CTCN
CLIMATE TECHNOLOGY CENTRE & NETWORK

UN environment

UNEP GELC Global Efficient Lighting Centre
UNEP Collaborating Centre for Energy Efficient Lighting

CIE 15 2004 COLORIMETRY

XIN Hongzheng

UNEP Collaborating Centre for Energy Efficient Lighting

1. SCOPE

This report is intended to provide a consistent and comprehensive account of the recommendations of the CIE for basic colorimetry. It summarises basic colorimetric data and practices; it does not, however, deal with colour appearance specification.

UNEP Collaborating Centre for Energy Efficient Lighting

2. PREFACE

The recommendations are divided into the following seven groups:

- concerning standard physical data of illuminants and sources.
- concerning the standard of reflectance.
- concerning geometric conditions for colorimetry.
- concerning standard observer data.
- concerning the calculation of tristimulus values and chromaticity coordinates.
- concerning uniform colour spacing and colour difference.
- concerning miscellaneous colorimetric practices and formulae.

3.

RECOMMENDATIONS CONCERNING STANDARD PHYSICAL DATA OF ILLUMINANTS AND SOURCES

- **CIE standard illuminant A**
- **CIE standard illuminant D65**
- **Other illuminants D**

RECOMMENDATIONS CONCERNING STANDARD OF REFLECTANCE

The perfect reflecting diffuser is the reference standard for reflectance (CIE, 1986a). It is defined as the ideal isotropic diffuser with a reflectance equal to unity. For real measurements, reflectance standards, such as pressed barium sulphate or PTFE (known also under the trade names Algoflon, Halon, Spectralon), must be calibrated in terms of the perfect reflecting diffuser (see CIE, 1979a; CIE, 1979b) for the required geometry.

5.

RECOMMENDATIONS CONCERNING GEOMETRIC CONDITIONS FOR COLORIMETRY

Terms and definitions used in this Section of CIE 15:2004 introduce a terminology not used in previous versions of CIE 15.

UNEP Collaborating Centre for Energy Efficient Lighting

5.

