355	22,48	605	98,48
360	23,94	610	99,27
365	25,45	615	99,16
370	26,96	620	99,04
375	25,72	625	97,38
380	24,49	630	95,72
385	27,18	635	97,29
390	29,87	640	98,86
395	39,59	645	97,26
400	49,31	650	95,67
405	52,91	655	96,93
410	56,51	660	98,19
415	58,27	665	100,60
420	60,03	670	103,00
425	58,93	675	101,07
430	57,82	680	99,13
435	66,32	685	93,26
440	74,82	690	87,38
445	81,04	695	89,49
450	87,25	700	91,60
455	88,93	705	92,25
460	90,61	710	92,89
465	90,99	715	84,87
470	91,37	720	76,85
475	93,24	725	81,68
480	95,11	730	86,51
485	93,54	735	89,55
490	91,96	740	92,58
495	93,84	745	85,40
500	95,72	750	78,23
505	96,17	755	67,96
510	96,61	760	57,69
515	96,87	765	70,31
520	97,13	770	82,92
525	99,61	775	80,60
530	102,10	780	78,27
535	101,43	—	—
540	100,75	—	—
545	101,54	—	—

NOTE The wavelength specification has been extended beyond the normal visual range because of the need to consider brighteners or dyes which can fluoresce.

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4.1.5 Ambient conditions

The visual environment shall be designed to minimize interference with the viewing task. It is important to eliminate extraneous conditions that affect the appraisal of prints or transparencies, and an observer should avoid making judgements immediately after entering a new illumination environment because it takes a few minutes to adapt visually to that new environment.

Extraneous light, whether from sources or reflected by objects and surfaces, shall be baffled from view and from illuminating the print, transparency, or other image being evaluated. In addition, no strongly coloured surfaces (including clothing) should be present in the immediate environment.

NOTE The presence of strongly coloured objects within the viewing environment is a potential problem because they can cause reflections that cannot easily be baffled and that can influence viewer adaptation.

Walls, ceiling, floors and other surfaces that are in the field of view shall be baffled or coloured a neutral matt grey, with a reflectance of 60 % or less. It should be noted that it may be easier to minimize these problems by using a viewing booth, rather than designing an open area for viewing within a room. Such apparatus can also make it easier to meet the specification for surround conditions specified in 4.2.4 and avoid the excessive viewing flare which may otherwise cause problems on transparency illuminators. However, even with such apparatus, adaptation and avoidance of extraneous light still need to be carefully considered.

4.1.6 Maintenance

Manufacturers of viewing apparatus shall specify the average number of hours during which the apparatus is expected to remain within specification. The apparatus should include a time-metering device or some other mechanism for indicating degradation.

However, it is the responsibility of the user, both before and beyond this time limit, to undertake measurements as specified in Clause 5 to ensure compliance, unless it can be otherwise demonstrated that the equipment remains within tolerance.

4.2 Conditions for critical comparison (viewing conditions P1 and T1)

4.2.1 Applicability

This subclause specifies viewing conditions for the critical comparison between two (or more) copies of an image. The comparison is usually either between the original and its reproduction or between different copies of a reproduction, such as samples from a press run or multiple photographic prints. The images being compared may be on the same media (reflective or transmissive) or on different media (including photographic or photomechanical prints and on-press proofs or off-press proofs), or even between transmissive and reflective media, such as that pertaining when a transparency is compared to a proof of its printed reproduction. The high illumination levels specified permit more critical evaluation of colour and tone gradation in higher density areas, which may not be perceived under most practical viewing conditions.

The viewing conditions for critical comparison are defined as follows:

— P1: condition for viewing a print;

— T1: condition for viewing a transparency directly on an illuminator that has a diffusing screen (as opposed to viewing by projection).

Viewing condition T1 normally applies for transparencies larger than 10 cm × 10 cm; in graphic technology, it normally applies for smaller transparencies, too.

NOTE 1 In the graphic arts industry, the primary viewing application involves comparison, which requires that condition P1 be used. Tone reproduction under lower levels of illumination can also be important. In this case, it is advisable that condition P1 be supplemented by condition P2 or the expected actual viewing condition. The same viewing illumination spectral characteristics (those of D50) are specified for both conditions P1 and P2.

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NOTE 2 ISO 13655 provides for colorimetric measurements under several spectral conditions. One, identified as condition M1, has the same spectral power distribution as is used in this International Standard, and samples deemed to match colorimetrically under that measurement condition can reasonably be expected to match visually under the viewing conditions specified in this International Standard. However, samples deemed to match colorimetrically under conditions M0, M2 or M3 of ISO 13655 can only be expected to match visually under the viewing conditions specified in this International Standard when the samples contain no optical brighteners and/or fluorescent colorants.

4.2.2 Illumination

The illumination at the plane of viewing shall approximate that of CIE standard illuminant D50. It shall have u'_{10}, v'_{10} chromaticity coordinates within the radius of 0,005 from that specified in 4.1.3 and a colour rendering index as specified in 4.1.4.

When assessed using the method defined in ISO/CIE 23603, illumination at the plane of viewing shall have a visible range metamerism index of less than 1,0, and should have a visible range metamerism index of less than 0,5. For condition P1, when assessed using the method defined in ISO/CIE 23603, illumination shall have a UV range metamerism index of less than 1,5, and should have a UV range metamerism index (CIELAB) of less than 1,0. See Annex D for guidance in calculation of these criteria.

NOTE 1 No specification is provided for the UV emission of the illumination for condition T1. In practice, fluorescence is not an issue for photographic transparencies, and the diffusing surface of the illuminator normally absorbs the majority of any UV emission from the source.

NOTE 2 The inclusion of a UV blocking filter in the viewing illumination path can be useful if a visual comparison of samples is being made with samples determined to be a match using measurement condition M2 of ISO 13655. See Annex E for further discussion of this issue.

The categories to which the equipment conforms at the time of manufacture shall be displayed on the equipment.

4.2.3 Illuminance (P1)

The illuminance at the centre of the illuminated viewing surface area shall be (2 000 ± 500) lx, and should be (2 000 ± 250) lx. Any departures from complete uniformity shall gradually diminish from centre to edge. For a viewing area up to 1 m^2, the illuminance at any point within the illuminated area shall not be less than 75 % of the illuminance measured at the centre of the illuminated viewing surface area. For larger viewing areas, the lower limit shall be 60 %. The uniformity should be evaluated by measuring at least 9 points equally distributed on the viewing surface.

4.2.4 Surround and backing for reflection viewing (P1)

The surround and backing shall be neutral and matt. The surround shall have a luminous reflectance (ratio of the luminous flux reflected from a surface to the luminous flux incident on the surface) between 10 % and 60 %. For critical appraisal when viewing flare is a concern, a mid-grey of 20 % reflectance is recommended.

The specific value selected is based on available equipment and normal practice within various industry segments. However, whatever value is selected, it is important that when images are being compared in multiple sites, the surrounds for each be similar. The ratio of the surround reflectance shall be 1,0 (±0,2):1 for comparison between sites.

