TECHNICAL SPECIFICATION

ISO/TS 23031

First edition
2020-08

Graphic technology — Assessment and validation of the performance of spectrocolorimeters and spectrodensitometers

Reference number
ISO/TS 23031:2020(E)

Contents

Page

Foreword .... **iv**
Introduction .... **v**
1 Scope **1**
2 Normative references **1**
3 Terms and definitions **1**
4 Known practices for instrument characterization **6**
4.1 Repeatability 6
4.1.1 General 6
4.1.2 Procedures 6
4.2 Reproducibility 7
4.2.1 General 7
4.2.2 Determination of temporal reproducibility 8
4.2.3 Determination of instrument reproducibility 10
4.2.4 Data collection and analysis 11
4.3 Accuracy 12
4.4 Quality of the influx spectrum 12
5 Reference materials for assessment of performance **13**
5.1 Reference materials for comparison to the manufacturer's specifications 13
5.2 Reference materials for comparison between identical models 15
5.2.1 General 15
5.3 Reference materials for comparison between different models 15
5.3.1 General 15
5.3.2 Measurements 16
5.3.3 Determination of instrument differences 16
6 Reported performance results **16**
6.1 Conformance to factory specifications 16
6.2 Inter-instrument agreement 17
6.3 Inter-model agreement 17
6.4 Repeatability 17
6.5 Reproducibility 17
6.6 Assessment of accuracy 17
Bibliography **18**

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 130, *Graphic technology*.

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

Instruments for the measurement of colour and colour difference have been in use since the middle of the 20th century. In the days before digital computers, converting spectral data into CIE tristimulus values was a difficult, manual operation. Additionally, the optics and electronic components were large and difficult to maintain. As a result, every instrument was supplied with a number of reference materials that could be used to assess the performance of the instrument or to adjust the operating parameters. These reference materials included coloured glass filters, rare earth glass filters, neutral density filters and porcelain on steel plaques. Concepts such as accuracy, precision, bias and reproducibility had special and unique applications to these instruments and reference materials.

As the optical and electronic technologies improved, the instruments became smaller, more precise and more affordable. At the same time, the science of metrology matured to the point that the colour-measuring instrument's performance out-paced the ability of the national testing laboratories to produce and certify standard materials suitable for testing. Modern optoelectronic instruments are more precise and more stable than the materials used to assess their performance. Thus, it has become problematic to determine if an instrument is within its factory specification or if two instruments produce results that are in agreement with each other.

Several industries that produce coloured products have chosen to address this situation by adopting and specifying a single brand and design of instrument. The paper and pulp industry have gone so far as to capture one particular design from the 1960s and enshrine it in an International Standard. ISO 2469 describes the optics, the geometry and the operation of an instrument that is ideally suited and specially designed for the measurement of the reflectance and colour of paper and pulp. Additionally, ISO/TC 6, has established a series of authorized laboratories which issue certified reference materials (CRM) for testing and calibrating the performance of an ISO 2469 compliant instrument. This was possible, in part, as the instrument captured in ISO 2469 was widely available on the market and it had no competitive designs and the authorized laboratories market sets of standards which are produced using materials with similar physical and optical properties as production papers or pulps. The authorized laboratories maintain a very close relationship to a single national standards laboratory and to each other. WG3 periodically audits these laboratories to verify that they have calibrated their instruments properly against the scale of radiance factor developed by the national standards laboratory.

In contrast, modern graphic reproduction has moved from the era of artistic interpretation into a time in which the image reproduction is driven by objective numerical assessments. With the availability of modern electro-optics, the number of companies providing instruments and the range of models of different size and capabilities has increased dramatically. Geometries utilized are nominally 45°:0° but may be uniplanar, biplanar, circumferential or annular. While referred to as bidirectional, they are always biconical and the sizes of the influx and efflux cones vary as much as the directionality.

Unfortunately, the national metrology laboratories have not been successful in defining a universally accepted scale of diffuse reflectance factor or diffuse radiance factor for these biconical instruments, especially when the sampling aperture is small. Without artefact standards that closely align with the properties to be measured in the printing industry, the result can easily be a match between two instruments on the reference material that does not correlate to a match on real world materials. As a result, colour-measuring instruments from different manufacturers or with different design intents do not provide adequate agreement on the determination of the colour values or methods for the assessment of the performance of an instrument system relative to its manufacturer declared performance specifications. Further, to make the instruments as simple as possible to operate, the end-user is given little to no access the underlying operation of the instrument. The operator can select an influx spectral quality (M0, M1, M2, M3) but has no way to determine or adjust the spectral quality of the influx. The realization of the scale of 45°:0° reflectance factor or radiance factor is different than that of hemispherical diffuse reflectance factor, even for nearly ideal materials. The operator only has the ability to request that instrument adjust the scale of the instrument using a single reference standard supplied with the instrument. The instrument scale is thus traceable only at the one point. Most do not even offer the ability to set or verify the mid-scale value or the optical null value. Today, optical metrologists refer to this process as standardization, since the instrument is forced to reproduce the values of the one standard.

