INTERNATIONAL STANDARD

ISO 18314-5

First edition
2022-11

Analytical colorimetry —

Part 5:
Procedure for colorimetric determination of colour differences of object colours according to equidistant colour spaces

Analyse colorimétrique —

Partie 5: Mode opératoire pour la détermination colorimétrique des différences de couleur des couleurs d'objets selon des espaces colorimétriques équidistants

Reference number
ISO 18314-5:2022(E)

Contents

Page

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 256, *Pigments, dyestuffs and extenders*.

A list of all parts in the ISO 18314 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The scope of ISO/TC 256 is standardization in the field of colorants, i.e. pigments, dyestuffs and extenders. Standards on test metrics in this field is a very effective basis for the introduction and improvement of quality management systems. The consequent use of standardized test metrics within a company can cut down testing costs to a fraction of the original costs. Carefully written test metrics improve the precision of the test results. Standards for pigments, dyestuffs and extenders used as raw materials support the trade of these materials.

Several formulas had been developed in the past for the assessment of colour differences. For presenting colours in a colour space, the CIELAB (CIE 1976 $L^*a^*b^*$) colour space (adopted by ISO and published as ISO/CIE 11664-4)[1] and colour coordinates are the most prominent. For predicting colour differences, the International Commission on Illumination (CIE) has standardized CIEDE2000 (adopted by ISO and published as ISO/CIE 11664-6)[2]. The CIEDE2000 formula is intended to be applicable within the sample colour-difference magnitude of 0 to 5 CIELAB units. However, it does not have a new associated analytical colour space, but is still based on CIELAB.

For the steering and adjustment of colorant production or extender production in colorants industry, a uniform colour space (UCS) is an essential tool in addition to a colour difference formula. This requires adjusting colorant formulations in a colour space. Both corrective actions in production and the delivery specifications with customers are based on tolerance ellipsoids in the colour space applied. In CIE 217, different colour difference formulas and colour space models have been analysed using actual and reliable visual data sets. Several models gave similar performance, so no specific uniform colour space model or Euclidian colour-difference formula can be proposed performing statistically significantly better than CIEDE2000. However, three colour spaces stood out: OSA-UCS, DIN99o and CAM02-UCS, in chronological order of their publications. In this document, the actual editions of these models are standardized for the assessment of coloristic properties of pigments, dyestuff and extenders.

Analytical colorimetry —

Part 5:
Procedure for colorimetric determination of colour differences of object colours according to equidistant colour spaces

1 Scope

This document specifies the procedure and test report for determining small colour differences of object colours according to equidistant colour spaces. Three suggestions for metrics for the quantitative determination of small colour differences (ΔE < 5) of non-luminous colours are given in Annexes A, B and C. These examples are related to the three colour space models: OSA-UCS modified by Oleari et al., DIN99o and CAM16-UCS (uniform colour space).

This document is applicable for the assessment of pigments, dyestuff and extenders in the field of coatings, plastic and prints only that are evaluated in pairs for colour conformity, and which have small perceptible colour differences.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Procedure

For determining small colour differences (ΔE < 5) of object colours according to equidistant colour spaces, one of the three procedures from Annexes A, B and C should be used. Three suggestions for metrics for the quantitative determination of small colour differences of non-luminous colours are given in detail in Annexes A, B and C for information. These examples are related to the three colour space models OSA-UCS modified by Oleari et al., DIN99o[1)] and CAM16-UCS. Further information on these models can be found in References [11] to [31].

The used calculation metric for the colour difference shall be stated in the test report.

When the formulae described in Annexes A, B and C are used for large colour differences (greater than approximately 10 CIELAB units), larger deviations between calculated colour differences and visual evaluations are to be expected. This is due to a nonlinear relationship between small and large colour differences. If it is intended to use the formulae in this range, it should be explicitly agreed between the interested parties.

1) DIN99o was denoted DIN99b[19] but has later been referred to as DIN99o [18] [21].

5 Test report

The test report shall contain at least the following information:

a) all details necessary to identify the product tested;

b) a reference to this document, i.e. ISO 18314-5:2022;

c) the colour space model used for the determination of the colour differences;

d) the results of the test;

e) any deviations from the procedure specified;

f) any unusual features (anomalies) observed during the test;

g) the date of the test.

Annex A
(informative)

OSA-UCS colour space modified by Oleari et al.

A.1 Description of the modified OSA-UCS colour space

The OSA-UCS colour space was first published in 1947 by the Optical Society of America (OSA) and further developed in the subsequent years. The model is based on the characterization of colours using approximately 500 lattice points in a regular rhombohedral shape in an Euclidian space. This can be illustrated by a cube with each of the eight corners being cut symmetrically. The CIE 10° standard observer and the D65 standard illuminant was used. This colour space is based on the three perpendicular coordinates lightness: L_{OSA}, Jaune J (the yellow/blue axis) and Green G (the green/red axis).

For OSA-UCS lightness, L_{OSA}, the value of 0 corresponds to a 30 % reflective neutral background. Assuming nearly zero values for G, positive values of J indicate yellowish or brownish colours, and negative values of J blue colours.

Assuming nearly zero values for J, positive values of G indicate greens and negative values of G purple colours.

In this document, Oleari's concept of a logarithmic compression in chroma and lightness leading to ΔE_E is applied, using the new coordinates J, and G. Further details are described in A.2 and the References [12] to [17].

For the transformation from the X_{10}, Y_{10}, Z_{10} coordinates or the x_{10}, y_{10}, z_{10}-chromaticity coordinates, respectively to the OSA-UCS system proposed by Oleari, the following and Formulae (A.1) to (A.5) are applied:

Let (Y_{10}, x_{10}, y_{10}) and (L_{OSA}, J, G) be the colour specification in two spaces. The unit of distance in the OSA-UCS space is approximately 10 just noticeable difference, assuming that this space conforms to Euclidean metrics.