NOTE 1 A wide range of surround reflectances is permitted in this International Standard because of the diverse requirements and conditions of the users of viewing equipment. The majority of viewing equipment installed and available within the graphic arts community has surrounds with reflectances between 40 % and 60 %. The preferred surround for some photographic and colour management applications, where viewing flare is a particular concern, is approximately 20 %. The most important consideration is that images for a particular application/industry segment area be viewed under similar conditions.

The surround shall extend beyond the materials being viewed on all sides by at least 1/3 of their dimension, except where objects are being compared, in which case they may be positioned edge to edge.

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The backing should be consistent with what will be used in practice and shall be identified when communicating the viewing condition. ISO 13655 makes provision and provides specifications for both black and white backings. A backing identified as “black” or “white” shall meet the appropriate requirements defined in ISO 13655. A black backing should be used for viewing images that are measured using a black backing, e.g. when back printing is an issue. A white backing should be used for viewing images that are measured using a white backing, e.g. when they are colour managed based on white backing characterization data. The backing shall not extend beyond the materials being viewed.

NOTE 2 The above requirements can be met by appropriate finishing of the viewing surface or by introduction of masking devices.

4.2.5 Luminance at the surface of the transparency illuminator (T1)

The luminance at the centre of the illuminated surface of the transparency illuminator shall be (1 270 ± 320) cd/m^2, and should be (1 270 ± 160) cd/m^2. Any departures from uniformity shall gradually diminish from centre to edge, such that the luminance (measured normal to the surface) at any point within the luminous area is not less than 75 % of the luminance measured at the centre of the image plane.

4.2.6 Transparency illuminator diffusion characteristics (T1)

The transparency illuminator surface shall provide diffuse light such that the luminance of the surface measured at any angle between 0° and 45° from the normal shall not be less than 90 % of the luminance of the same point measured normal to the surface.

4.2.7 Transparency surround (T1)

The surround shall be at least 50 mm wide on all sides. It shall appear neutral compared to the source and shall have a luminance that is between 5 % and 10 % of that of the surface of the image plane of the illuminator in the direction of observation. A transparency mounted with an opaque border may be viewed without removing the mount.

NOTE This condition is similar to that specified for direct viewing of transparencies in the first edition of this International Standard (ISO 3664:1975). However, the first edition specified an “illuminated” surround when transparencies were compared to prints. The purpose of this surround was to effect a reduction in transparency contrast to facilitate comparison to prints. Unfortunately, this method of contrast reduction significantly reduces tonal differentiation in the dark tones of the image. With modern imaging systems, contrast reduction can be achieved through a variety of means that maintain shadow contrast. The illuminated surround approach could therefore result in a misleading interpretation of transparency shadow detail, particularly for low-key subjects. The dark surround has therefore been incorporated for all assessment conditions in this edition of this International Standard. In practice, this condition can be met by using an opaque black mask; such a mask will appear to have a luminance somewhat above absolute black because of ambient illumination falling on the mask.

4.2.8 Relationship between transparency luminance and print illuminance (P1 and T1)

For critical comparison between transparencies and reflecting materials, the illuminance at the reflecting material surface shall be that specified in 4.2.3, i.e. (2 000 ± 500) lx. The transparency illuminator shall have a luminance as specified in 4.2.5, i.e. (1 270 ± 320) cd/m^2. However, the combined tolerances shall be such that the ratio of the maximum luminance of the transparency illuminator to the maximum luminance of a perfectly reflecting and diffusing material, at the plane of the reflecting material, shall be 2,0 (±0,2):1. The maximum luminance by reflection from the perfectly reflecting and diffusing material is equal to the incident illuminance divided by π.

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4.3 Conditions for practical appraisal of prints, including routine inspection (viewing condition P2)

4.3.1 Applicability

The specifications in this subclause are applicable for the appraisal of tone reproduction of individual images, photographic image inspection or the judgement of prints. They are not appropriate for the simultaneous comparison of media, where colour matching is the primary concern, such as any comparison between proof and photomechanical print, transparency and proof (or print), or between different photographic prints and transparencies. The only exception is when comparing a print to a colour monitor because of the low luminance level exhibited by current monitors, but such comparisons are outside the scope of this International Standard, which only deals with appraisal of images on a monitor in isolation from hardcopy (see 4.5).

It should be noted that the relative spectral power distribution characteristics specified for P2 are exactly the same as those specified for condition P1. Therefore, images that match under the conditions of P1 will match under the conditions of P2. However, the reverse is not necessarily true, particularly if there are significant dark tonal areas involved.

Experience has shown that the high levels of illumination specified for P1 can give a misleading impression of the tone reproduction and colourfulness of an image, which will ultimately be viewed by the consumer in much lower levels of illumination. Images that appear quite acceptable when viewed at the higher levels of illumination may not appear satisfactory when viewed at more typical levels of illumination. To avoid this problem, the illumination level for inspection of photographic prints is often set arbitrarily, while many graphic technology users take proofs into lower illumination levels of unknown conditions in order to verify that their tone reproduction will prove acceptable in use. Because neither the level nor the characteristics of the illumination in these situations is controlled, this practice introduces uncertainties into the process and prevents effective communication.

The viewing conditions specified in this subclause are intended to minimize those problems. The viewing conditions specified are for the appraisal of tone reproduction, for photographic image inspection or judgement of prints under illumination levels that correspond to an office, library or a relatively brightly illuminated area in a residence. By appraising images under such conditions, it is possible to ensure that they provide a satisfactory tone reproduction. Such a judgement cannot be made unambiguously at the higher level of illumination specified for condition P1.

NOTE In the graphic arts industry, the primary viewing application involves comparison, which requires that level P1 be used. However, when it is important that tone reproduction that will be perceived under lower levels of illumination be assessed, it is advisable that P1 be supplemented by level P2 or the expected actual viewing condition. Both P1 and P2 have the same correlated colour temperature of D50.

4.3.2 Illumination

The illumination at the surface of viewing shall comply with that described in 4.2.2.

4.3.3 Illuminance

The illuminance at the centre of the viewing surface shall be (500 ± 125) lx. The illumination uniformity shall comply with that described in 4.2.3.

4.3.4 Surround and backing

The surround and backing shall be in compliance with 4.2.4 unless communicated otherwise to others involved in the production chain, in which case the reflectance of the surround and backing shall be specified.

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4.4 Conditions for viewing small transparencies by projection (viewing condition T2)

4.4.1 Applicability

The specifications for the equipment used for viewing a projected image of a slide on a screen are given in 4.4.2 to 4.4.8. These conditions are not to be confused with those normally used for viewing slides in a commercial projector, where the magnification is generally much greater and there is no intent to compare such images with reflection prints.

4.4.2 Illumination

The light emitted from the screen with an empty slide mount in the projector gate shall comply with that described in 4.2.2.

4.4.3 Luminance

The luminance at the screen in the direction of the observer shall be (1 270 ± 320) cd/m^2 when measured with an empty slide mount in the projector gate.