This document has been prepared to provide the users of portable spectrocolorimeters and spectrodensitometers with guidance on the methods for validation of the performance of those instruments. Since calibration is not possible, the use of a series of certified reference materials (CRM) or a series of stable, idealized reference materials is required. ISO 15790 provides guidance on the development of CRM standards for the scale of optical density. But optical density is a more forgiving measurement than tristimulus colorimetry. Measurement of colour is inherently more complicated than the measurement of optical density, since the logarithmic function compresses the measurement scale and the associated errors. Computing colorimetric tristimulus values from spectral data requires the use of the entire range of reflectance factor values while ISO status density is based on the response of the spectral product. Bright colours, useful for producing a large gamut of colour in image reproduction, possess large differences between the spectral regions of absorption and non-absorption of light but density is only assessing the spectral regions of maximum absorbance. While the human visual system has broad spectral responses, in terms of the cone fundamentals, the post receptor processing allows an observer to perceive hue differences as small as 1 nm. So, the instrumentation for colour assessment needs to have an accuracy several times small than the human visual system.

There is a need to use a set of 10 to 20 physical standards to sample the visible spectrum with materials possessing both high and low reflectance levels and that transition between the two extremes over a very small range of wavelengths. Those materials are stable and nearly opaque to avoid the problems of lateral diffusion observed when the sampling aperture are small. The procedures described here have been shown to provide end-users with methods to quantify the performance of spectrocolorimeters on the day it arrives from the manufacturer or distributor until the day it is retired from service. The methods may also be used to validate the instrument system against manufacturer's specifications and against the requirements for product quality.

National measurement laboratories (NML) continue to develop new scales and new methods of assessing artefacts with the goal of providing certified standard materials for establishing the level of traceability and reproducibility of commercial instruments. Unfortunately, these standards have historically been too expensive for routine use. Only recently have the NMLs began developing automated methods for characterizing reference colours or even user supplied materials. Currently, only large corporations or instrument makers can afford to own such materials. Practical users rely on secondary laboratories and reference standards designed specifically for the end use case. In the graphic arts, that should be some form of printed material with a relatively short duty lifetime.

Finally, even after the CRM has been obtained, the methods for assessing the measurement data are not well described. A spectral reflectance factor curve should include 31, 36, 40 or more measurements. Trying to assign values, tolerances and uncertainties to the individual wavelengths is a challenge. For example, it is possible that measurements of an artefact are consistent for 28 wavelengths and inconsistent at 3 others. Should these instruments be considered as acceptable or failures? Converting the measured data to colorimetric values (XYZ or L*a*b*) improves the situation slightly, but the dilemma of comparing 3 individual readings from one lab or instrument to 3 individual values from another lab, remains a problem not conveniently described in the standards literature. It is the intent of this document to document and describe objective ways of assessing and comparing the performance of a colour-measuring instrument with the ultimate goal of identifying an optimum method for application in the graphic reproduction workflow.

Graphic technology — Assessment and validation of the performance of spectrocolorimeters and spectrodensitometers

1 Scope

This document describes procedures for the assessment and validation of the performance of an optical spectrometer intended for use in capturing the spectral reflectance factor or the spectral radiance factor of printed areas comprised of non-fluorescent or fluorescent materials, respectively. While it does not describe the application to transmitting materials directly, many of the procedures can be applied to transmitting systems by backing them with a reflective white backing material.

This document does not address spectral measurements appropriate to other specific application needs, such as those used during the production of materials (e.g. printing paper and proofing media), which are well described by ISO standards under the jurisdiction of ISO/TC 6. It does not describe the special requirements for testing instruments that make in-process or online colour measurements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 13655:2017, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*

ISO 15790:2004, *Graphic technology and photography — Certified reference materials for reflection and transmission metrology — Documentation and procedures for use, including determination of combined standard uncertainty*

3 Terms and definitions

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

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

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

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

3.1
accuracy
closeness of agreement between a test result and an accepted reference value

Note 1 to entry: The qualitative term accuracy, when applied to a set of observed values, is a combination of a random precision component and a systematic error or bias component. Since, in routine use, random components and bias components cannot be completely separated, the reported "accuracy" is interpreted as a combination of these two elements.