5.1 Recommended nomenclature for directional irradiation

…

5.2 Recommended geometry for reflection measurements

…

5.3 Recommended geometry for transmission measurements

…

6. STANDARD OBSERVER DATA

6.1 CIE 1931 standard colorimetric observer

…

6.2 CIE 1964 standard colorimetric observer

…

7 THE CALCULATION OF TRISTIMULUS VALUES AND CHROMATICITY COORDINATES

7.1 Calculation of tristimulus values

…

7.1.1 Secondary light sources (reflecting or transmitting objects)

…

7.1.2 Illuminants and self-luminous objects

…

7.2 The use of abridged or truncated data

7.2.1 Abridgement…

7.2.2 Truncation…

7.2.3 Weighting factors…

7.2.4 Numerical procedures…

7.2.5 Bandwidth of a spectrometer…

7.3 Calculation of chromaticity coordinates

7.4 Equations representing relationships between colour stimuli

UNEP Collaborating Centre for Energy Efficient Lighting

8 UNIFORM COLOUR SPACING AND COLOUR DIFFERENCES

8.1 CIE 1976 uniform chromaticity scale diagram (UCS diagram)

8.2 CIE 1976 uniform colour spaces

8.2.1 CIE 1976 (L*a*b*) colour space; CIELAB colour space

8.2.1.1 Basic coordinates

8.2.1.2 Correlates of lightness, chroma and hue

8.2.1.3 Colour differences

8.2.2 CIE 1976 (L*u*v*) colour space; CIELUV colour space

8.2.3 Notes on CIE 1976 uniform colour spaces

8.3 Improved industrial colour difference evaluation

8.3.1 CIEDE2000 total colour difference formula

UNEP Collaborating Centre for Energy Efficient Lighting

9 MISCELLANEOUS COLORIMETRIC

9.1 Dominant wavelength and purity

9.1.1 Dominant wavelength (of a colour stimulus), λd

9.1.2 Complementary wavelength (of a colour stimulus), λc

9.1.3 Colorimetric purity, pc

9.1.4 Excitation purity, pe

9.2 Special metamerism indices

9.2.1 Special metamerism index: change in illuminant

9.2.1.1 Tristimulus values under reference illuminant

9.2.1.2 Tristimulus values under test illuminant

9.2.1.3 Colour difference and metamerism index

National Lighting Test Centre China

9.2.2 Special metamerism index: change in observer

9.2.2.1 Tristimulus values for standard colorimetric observers

9.2.2.2 Tristimulus values for standard deviate observer

9.2.2.3 Colour difference and metamerism index

9.3 Assessment of the quality of a daylight simulator for colorimetry

9.4 The evaluation of whiteness

9.5 Calculation of correlated colour temperature

The concept of correlated colour temperature used to be based on visual observations.Recent investigations have shown (see Borbély et al., 2001) that no metrological definition can be based on such perceptual investigations. Therefore a new definition has been proposed. The definition agrees with the previously recommended calculation method and thus does not cause any changes to calculated values.

correlated colour temperature (*T*cp)

temperature of a Planckian radiator having the chromaticity nearest the chromaticity associated with the given spectral distribution on a diagram where the (CIE 1931 standard observer based) *u'*, 2/3*v'* coordinates of the Planckian locusXIII and the test stimulus are depicted.

- Note 1:

The concept of correlated colour temperature should not be used if the chromaticity of the test source differs more than

$$\Delta C = [(u't-u'P)^2+4/9 \cdot (v't-v'P)^2]1/2 = 5 \cdot 10^{-2}$$

from the Planckian radiator, where $u't, v't$ refer to the test source, $u'P, v'P$ to the Planckian radiator.

- Note 2:

Correlated colour temperature can be calculated by a simple minimum search computer program that searches for that Planckian temperature that provides the smallest chromaticity difference between the test chromaticity and the Planckian locus, or e.g. by a method recommended by Robertson (1968).

10. REFERENCES

11. TABLES

11.1 Table T.1. Relative spectral power distributions of CIE illuminants

11.2 Table T.2. Components S0(λ), S1(λ), S2(λ)

11.3 Table T.3. Tristimulus values, chromaticity coordinates of CIE illuminants

11.4 Table T.4. CIE 1931 standard colorimetric observer

11.5 Table T.5. CIE 1964 standard colorimetric observer

11.6 Table T.6. Relative spectral power distributions of illuminants representing typical fluorescent lamps, for wavelengths λ = 380 nm to 780 nm at 5 nm intervals

11.7 Table T.7. High pressure discharge lamps. HP1: Standard high pressure sodium lamp; HP2: Colour enhanced high pressure sodium lamp; HP3-5: Three types of high pressure metal halide lamps

11.8 Table T.8. Colorimetric data for the fluorescent lamp illuminants of Table T.6

11.9 Table T.9. Colorimetric data for the high pressure illuminants of Table T.7

11.10 Table T.10. Values of the first deviation function used in the calculation of the observer metamerism index

APPENDIX A. OLD RECOMMENDATIONS, NOW OBSOLETE, AS WELL AS REFERENCES TO NON-CIE COLOUR DIFFERENCE FORMULAE

UNEP GELC Global Efficient Lighting Centre

UNEP Collaborating Centre for Energy Efficient Lighting

UN environment

nltc National Lighting Test Centre China

The Climate Technology Centre and Network (CTCN) fosters technology transfer and deployment at the request of developing countries through three core services: technical assistance, capacity building and scaling up international collaboration. The Centre is the operational arm of the UNFCCC Technology Mechanism, it is hosted and managed by the United Nations Environment and the United Nations Industrial Development Organization (UNIDO), and supported by more than 300 network partners around the world.

CTCN contact details:

Climate Technology Centre and Network
UN City, Marmorvej 51
DK-2100 Copenhagen, Denmark
+45 4533 5372
www.ctc-n.org
ctcn@unep.org