4.4.4 Uniformity of screen luminance

Any departure from uniformity of screen luminance shall be approximately radially symmetrical about the centre of the screen, the luminance gradually diminishing from the centre to the edges of the projected image of the open slide mount. When the screen is viewed at any angle up to 25° from the perpendicular to its surface, and at the normal viewing distance for the equipment, the luminance of any point within the image of the open slide mount shall be not less than 75 % of that at the centre. The screen on which the image is displayed shall exhibit no more speckle, scintillation or graininess than that exhibited by an untextured flat, matt, front-projection screen.

4.4.5 Surround

The surround shall comply with that described in 4.2.7.

4.4.6 Ambient light and veiling flare

Provisions shall be made for shielding the screen from ambient light. The surfaces of the ambient light shield(s) facing the screen shall be matt black.

Ambient light and veiling flare shall be such that, when evaluated with a test transparency conforming to 5.2, the luminance at the centre of the spot image on the screen shall not exceed 1 % of the maximum screen luminance for any point in the surrounding field.

4.4.7 Resolution

The resolving power of the optical system shall be such that, when evaluated with a test transparency conforming to 5.3, all patterns having a spatial frequency up to 40 line pairs per millimetre shall be resolved at any point in the projected image.

4.4.8 Distortion

The projection system shall not exhibit noticeable spatial distortion or cause noticeable chromatic distortion of the projected image.

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4.5 Conditions for appraisal of images displayed on colour monitors

4.5.1 Applicability

In order to ensure consistency of assessment of images viewed on colour monitors, it is important that the viewing conditions in which the monitors are placed be reasonably well specified. In the context of this International Standard, colour monitors include CRT monitors and other display technologies, e.g. liquid crystal display (LCD), plasma and rear projection.

However, it should be noted that the specifications provided in this International Standard are for images viewed independently of any form of hardcopy; conditions for direct comparisons between hardcopy and softcopy (even where a colour transformation designed to provide a colour match has been applied) are outside the scope of this International Standard. Thus, these specifications can be seen as being primarily relevant where successive viewing of hardcopy and softcopy takes place.

NOTE ISO 12646 provides more detailed recommendations where direct comparison is required.

4.5.2 Chromaticity

The chromaticity of the white displayed on the colour monitor should approximate that of D65. It shall have u'_{10}, v'_{10} chromaticity coordinates within the radius of 0,025 of $u'_{10} = 0{,}197\,9$ and $v'_{10} = 0{,}469\,5$ in the CIE 1976 Uniform Chromaticity Scale (UCS) diagram.

NOTE When viewed under the conditions specified in 4.5, the monitor itself will provide the primary adapting stimulus to the eye. The chromaticity of the white of the monitor is not too important in this situation, although many users prefer that the chromaticity of that white be close to that of D65. There is some evidence that, at the low luminance levels obtained with monitors, a chromaticity close to that of D65 provides a better evocation of white and, furthermore, such a chromaticity permits a higher level of luminance to be achieved with current display technology. However, if the monitor is to be directly compared with prints or transparencies, then the chromaticity of the white of the monitor needs to be close to that of the hardcopy to which it is being compared. This means that a colour monitor used for such a purpose needs to have a chromaticity close to illuminant D50. Such a chromaticity is within the tolerance specified in this International Standard. The specifications for comparing colour monitor to hardcopy are described in greater detail in ISO 12646.

4.5.3 Monitor luminance

The luminance level of the white displayed on the monitor shall be at least 80 cd/m^2, and should be at least 160 cd/m^2.

4.5.4 Ambient illumination

The level of ambient illumination shall be sufficiently low that the luminance of a perfect reflecting diffuser, placed at the position of the faceplate of the monitor, with the monitor switched off, is not greater than 1/4 of the monitor white point luminance. The level of ambient illumination should be sufficiently low that the luminance of a perfect reflecting diffuser, placed at the position of the faceplate of the monitor, with the monitor switched off, is not greater than 1/8 of the monitor white point luminance. These limits should also be achieved when measured in any plane which might affect the state of adaptation of the observer.

The correlated colour temperature of the ambient illumination shall be less than or equal to that of the monitor white point. If the level of ambient illumination approaches the higher limit specified in this subclause, the chromaticity of the illumination should be approximately the same as the white point of the monitor in order to minimize chromatic adaptation complications.

NOTE The level of ambient illumination needs to be significantly lower than the luminance level of the monitor white point. This is partly to ensure that the observer is reasonably adapted to the monitor, but primarily to ensure that the contrast range of the monitor is not significantly reduced by the effects of veiling glare.

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4.5.5 Surround condition

The area immediately surrounding the displayed image and its border shall be neutral, preferably dark grey or black, and of approximately the same chromaticity as the white point of the monitor. The luminance of the border should be ⩽ 20 % of the white point luminance, and preferably ⩽ 3 % of the white point luminance.

When the monitor is being used to visualize images which will be reproduced as hardcopy, the recommended lightness of any border displayed around the image will depend upon the comparison. In general, for comparison to prints, which may well be reproduced with a white border consisting of unprinted substrate, the border of the image should simulate the colour of the substrate; for comparison to transparencies, it should be dark. However, it is generally preferable that any such border be no more than 1 cm to 2 cm wide, even if it would normally be wider on the hardcopy reproduction.

4.5.6 Environmental conditions

The monitor shall be situated so there are no strongly coloured areas (including clothing) directly in the field of view or which may cause reflections in the monitor screen. Ideally, all walls, floors and furniture in the field of view should be grey and free of any posters, notices, pictures, wording or any other object which may affect the vision of the viewer.

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4.5.7 Veiling glare

Sources of veiling glare should be avoided as far as possible, since they significantly degrade the quality of the image. The monitor shall be situated so that no illumination sources, such as unshielded lamps or windows, are directly in the field of view or are causing discernible reflections from the surface of the monitor.

5 Test methods

5.1 Spectral measurements

To determine the colour rendering index of the illumination (as defined in 4.1.3) and the chromaticity and metameric index (as defined in 4.2.2), it is necessary to measure the spectral power distribution of the illumination. This requires measurement over the range 300 nm to 730 nm for conditions P1 and P2, and over the range 380 nm to 730 nm for conditions T1 and T2. The bandpass of the measuring instrument (spectroradiometer) shall be 5 nm or narrower. The sampling interval shall not be greater than the bandpass.

As in any measurement process, the measuring equipment should be regularly calibrated. In this case, the calibration of the spectroradiometer shall include assessment of veiling flare, linearity, wavelength accuracy and spectral power accuracy.

5.2 Illuminance and luminance

All illuminance or luminance measurements shall be made with a photometer meeting the requirements of CIE 69-1987, having the spectral responsivity of the CIE standard photopic photometric observer, $V(\lambda)$, and measuring an area having a diameter no greater than 1/20 of the shortest linear dimension of the illuminated surface area. For illuminance measurements, the photometer shall be cosine-corrected.

For projection-viewing apparatus, ambient light and veiling flare shall be evaluated with the aid of a test transparency that is clear, neutral and transparent everywhere, except for an opaque central circular spot producing an image with a diameter 1/10 of the smallest linear dimension of the projected opening in an open slide mount. Measurement shall be made perpendicular, within 7°, to the spot, and 35 cm from the screen.