The lightness is defined as in the original OSA-UCS formula [Formula (A.1)]:

$$L_{OSA} = \left\{5{,}9\left[\left(Y_0^{1/3} - \frac{2}{3}\right) + 0{,}042\left(Y_0 - 30\right)^{1/3}\right] - 14{,}4\right\}\frac{1}{\sqrt{2}} \quad \text{(A.1)}$$

with

$$Y_0 = Y_{10}\left(4{,}493\,4x_{10}^2 + 4{,}303\,4y_{10}^2 - 4{,}276\,0x_{10}y_{10} - 1{,}374\,4x_{10} - 2{,}564\,3y_{10} + 1{,}810\,3\right).$$

The lightness L_{OSA} has no simple analytical conversion from the OSA-UCS space to the tristimulus space.

The coordinates J and G, which correspond to the empirical j and g of the OSA-UCS system, are obtained by a sequence of linear transformations and a logarithmic compression – see Formula (A.2) and Formula (A.3):

$$\begin{pmatrix} A \\ B \\ C \end{pmatrix} = \begin{bmatrix} 0{,}659\,7 & 0{,}449\,2 & -0{,}108\,9 \\ -0{,}305\,3 & 1{,}212\,6 & 0{,}092\,7 \\ -0{,}037\,4 & 0{,}479\,5 & 0{,}557\,9 \end{bmatrix} \begin{pmatrix} X_{10} \\ Y_{10} \\ Z_{10} \end{pmatrix}, \quad \text{(A.2)}$$

$$\begin{pmatrix} J \\ G \end{pmatrix} = \begin{bmatrix} S_J & 0 \\ 0 & S_G \end{bmatrix} \begin{bmatrix} -\sin\alpha & \cos\alpha \\ \sin\beta & -\cos\beta \end{bmatrix} \begin{pmatrix} \ln\left(\dfrac{A/B}{A_n/B_n}\right) \\ \ln\left(\dfrac{B/C}{B_n/C_n}\right) \end{pmatrix}$$

$$= \begin{bmatrix} 2(0{,}573\ 5L_{\text{OSA}} + 7{,}089\ 2) & 0 \\ 0 & -2(0{,}764\ 0L_{\text{OSA}} + 9{,}252\ 1) \end{bmatrix} \begin{bmatrix} 0{,}179\ 2 & 0{,}983\ 7 \\ 0{,}948\ 2 & -0{,}317\ 5 \end{bmatrix} \begin{bmatrix} \ln\left(\dfrac{A/B}{0{,}936\ 6}\right) \\ \ln\left(\dfrac{B/C}{0{,}980\ 7}\right) \end{bmatrix} \quad \text{(A.3)}$$

S_G and S_J are suitable normalization-scale factors and α and β are the angles between the reference axes of the main chromatic opponent functions and the directions of parallel lines with constants g and j, respectively[11]. A_n, B_n and C_n are the values of A, B and C according to Formula (A.3) for the neutral standard illuminant D65.

The analytical reversibility of this transformation is straightforward, excluding the conversion of L_{OSA}.

The chroma and hue angles are obtained in OSA-UCS space from J and G coordinates as in CIELAB from a^* and b^* according to Formulae (A.4) and (A.5):

$$C_{\text{OSA}} = \sqrt{J^2 + G^2} \quad \text{(A.4)}$$

$$h_{\text{OSA}} = \arctan\left(\frac{J}{-G}\right) \quad \text{(A.5)}$$

NOTE h_{OSA} is expressed in degrees (°).

A.2 Determination of colour differences according to OSA-UCS colour space modified by Oleari et al.

From colour space proposed by Oleari et al. (see A.1), the colour-difference formula ΔE_{GP}[12] was introduced. Next, based on a logarithmic compression of the OSA-UCS coordinates in the colour space modified by Oleari et al., new coordinates L_{E}, J_{E}, G_{E} were proposed, defining a new colour space with an Euclidean colour-difference formula named ΔE_{E}[13]. The ΔE_{GP} and ΔE_{E} colour-difference formulas were tested by CIE/TC 1-55 in CIE 217, together with CIEDE2000, DIN99o and other colour-difference formulas.

Based on the original coordinates OSA-chroma C_{OSA} and L_{OSA}, the definitions of this formula and of the OSA-UCS space with chroma and lightness log compressed are recalled by Formula (A.6) to Formula (A.10):

$$\Delta E_{\text{E}} = \sqrt{(\Delta L_{\text{E}})^2 + (\Delta G_{\text{E}})^2 + (\Delta J_{\text{E}})^2}\ , \quad \text{(A.6)}$$

$$L_{\text{E}} = \left(\frac{1}{b_{\text{L}}}\right) \ln\left[1 + \frac{b_{\text{L}}}{a_{\text{L}}}(10L_{\text{OSA}})\right] \quad \text{(A.7)}$$

with $a_{\text{L}} = 2{,}890$, $b_{\text{L}} = 0{,}015$,

$$G_{\text{E}} = -C_{\text{E}} \cos(h),$$

$$J_E = C_E \sin(h), \tag{A.8}$$

with

$$h = \arctan\left(-\frac{J}{G}\right),$$

$$C_E = \left(\frac{1}{b_C}\right)\ln\left[1 + \frac{b_C}{a_C}\ (10C_{OSA})\right] \tag{A.9}$$

with $a_C = 1,256$, $b_C = 0,050$,

$$C_{OSA} = \sqrt{G^2 + J^2}\ . \tag{A.10}$$

Greater insight into this concept and the introduction or derivation of the colour coordinates, as well as the formulae, can be obtained from References [14] to [17].