International Standard 7724/3

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Paints and varnishes — Colorimetry — Part 3: Calculation of colour differences

Peintures et vernis — Colorimétrie — Partie 3: Calcul des différences de couleur

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

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Contents

INTERNATIONAL STANDARD ISO 7724/3-1984 (E)

Paints and varnishes — Colorimetry — Part 3 : Calculation of colour differences

0 Introduction

This International Standard, ISO 7724, comprises the following parts :

Part 1 : Principles.

Part 2 : Colour measurement.

Part 3 : Calculation of colour differences.

Parts 1, 2 and 3 of ISO 7724 describe methods for the instrumental determination of the colour co-ordinates and colour differences of paint films, as required for such purposes as

a) the objective description of colour differences between a test specimen (a test panel coated with a paint, or a specimen from a painted article) and a reference specimen;

b) determining colour deviations in the production of painted articles so that the results may be used for the control or regulation of the process;

c) the objective description of changes in colour caused by weathering and other chemical or physical influences;

d) the objective supervision of colour reference standards.

NOTE — Colour reference standards are subject to ageing, which may lead in the course of time to pronounced changes in colour. High accuracy colorimetry is required for the timely detection of these changes. This is of particular importance when ordering against such reference standards.

1 Scope and field of application

This part of ISO 7724 describes a method for the quantitative colorimetric evaluation of small colour differences between paint films.

NOTE — There are numerous formulae for calculating a colour difference from the colour co-ordinates of two specimens. For various reasons the results given by such formulae, including the one defined here, do not in all cases agree satisfactorily with visual perception nor are they likely to agree with each other. The Commission Internationale de l'Éclairage (CIE) recommended in 1976 two formulae for general use. One of these, the CIE 1976 ($L^*a^*b^*$) colour difference formula (see CIE Publication No. 15 Supplement No. 2), has proved to be of practical value for the colorimetric evaluation of paint films and is specified for this application in this part of ISO 7724.

2 References

ISO 3668, *Paints and varnishes — Visual comparison of the colour of paints.*

ISO 7724/1, *Paints and varnishes — Colorimetry — Part 1 : Principles.*

ISO 7724/2, *Paints and varnishes — Colorimetry — Part 2 : Colour measurement.*

CIE Publication No. 15, Supplement No. 2, *Recommendations on uniform color spaces — Color difference equations — Psychometric color terms.*

CIE Publication No. 38, *Radiometric and photometric characteristics of materials and their measurement.*

3 Calculation

3.1 General

Calculate the differences in colour, lightness, chroma and hue between the paint films of a test specimen and a reference specimen from their colour co-ordinates in the CIE 1976 ($L^*a^*b^*$) colour space (see ISO 7724/1).

NOTE — The abbreviation CIELAB is used for CIE 1976 ($L^*a^*b^*$).

Determine L^*_T, a^*_T, b^*_T, the colour co-ordinates of the test specimen, and L^*_R, a^*_R, b^*_R, the colour co-ordinates of the reference specimen according to ISO 7724/2 (see note 1) by use of a measurement condition that depends on the information that is to be obtained:

a) If the colour difference between the test specimen and the reference specimen, resulting only from the colour difference of the colouring material, is to be determined (for example when colour changes in pigments caused by weathering shall be objectively described) L^*, a^*, b^* colour co-ordinates have to be calculated from the tristimulus values measured including specular reflection as described in subclause 4.1.1 or 4.2.1 of ISO 7724/2.

The measurements include the entire surface reflection. Therefore a mathematical correction of the measured tristimulus values X_m, Y_m, Z_m is necessary to avoid the evaluation of colour differences that are too small because of the curve of the cube root functions $f(X/X_n)$, $f(Y/Y_n)$, $f(Z/Z_n)$ used for the calculation of L^*, a^*, b^*. The correction is made by use of the following equations :

$$X = X_m - \varrho_0 X_n\,,\quad Y = Y_m - \varrho_0 Y_n\,,\quad Z = Z_m - \varrho_0 Z_n$$

where

X_n, Y_n, Z_n are the tristimulus values for the perfect reflecting diffuser (see table 2 in ISO 7724/1);

ϱ_0 is the Fresnel reflectance (see CIE Publication No. 38) and is assumed to be 0,04 based on a refractive index $n = 1{,}5$ (see note 2).

b) If the colour difference between the test specimen and the reference specimen, resulting from both the colour difference of the colouring material *and* the difference in the surface reflection, is to be determined (as they are perceived roughly when visually comparing the colour according to ISO 3668) L^*, a^*, b^* colour co-ordinates have to be determined excluding specular reflection, as described in subclause 4.1.2 or 4.2.2 of ISO 7724/2.