The measurement should be made over an area not greater than 30 % of the opaque (black) spot diameter, approximately centred on the centre of the spot.

All measurements shall be conducted in the presence of environmental illumination that would normally exist when the apparatus is used.

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5.3 Resolution assessment for projection viewing apparatus

A test target shall be used which contains square wave resolution patterns varying in spatial frequency and with two mutually perpendicular orientations. The range of frequencies included should be at least 20 to 60 line pairs per millimetre and shall include 40 line pairs per millimetre. The dark bars of the test patterns shall have a visual diffuse transmission density, as defined in ISO 5-2 and ISO 5-3, at least 2,0 higher than the density of the transparent background. A pattern having a given spatial frequency shall be considered resolved if the sets of lines of the projected image of that pattern, oriented both radially to the centre of the field and tangentially to a circle about the centre, are clear enough to be counted with reasonable confidence. The concept of “reasonable confidence” is intended to indicate a level of confidence that is somewhere between complete confidence and no confidence at all. All resolution evaluations shall be made with the optical system set at the same focus. A low-power magnifying glass may be used.

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Annex A
(informative)

Summary of viewing conditions specified in this International Standard

Table A.1 summarizes the main requirements specified in this International Standard.

Table A.1 —Summary of viewing conditions specified in this International Standard

Viewing condition	Reference illuminant [a]		Illuminance/luminance		Colour rendering index in accordance with CIE 13.3-1995		Metamerism index in accordance with ISO/CIE 23603		Illumination uniformity (min:max)		Surround luminous reflectance/ luminance/ illuminance
	illuminant	chroma-ticity tolerance	illuminance lx	luminance cd/m²	general index	special indices for samples 1 to 8	visual	UV	surface: ⩽ 1 m × 1 m	surface: > 1 m × 1 m	
Prints Critical comparison (P1)	CIE illuminant D50	0,005	2 000 ± 500 (2 000 ± 250)[b]	—	⩾ 90	⩾ 80	C or better (B or better)[b]	< 1,5 (< 1)[b]	⩾ 0,75	⩾ 0,6	< 60 % (neutral and matt)
Transpa-rencies Direct viewing (T1)	CIE illuminant D50	0,005	—	1 270 ± 320 (1 270 ± 160)[c]	⩾ 90	⩾ 80	C or better (B or better)[b]	—	⩾ 0,75		5 % to 10 % of the luminance level (neutral and extending at least 50 mm on all sides)
Prints Practical appraisal (P2)	CIE illuminant D50	0,005	500 ± 125	—	⩾ 90	⩾ 80	C or better (B or better)[b]	< 1,5 (< 1)[b]	⩾ 0,75		< 60 % (neutral and matt)
Transpa-rencies Projection viewing (T2)	CIE illuminant D50	0,005	—	1 270 ± 320	⩾ 90	⩾ 80	C or better (B or better)[b]	—	⩾ 0,75		5 % to 10 % of the luminance level (neutral and extending at least 50 mm on all sides)
Colour monitors	CIE illuminant D65	0,025	—	> 80 (> 160)[b]	Not applicable		Not applicable		Not applicable		Neutral, and dark grey or black [d]

[a] Specifies the relative spectral power distribution of the reference illuminant, except for colour monitors, in which case it specifies the chromaticity of the white point of the monitor. Permitted tolerances in chromaticity, from that of the reference illuminant, are specified at the plane of viewing, in accordance with the 1976 u'_{10}, v'_{10} UCS system.

[b] Recommended value given in parentheses.

[c] Recommended value given in parentheses. When comparing a transparency to a print, the ratio of the luminance of the transparency illuminator to the equivalent illuminance of the print viewing surface shall be 2,0 (± 0,2):1.

[d] Recommended ambient illumination for colour monitors: ⩽ 32 lx. Required ambient illumination for colour monitors: ⩽ 64 lx.

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Annex B
(informative)

Experimental data leading to selection of metamerism indices and reference illuminant for this International Standard [2)]

B.1 General

In order to establish a suitable reference illuminant for this International Standard, as well as to determine tolerances which are both acceptable and practical, a good deal of experimental work was carried out. The objective of the work was threefold:

— to determine which reference illuminant would be most appropriate for specifying viewing conditions for the evaluation of hardcopy images for both graphic technology and photography;

— to define the most appropriate measures of acceptability between this reference illuminant and real sources (together with any other components of the viewing environment); and

— to establish suitable tolerances for these measures.

Since it was considered important that any tolerances specified not be unreasonably stringent, a small number of practical sources were studied rather extensively. Subsequently, the work was extended to verify that a reasonably large number of existing viewing apparatus, in use in industry, were not significantly deviant from these tolerances, although it would not be a concern if many were somewhat outside. Since much of this viewing apparatus had been in use for some time, this would not be considered unacceptable. It is inevitable that in such a situation many viewing environments would be due to be updated or need to have their sources replaced. It would be hoped, and expected, that such a situation would result in the availability of sources of viewing apparatus that are more consistent with one another than with older equipment.

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B.2 Reference illuminant and acceptability tolerances

In the first edition of this International Standard (ISO 3664:1975) the reference illuminant had been specified as D50 and the acceptability tolerances had been specified by a limit on the permitted chromaticity deviation from D50, together with colour rendering indices as defined by CIE 13.3-1995. However, in the intervening years, various workers had expressed reservations about this specification for quite different reasons. Many practical users had been heard to comment on the wide variation in colour of the illumination they perceived between different apparatus that were assumed to meet the specification of the first edition of this International Standard and, as a result of this, it was considered that the specification of the tolerance in chromaticity was therefore in need of some reduction. Various research workers had noted that the media encountered in the industries for which this International Standard was appropriate were far more metameric than had previously been the case. The colour rendering index (which simply measures the difference in colour for eight Munsell samples as they would appear under both test and reference illuminants) provided no indication that different apparatus conforming to this specification would render such practical metamers in a similar way. Furthermore, it had been suggested that since most viewing apparatus used fluorescent tubes for simulating the reference illuminant, they could not be spectrally similar to D50; supporters of this position concluded that a new reference illuminant was therefore more appropriate because of the metamerism described earlier.

2) This annex has been carried forward, with only minor editorial changes, from the second edition of this International Standard (ISO 3664:2000) for historical and informative reasons.

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At the time this revision was started, proposals had already emanated from the USA (though not finally agreed nationally) to reduce the tolerance on chromaticity, replace the reference source with F8 (a relative spectral power distribution defined by CIE as "typical" of fluorescent tubes with a chromaticity the same as D50) and add a "band method" to reduce the incidence of metamerism.

It was felt that there was substantial justification for considering these proposals, although it was agreed that it was desirable to undertake some experimental work to verify their acceptability. It was also noted that the "band method" was not supported by CIE who had, in 1981, published a procedure for verifying the acceptability of daylight simulators, which provided a set of theoretical metamers for each of the three reference illuminants, D55, D65 and D75, and specified a procedure for calculating a metamerism index [3].

B.3 Metamerism index

The CIE method specifies eight theoretical metamers; that is, the relative spectral power distribution for colours which match (thereby giving a colour difference of 0) for a specified illuminant and observer. Five of these are metameric in the visible region of the spectrum, the other three are fluorescent samples which are metameric with respect to the UV radiation emitted by the source. The specified procedure requires measurement of the relative spectral power distribution of the test source and calculation of the tristimulus values for these metamers for both the test and reference source, normalized by area in accordance with Equation (B.1) so that the assessment is independent of the absolute level of illumination.

$$S_{\text{n}}(\lambda) = \frac{100\, S(\lambda)}{\sum_{400}^{700} S(\lambda)\bar{y}_{10}(\lambda)\Delta\lambda} \tag{B.1}$$

where

y_{10} is the CIE 1964 Supplementary Standard Colorimetric Observer Y10 function;

λ is the wavelength;

S is the irradiance;

S_{n} is the normalized irradiance;

$\Delta\lambda$ is the wavelength interval.

If the test source has a different relative spectral power distribution from the reference illuminant, the metamers are likely to fail to match under the former; thereby giving rise to a colour difference between each pair of metamers. The magnitude of this difference will depend upon the differences between the relative energies of the test and reference illuminants. The CIE procedure then requires that the differences be averaged to produce two indices, one for the visible region and one for the UV region. A category scale is defined which ranks the test source, covering the range from A (best) to E (worst).

3) Subsequent to the publication of the previous edition of this International Standard (ISO 3664:2000), the theoretical metamers for D50 that it included were published as part of CIE 51.2-1999, which was later superseded by ISO/CIE 23603:2005.

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B.4 Experimental work

The experimental work undertaken initially was divided into three stages. The first was to evaluate whether there was any advantage in using F8 as the reference illuminant. The second was to determine whether the metamers in CIE 51.2-1999 provided reasonable correlation with the differences anticipated for practical metamers found in practice. The third was to determine the effect of the standard colorimetric observer selected. (The method specified in CIE 51.2-1999 uses the 1964 Supplementary Standard Colorimetric Observer, whereas it is common practice in the graphic technology and photograph industries to use the 1931 Standard Colorimetric Observer).

In order to make this evaluation, two additional sets of metamers were calculated, derived from practical samples.

For the first set of metamers, the reference consisted of the spectral reflectance data listed in ANSI CGATS TR 001-1995 for the 928 colours defined in ISO 12642. [These are effectively the colours produced when the data set is printed in accordance with the U.S. Specifications for Web Offset Publications (SWOP)]. The metamers to the SWOP patches were calculated for the cyan, magenta and yellow dyes of a continuous tone dye diffusion proofing printer, using a tristimulus matching algorithm. Three reference illuminant and observer combinations were used to derive three sets of metameric matches (D50/CIE 1964 Supplementary Standard Colorimetric Observer, F8/CIE 1964 Supplementary Standard Colorimetric Observer, and D50/CIE 1931 Standard Colorimetric Observer). The metamers calculated were defined such that they had a colour difference (ΔE^*_{ab}) of less than 0,02.

The reference for the second set of metamers consisted of spectral reflectances for eight colour patches printed with offset inks in accordance with ISO 12647-2 (paper type 1). The metamers of these printed patches were calculated using a special matching algorithm with eight sets of cyan, magenta and yellow colorants belonging to the imaging systems shown in Table B.1.

Six commercial fluorescent lamps (labelled A to F), all nominally D50 simulators, were measured and evaluated using all three sets of metamers described above (the set provided by McCamy, the set based on the SWOP printing, and the set based on ISO 12647-2). Tables B.2 and B.3 summarize the results of these calculations. The deviation in chromaticity of the lamps from D50, calculated using the CIE 1976 Uniform Chromaticity Scale, is included in the first column of Tables B.2 and B.3. It was proposed, when this revision was started, that the tolerance be defined as a circle of radius 0,005 centred on the chromaticity of D50. It should be noted that lamps C and F do not meet the chromaticity recommendation.

Each table contains the CIE visible range metamerism index (MI_{VIS}) based on the McCamy metamers (the average colour difference for the five metamers). As described in CIE 51.2-1999, the MI_{VIS} is converted to a category scale, in which a “C” has a value ranging from 0,5 to 1,0, and a “D” ranging from 1,0 to 2,0. These results show that most lamps fell within the category “C” (proposed as the minimum in this specification), but that two of them were outside this criteria.

Also shown in Tables B.2 and B.3 are the values for the average and maximum ΔE^*_{ab} encountered with each practical data set. Comparing the metameric index MI_{VIS} with the metameric differences obtained with different imaging systems, it may be seen that the index values fall between the average and the maximum colour differences. The “artificial” metameric pairs used for the index calculation may therefore be regarded as valid indicators of metameric differences based on the comparison with differences occurring with real imaging systems.

The testing with the metamers based on the 928 SWOP samples was also extended to derive two additional sets of metameric matches for F8/CIE 1964 Supplementary Standard Colorimetric Observer, and D50/CIE 1931 Standard Colorimetric Observer. Again, the metamers calculated were defined such that they had a colour difference (ΔE^*_{ab}) of less than 0,02. Tables B.4 and B.5 show these data. (It should be noted that although the MI_{VIS} and category data are shown in each table, these values are only calculated for D50 and the CIE 1964 Supplementary Standard Colorimetric Observer as defined in CIE 51.2-1999.)

The average ΔE^*_{ab} statistics were similar whether D50 or F8 was taken as the reference (with the CIE 1964 Supplementary Standard Colorimetric Observer), and there was no consistent change in deviation between the two sets of results. The magnitude of the values was generally larger for the 1931 Standard Colorimetric Observer, but this was not unexpected; it has been reported before.

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However, based on the 928 SWOP samples, the relative ranking between the lamps was very similar regardless of which illuminant or observer was taken as the reference (see Tables B.3, B.4 and B.5). The worst three lamps were, in ascending order, F, then A, then C, while the ranking of lamps D, B and E varied slightly. This ranking was the same when the proposed CIE D50 metamers were used. For this reason, it was decided to continue to specify D50 as the reference illuminant in this International Standard to enable consistency with existing products and to use the CIE method with the metamers proposed by McCamy. It was accepted that the experimental data (despite the fact that it is fairly extensive in itself) was fairly minimal in terms of the possible variations which may be encountered in practice and more data would always be welcome. When the data for the eight metamers based on the eight colour patches were subsequently provided, it confirmed the view, as described earlier, that the CIE method (based on illuminant D50) was robust enough for application in this International Standard. On the basis of the proposals made in this International Standard, only three of the lamps tested would be acceptable. C would fail because of its chromaticity, A because of its metamerism index and F on both counts. However, it is probable that the first of these lamps could easily be made acceptable by suitable design of the apparatus. This "pass" rate was considered acceptable in the interest of minimizing the difference between products, as requested by many users, and led to this specification being confirmed. Support was given to this when data was supplied showing that a number of Japanese lamps, not tested in this study, all conformed to the specifications proposed.