If methods a) and b) are carried out, comparable results are obtained for high gloss paint films. In all other cases, the degree of comparability of the colour differences obtained using the two methods will be dependent on the gloss differences between the test specimens and the reference specimens and on the construction of the photometer head.

NOTES

1 With modern instruments it is not absolutely necessary to calculate the co-ordinates of the test specimens because the colour difference is calculated automatically from the reference values stored in the instrument.

2 When the correction is made for very dark or highly chromatic paint films it may be appropriate to use a more precise value of ϱ_0; this should be stated in the test report.

The mathematical elimination of the surface reflection affects the correspondence of the colour differences thus obtained to those that are seen by an observer when examining highly reflecting test specimens with the exclusion of gloss.

3.2 Total colour difference using the CIELAB colour difference formula

The total difference ΔE^*_{ab} between two colours is the geometrical distance between their positions in the CIE 1976 ($L^* a^* b^*$) colour space (see ISO 7724/1), and is calculated from the equation

$$\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

where

$$\Delta L^* = L^*_T - L^*_R$$

$$\Delta a^* = a^*_T - a^*_R$$

$$\Delta b^* = b^*_T - b^*_R$$

3.3 Lightness difference

The lightness difference between the test specimen and the reference specimen is defined by the CIE 1976 psychometric lightness difference

$$\Delta L^* = L^*_T - L^*_R$$

3.4 Chroma difference

The chroma difference between the test specimen and the reference specimen is defined by the CIE 1976 $a\ b$ chroma difference

$$\Delta C^*_{ab} = C^*_{ab,\,T} - C^*_{ab,\,R}$$

where

$C^*_{ab,\,T}$ is the CIE 1976 $a\ b$ chroma of the test specimen and is defined by the equation

$$C^*_{ab,\,T} = (a^{*2}_T + b^{*2}_T)^{1/2}$$

$C^*_{ab,\,R}$ is the CIE 1976 $a\ b$ chroma of the reference specimen and is defined by the equation

$$C^*_{ab,\,R} = (a^{*2}_R + b^{*2}_R)^{1/2}$$

3.5 Hue difference

The hue difference ΔH^*_{ab} between the test specimen and the reference specimen is defined by the CIE 1976 $a\ b$ hue difference

$$\Delta H^*_{ab} = k_H\,|[(\Delta E^*_{ab})^2 - (\Delta L^*)^2 - (\Delta C^*_{ab})^2]^{1/2}|$$

where

$k_H = +1$ for $(a^*_R\, b^*_T - a^*_T\, b^*_R) \geqslant 0$

$k_H = -1$ for $(a^*_R\, b^*_T - a^*_T\, b^*_R) < 0$

The differences in lightness, chroma and hue are defined such that the sum of their squares equals the square of the colour difference.

3.6 Colour difference of near white test specimens

The colour difference of near white test specimens should be described by use of ΔE^*_{ab}, ΔL^* and the differences Δa^* and Δb^* in place of ΔC^*_{ab} and ΔH^*_{ab}.

4 Test report

The test report shall contain at least the following information:

a) the type and identification of the paint film tested and of the reference specimen;

b) a reference to this International Standard (ISO 7724/3);

c) a description or other identification of the method of preparing the test specimen and the reference specimen;

d) the identification of the method a) or b) used (see 3.1);

e) the results of the test, expressed as

— the colour difference ΔE^*_{ab} and, if necessary,

— the psychometric lightness difference ΔL^*, the CIE 1976 $a\ b$ chroma difference, ΔC^*_{ab}, and the CIE 1976 $a\ b$ hue difference, ΔH^*_{ab}

— or the differences Δa^* and Δb^*, as appropriate;

f) any deviation, by agreement or otherwise, from the procedures specified;

g) the date of the test.