As a final validation of the proposals made in this specification, 61 viewing apparatus were measured *in situ*. It was found that only 11 % fully met the chromaticity, colour rendering and metamerism index criteria. Another 17 % met the latter two but failed slightly on chromaticity. 13 % met the chromaticity and colour rendering specification, but failed slightly on the metamerism index. 7 % met the metamerism index and chromaticity criteria but failed slightly on colour rendering. The remaining 52 % failed on at least two criteria, but in many cases the deviations in both cases were relatively small.

Given that the maintenance schedule on these units was unknown, it was this data that served to provide confidence in the specification proposed. Given the requirement by the industry that deviations between the viewing apparatus be reduced, simply producing a specification that included all current apparatus that met the specification of the first edition of this International Standard would be rather pointless. By reducing the chromaticity tolerance from that required in the first edition of this International Standard and adding the metamerism index, the industrial requirements should, at least in part, be met. Whilst it is a guess, it seems likely that the number of these existing units fully meeting the specification could be significantly increased by cleaning and replacement of lamps. Others could be brought into line by suitable modification of the apparatus itself (reflectors, diffusers, etc). Most importantly, however, in view of the fact that lamps exist with satisfactory properties, equipment vendors can be expected to modify their designs to meet the new specification. The one remaining question is whether the lamp samples measured are taken from batches with large or small distributions of the various criteria, although there is no reason to believe that those selected are atypical.

Thus, users who wish to improve communication by reducing the deviation between their units and others can choose to try to modify existing apparatus or purchase new apparatus. This needs to be the compromise between user requirements and practical production that is so important in an International Standard. Of course, at the next revision we may find that production has improved such that we can further tighten the specification – only time will tell.

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Table B.1 — Imaging systems used to assess the metamerism of light sources

Process	Device
Electrophotography (dry toner)	Canon CLC 800 Xerox DocuColor 40
Electrophotography (liquid toner)	Indigo E-Print 1000
Ink jet (continuous)	Scitex Iris
Ink jet (solid)	HP Design Jet 750
Thermal transfer (dye sublimation)	Tektronix Phaser 440
Silver halide	Fuji Pictrography 3000
Photomechanical	Fuji Color-Art

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Table B.2 — Matched for D50, CIE 1931 Standard Colorimetric Observer, eight imaging systems, eight patches

Lamp (chromaticity difference)	CIE 51 MI_{VIS} [a]	CIE 51 category	Metameric sample difference [b]	
			Average ΔE^*_{ab}	Maximum ΔE^*_{ab}
A (0,003)	1,15	D	0,50	1,45
B (0,005)	0,88	C	0,42	0,91
C (0,008)	0,97	C	0,59	1,33
D (0,001)	0,73	C	0,55	1,34
E (0,002)	0,89	C	0,48	1,20
F (0,007)	2,42	E	1,60	3,87
F8	0,63	C	0,29	0,87

[a] Values refer to the CIE 1964 Supplementary Standard Colorimetric Observer.

[b] Values refer to the CIE 1931 Standard Colorimetric Observer.

Table B.3 — Matched for D50, CIE 1964 Supplementary Standard Colorimetric Observer, 928 patches

Lamp (chromaticity difference)	CIE 51 MI_{VIS} [a]	CIE 51 category	Metameric sample difference [a]	
			Average ΔE^*_{ab}	Maximum ΔE^*_{ab}
A (0,003)	1,15	D	0,94	1,75
B (0,005)	0,88	C	0,72	1,66
C (0,008)	0,97	C	0,74	1,69
D (0,001)	0,73	C	0,65	1,81
E (0,002)	0,89	C	0,59	1,67
F (0,007)	2,42	E	1,20	3,06
F8	0,63	C	0,34	1,67

[a] Values refer to the CIE 1964 Supplementary Standard Colorimetric Observer.

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Table B.4 — Matched for F8, CIE 1964 Supplementary Standard Colorimetric Observer, 928 patches

Lamp (chromaticity difference)	CIE 51 MI_{VIS} [a]	CIE 51 category	Metameric sample difference [a]	
			Average ΔE^*_{ab}	Maximum ΔE^*_{ab}
A	1,15	D	0,97	1,73
B	0,88	C	0,79	1,66
C	0,97	C	0,87	2,10
D	0,73	C	0,60	1,81
E	0,89	C	0,58	1,67
F	2,42	E	1,21	2,83
D50	—	—	0,33	1,78

[a] Values refer to the CIE 1964 Supplementary Standard Colorimetric Observer.

Table B.5 — Matched for D50, CIE 1931 Standard Colorimetric Observer, 928 patches

Lamp (chromaticity difference)	CIE 51 MI_{VIS} [a]	CIE 51 category	Metameric sample difference [b]	
			Average ΔE^*_{ab}	Maximum ΔE^*_{ab}
A	1,15	D	1,19	2,91
B	0,88	C	0,84	1,88
C	0,97	C	0,94	2,02
D	0,73	C	0,76	2,26
E	0,89	C	0,81	2,58
F	2,42	E	1,38	3,03
F8	0,63	C	0,43	1,88

[a] Values refer to the CIE 1964 Supplementary Standard Colorimetric Observer.

[b] Values refer to the CIE 1931 Standard Colorimetric Observer.

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Annex C
(informative)

Guidelines for judging and exhibiting photographs

C.1 General

The subjective impression produced by photographs that are judged for contests or juried exhibitions is of particular importance. It follows that photographs intended for such purposes should be optimized for a particular known viewing condition. The viewing conditions specified in this International Standard are appropriate for this application, but other considerations have led to the use of somewhat wider tolerances in certain directions and illumination levels that, at first glance, might seem inappropriate.

The preferred illumination levels for judging and exhibition are those specified for conditions P1, T1 and T2. The higher illumination level is chosen to allow maximum utilization of the density range and colourfulness capabilities of output media, particularly for judging. Prints and transparencies optimized for these illumination levels will appear rather dark when viewed under typical indoor illumination, but photographers produce the darker images specifically for contests. The feeling is that the increase in "impact" resulting from the larger dynamic range is more important than having the prints look perfect under typical indoor illumination. It is highly desirable, therefore, that illumination levels similar to those specified in this International Standard for viewing conditions P1, T1 and T2 be adhered to for judging. For exhibition, it may be impractical to achieve the high levels of illumination required, and lower levels are acceptable.

Another practical consideration concerns the relative spectral power distribution of the illumination. The human visual system is excellent at adapting to the correlated colour temperature of illumination sources which approximate a Planckian radiator between 2 800 K and 6 500 K. Along this locus, typical photographic materials exhibit larger perceptual shifts due to sources failing to approximate a Planckian radiator than from changes in correlated colour temperature. This is particularly true for sources which emit sharp spectral lines. A fluorescent source may have exactly the same chromaticity as a particular Planckian source, but a photographic material may appear substantially different under the two sources.

The purpose of the metamerism and colour rendering index requirements in this International Standard is to minimize the likelihood of substantial changes in appearance due to different source spectral power distributions. If the viewing condition recommendations in this International Standard are adhered to, metamerism should be minimized and colour rendering should be appropriate. Unfortunately, many small photographic associations do not have access to lighting equipment that meets these strict requirements. It is therefore necessary to establish in which directions tolerances can be extended with minimal impact if practical considerations impose derogations from this International Standard.

In the photographic community, experience has indicated that the smallest effect on the perception of photographs results from allowing the correlated colour temperature to decrease. Tungsten sources can be filtered to produce excellent 5 000 K illumination, but there is a financial cost due to the filters required and the fact that more powerful sources are needed to produce the same illumination level. Fluorescent sources designed to meet the metamerism and colour rendering index requirements of this International Standard are also expensive, and fluorescent sources tend to be diffuse. Because tungsten sources produce more directional illumination, they can be positioned to minimize surface reflections, thus affording the best view of prints that have a high dynamic range.

The result of all these considerations is that the sources preferred for judging photographic prints are moderately directional tungsten or filtered tungsten sources with correlated colour temperatures between 2 800 K and 5 000 K. The use of filtered tungsten minimizes metamerism and colour rendering problems, and differences in correlated colour temperature are dealt with by the adaptation of the human visual system. Tungsten and filtered tungsten sources are also used for projected transparencies. Fluorescent sources which meet the requirements of this International Standard are preferred for the direct viewing of transparencies, where diffuse illumination is desirable.

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C.2 Recommendations

Table C.1 summarizes the recommendations for the judging and exhibition of photographs. These recommendations assume that comparisons will be made only of similar media under the same illumination and that observers will adapt to the illumination. If a non-standard correlated colour temperature or illumination level is used, it should remain constant for all evaluations conducted. If prints and transparencies are to be compared, non-standard illumination should be avoided to the greatest extent possible. Any comparisons that involve different effective correlated colour temperatures or illumination levels should be successive, and observers should be given sufficient time to adapt to the illumination before being allowed to view the photograph. In addition, the correlated colour temperature of any ambient illumination present when transparencies are viewed should be less than or equal to the correlated colour temperature of the viewing illumination.

Table C.1 — Recommendations for viewing conditions for judging and exhibiting photographs

Material	Recommended viewing conditions
Judging	
Photographic prints	Condition P1 with 0°/45° viewing geometry, but the correlated colour temperature can be as low as 2 800 K if tungsten sources are used [a].
Transparencies (direct viewing)	Condition T1 (diffuse illumination).
Transparencies (projection viewing)	Condition T2, but the correlated colour temperature can be as low as 2 800 K if tungsten sources are used [b].
Exhibiting	
Photographic prints	Condition P1 with 0°/45° viewing geometry, but the correlated colour temperature can be as low as 2 800 K if tungsten sources are used [a], and the illuminance level can be as low as 375 lx.
Transparencies (direct viewing)	Condition T1 (diffuse illumination), but the correlated colour temperature can be as low as 2 800 K if tungsten sources are used [a], and the luminance level can be as low as 240 cd/m^2, or 1 000 times the veiling glare luminance, whichever is greater [c].
Transparencies (projection viewing)	Condition T2, but the correlated colour temperature can be as low as 2 800 K if tungsten sources are used [a], and the luminance level can be as low as 40 cd/m^2, or 1 000 times the veiling glare luminance, whichever is greater [b].

[a] With sources at correlated colour temperatures other than 5 000 K, the metamerism and colour rendering index qualifications described in this International Standard are not applicable. In such cases, the user needs to rely on the similarity of the tungsten source relative spectral power distribution to that of a theoretical Planckian radiator. If the relative spectral power distributions are sufficiently similar, the chromaticities, metameric differences and colour rendering will also be similar.

[b] The veiling glare luminance in a typical projection viewing situation will be approximately 0,3 times the ambient light illuminance incident on the projection screen.

[c] The veiling glare luminance in a typical direct viewing situation will be approximately 0,001 6 times the ambient light illuminance incident on the illuminator surface.

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Annex D
(informative)

Spectral power distribution conformance testing

D.1 General

This International Standard specifies six related, but independent, requirements that illumination systems used for viewing booths are required to meet. Four of these are based on the analysis of the relative spectral power distribution of the illumination system. The other two are based on integrated intensity measurements (illuminance level and uniformity). Although integrated intensity measurements can be derived from spectral measurements, this would require absolute calibration of the spectral measurement data and therefore is probably best accomplished with other (simpler) instrumentation.

This annex focuses on the steps necessary to confirm conformance with the four spectrally-based criteria (given that appropriate measurements are completed), which are:

— chromaticity aim and tolerance (see D.4.1);

— colour rendering index, general and special (see D.4.2);

— visible metamerism index (see D.4.3);

— UV metamerism index (see D.4.4).

It provides worked examples of each by utilizing CIE illuminants D55 and F8 as test sources to simulate the reference D50 illuminant. Both D50 and D55 are taken from CIE 15-2004, Table T.1, and F8 is taken from CIE 15-2004, Table T.6, with the added assumption that F8 has no energy below 380 nm.

D.2 Measurement instrumentation requirements

To ensure that the evaluations of the four criteria are properly correlated with each other, they should be accomplished using a common set of measurement data. This requires that the instrument used be capable of collecting data from 300 nm to 780 nm and reporting these data corresponding to measurements made at a data interval of 5 nm with a triangular bandpass and with a half-power width of 5 nm. These measurements can be accomplished using an instrument that collects incident energy directly using a cosine corrected (Lambertian) diffuser (see IEC 61966-2-1) or using a telescopic spectrophotometer that measures energy reflected from a reference diffuse (Lambertian) surface. Unfortunately, there is a limited selection of instruments capable of making such measurements, and care needs to be exercised in the selection of equipment to be used.

D.3 Data collection

Regardless of the instrumentation used, care needs to be exercised to ensure that the viewing equipment is measured in the particular configuration in which it is used. That means that the viewing booth enclosure (or lack of an enclosure) is included in the measurement configuration because the energy arriving at the viewing surface may include energy reflected from the enclosure, as well as energy arriving directly from the luminaire.

For an instrument that measures the incident energy directly, the collection diffuser should be placed at the middle of the intended viewing surface and as close as possible to the plane upon which the elements to be viewed will lie. The axis of the collection system should be perpendicular to the intended viewing surface.

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For a telescopic instrument that measures energy reflected from a reference surface, the reference surface should be placed in the plane of the intended viewing surface. The reference surface should be diffuse and its reflectance should be spectrally neutral. Where there is any identified variation in spectral reflectance of the reference surface, this variation can be included by dividing the measurement data (wavelength by wavelength) by the known reflectance of the reference surface. The measuring instrument should be placed and oriented similarly to the position and orientation of a typical observer viewing the reference surface. Multiple measurements should be made and averaged to minimize data noise. Once the raw data is averaged and any instrument or reference surface corrections are applied, it should be adjusted to be equivalent to data collected at 5 nm intervals with a triangular bandpass of 5 nm. ISO 13655 provides guidance on techniques for such data adjustment.

Before using the data collected and adjusted as described above, it should be normalized to bring it into the correct range for some of the subsequent steps. This is accomplished by computing the CIE Y value based on either the CIE 1931 standard observer (CIE 15-2004, Table T.4) or the 1964 standard observer (CIE 15-2004, Table T.5) and dividing each of the measured energy values by the value of Y. The choice of the normalizing constant depends on which tristimulus values will be computed for later use. It is important to use the same wavelength range for the normalization as will be used for the subsequent tristimulus computations. Ranges will be either 380 nm to 780 nm or 400 nm to 700 nm.

D.4 Computation

D.4.1 Chromaticity

The suggested first computation to be made is the chromaticity and its comparison to the chromaticity aim and tolerance. The reference document for calculation of chromaticity is CIE 15-2004. The steps involved are as follows.

Using the CIE 1964 (10°) colour matching functions given in CIE 15-2004, Table T.5, and the normalized energy data of step 3 using the range 380 nm to 780 nm, determine the CIE X, Y, Z values. These values are not normalized by a reference value and so are used directly as computed. The exact computation of these values is as shown in Equations (D.1) to (D.4):

$$X = k \cdot \sum_{\lambda} S_{\lambda} \cdot R_{\lambda} \cdot \overline{x_{\lambda}} \tag{D.1}$$

$$Y = k \cdot \sum_{\lambda} S_{\lambda} \cdot R_{\lambda} \cdot \overline{y_{\lambda}} \tag{D.2}$$

$$Z = k \cdot \sum_{\lambda} S_{\lambda} \cdot R_{\lambda} \cdot \overline{z_{\lambda}} \tag{D.3}$$

$$k = \frac{100}{\sum_{\lambda} S_{\lambda} \overline{y_{\lambda}}} = \frac{100}{Y} \tag{D.4}$$

The chromaticity coordinates are computed as shown in Equations (D.5) to (D.7):

$$x = \frac{X}{X + Y + Z} \tag{D.5}$$

$$y = \frac{Y}{X + Y + Z} \tag{D.6}$$

$$z = \frac{Z}{X + Y + Z} \tag{D.7}$$

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The chromaticity coordinates are converted to the 1976 u'_{10}, v'_{10} chromaticity coordinates using Equations (D.8) and (D.9):

$$u'_{10} = \frac{4X_{10}}{X_{10} + 15Y_{10} + 3Z_{10}} \tag{D.8}$$

$$v'_{10} = \frac{9Y_{10}}{X_{10} + 15Y_{10} + 3Z_{10}} \tag{D.9}$$

The error in chromaticity is determined using Equations (D.10) to (D.12).

The aim chromaticity for D50 is $u'_{10} = 0{,}210\,2$ and $v'_{10} = 0{,}488\,9$.

The computed chromaticity for D55 is $u'_{10} = 0{,}205\,1$ and $v'_{10} = 0{,}481\,7$.

The computed chromaticity for F8 is $u'_{10} = 0{,}211\,0$ and $v'_{10} = 0{,}489\,0$.

The error in chromaticity is:

$$\sqrt{\left(\left(u_{\text{actual}} - u_{\text{aim}}\right)^2 + \left(v_{\text{actual}} - v_{\text{aim}}\right)^2\right)} \tag{D.10}$$

For D55, the error is:

$$\sqrt{(-0{,}005\,1)^2 + (-0{,}007\,2)^2} = 0{,}008\,8 \tag{D.11}$$

For F8, the error is:

$$\sqrt{(-0{,}000\,8)^2 + (-0{,}000\,1)^2} = 0{,}000\,8 \tag{D.12}$$

In accordance with 4.2.2, this error shall be less than 0,005. Consequently, based on the chromaticity criteria, this means that D55 fails to meet the requirements of this International Standard, whereas F8 meets the requirements of this International Standard.

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D.4.2 Colour rendering index

The reference document for the calculation of the colour rendering index is CIE 13.3-1995.

Using the CIE 1931 (2°) colour matching functions given in CIE 15-2004, Table T.4, and the sample reflectance factors given in CIE 13.3-1995, Table 1, the CIE X, Y, Z, u, and v values for colours 1 to 8 need to be determined, as shown in Equations (D.13) and (D.14) (these values are normalized to $Y = 100$):

$$u = \frac{4X}{X + 15Y + 3Z} \tag{D.13}$$

$$v = \frac{6X}{X + 15Y + 3Z} \tag{D.14}$$

For the two light sources being tested, using the u and v values, c_i and d_i are computed for the light source and the eight metameric reflectance samples, as shown in Equations (D.15) and (D.16):

$$c = \frac{(4 - u - 10v)}{v} \tag{D.15}$$

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$$d = \frac{(1{,}708v + 0{,}404 - 1{,}481u)}{v} \tag{D.16}$$

A chromatic adaption correction to the chromaticities (u, v) of the data associated with the two test sources is computed as shown in Equations (D.17) and (D.18):

$$u' = \frac{10{,}872 + 0{,}404\frac{c_r}{c_t}c_k - 4\frac{d_r}{d_t}d_k}{16{,}518 + 1{,}481\frac{c_r}{c_t}c_k - \frac{d_r}{d_t}d_k} \tag{D.17}$$

$$v' = \frac{5{,}520}{16{,}518 + 1{,}481\frac{c_r}{c_t}c_k - \frac{d_r}{d_t}d_k} \tag{D.18}$$

The tristimulus values (W^*, U^*, V^*) are computed from the CIE 1964 uniform colour space chromaticity coordinates and the 1931 standard observer using the (u, v) of D50 and the (u', v') of the test sources (D55 and F8), as shown in Equations (D.19) to (D.21):

$$W_r^* = 25 \cdot Y_r^{\frac{1}{3}} - 17 \qquad W_k^* = 25 \cdot Y_k^{\frac{1}{3}} - 17 \tag{D.19}$$

$$U_r^* = 13 \cdot W_r^*(u - u_0) \qquad U_k^* = 13 \cdot W_k^*(u' - u'_0) \tag{D.20}$$

$$V_r^* = 13 \cdot W_r^*(v - v_0) \qquad V_k^* = 13 \cdot W_k^*(v' - v'_0) \tag{D.21}$$

The values for the reference D50 illuminant are shown in Table D.1.

Table D.1 — Computed values for reference D50 illuminant

Colour	u	v	c	d	U^*	W^*	V^*
1	0,253 1	0,334 0	1,217 79	1,795 09	34,91	61,05	6,84
2	0,230 3	0,349 6	0,781 88	1,887 83	16,54	60,07	18,93
3	0,197 7	0,361 9	0,505 24	2,015 21	−9,11	61,17	29,07
4	0,163 6	0,344 3	1,142 72	2,177 81	−35,44	59,80	14,70
5	0,171 6	0,318 1	2,035 39	2,179 30	−29,76	60,89	−5,77
6	0,182 0	0,293 7	3,001 40	2,165 82	−21,15	59,92	−24,72
7	0,223 3	0,297 2	2,709 14	1,954 63	11,06	60,15	−22,07
8	0,250 2	0,308 9	2,137 88	1,816 36	33,18	62,23	−13,31

The corresponding values for the first test illuminant, D55, are shown in Table D.2.

The corresponding values for the second test illuminant, F8, are shown in Table D.3.

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