[SOURCE: ASTM E 284]

3.2
bandwidth
width of the spectral response function of the instrument, measured between the half-power points often termed full width at half maximum (FWHM)

3.3
calibration
set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards

Note 1 to entry: Contrary to a common usage, calibration is not the process of adjusting a measurement system such that it produces values that are believed to be correct. Calibration permits either the assignment of values of measurands to the indications (creating a reference table) or the decision to reset or adjust the device.

Note 2 to entry: Following the resetting or adjusting of the device, a calibration needs to be verified to ensure that the new device setting(s) provide indications within the accepted values. Verification of a measuring device requires determination of the uncertainty of the calibration.

[SOURCE: ISO/IEC Guide 99:2007:2.39, modified — The definition has been editorially revised and the original Notes to entry have been replaced.]

3.4
certified reference material
CRM
reference material, accompanied by a certificate, one or more of whose property values are certified by a procedure which establishes traceability to an accurate realization of the unit in which the property values are expressed, and for which each certified value is accompanied by an uncertainty at a stated level of confidence

[SOURCE: ISO 15790:2004, 3.1.2]

3.5
combined standard uncertainty
u_c

standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms, the terms being the variance or covariance of these other quantities weighted according to how the measurement result varies with changes in these quantities

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.4]

3.6
coverage factor
k
numerical factor used as a multiplier of the *combined standard uncertainty* (3.5) in order to obtain an expanded uncertainty

Note 1 to entry: The coverage factor is chosen based on the level of confidence desired. This coverage factor, k, is typically in the range of 2 to 3. A coverage factor (k) of 2 generally results in a level of confidence of approximately 95 %, and a coverage factor of 3 generally results in a level of confidence of approximately 99 %. This association of confidence level and coverage factor is based on assumptions regarding the probability distribution of measurement results. For a more thorough explanation, see the Guide to the Expression of Uncertainty in Measurement[13].

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.6, modified — Note 1 to entry has been elaborated.]

3.7
CRM reference value
value of the certified property of a Certified Reference Material (CRM), reported in the documentation supplied with it

3.8
expanded uncertainty
U
quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of values that could reasonably be attributed to the measurand

Note 1 to entry: Expanded uncertainty is the product of the combined standard uncertainty (u_c) and the chosen coverage factor (k).

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.5, modified — Notes to entry 1 and 2 have been omitted.]

3.9
inter-instrument agreement
expected level of reproducibility between two or more instruments of exactly the same design and manufacturer

3.10
inter-model agreement
expected level of reproducibility between two or more instruments of different designs, models or manufacturer

3.11
manufacturer's calibration reference material
physical device or material, certified or non-certified, supplied by the instrument manufacturer, which is used to standardize a specific instrument to the manufacturer's scale calibrated to a reference material

3.12
mean colour difference from the mean
MCDM
measure of the dispersion of the results of a series of colour measurements

Note 1 to entry: The MCDM quantifies the average colour difference between each reading and the mean of the group of readings

Note 2 to entry: MCDM is a better single number indicator of the dispersion of a set of colour readings than is the standard deviation of the colour difference (ΔE). This is because the distribution of colour difference is not Normally distributed.

3.13
measurand
particular quantity subject to measurement

Note 1 to entry: Examples are: density, lightness, transmittance, reflectance factor.

[SOURCE: ISO/IEC Guide 99:2007, 2.3, modified — The notes to entry have been deleted.]

3.14
measurement uncertainty
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the *measurand* (3.13)

Note 1 to entry: Each component of the uncertainty is assumed to have a normal distribution. For cases where this assumption may not be valid, users follow the concepts and rules shown in the Guide to the Expression of Uncertainty in Measurement[13].

Note 2 to entry: The result of a measurement is only an approximation or estimate of the value of the measurand and thus is complete only when accompanied by a statement of the uncertainty of that estimate (see 3.3 and ISO 15790:2004, 7.1.6).

Note 3 to entry: Colour values are three dimensional variables. The uncertainties of a colour are derived from the propagation of the uncertainty from the spectral readings. The method for this process has been documented in the literature[1].

[SOURCE: ISO/IEC Guide 99:2007, 2.26, modified — The definition has been slightly modified and the Notes to entry have been replaced.]

3.15
precision
closeness of agreement between test results obtained under prescribed conditions

[SOURCE: ASTM E 284]

3.16
radiance factor
ratio of the radiance from a point on a specimen, in a given direction, to that from the perfect reflecting or transmitting diffuser, similarly irradiated and viewed

Note 1 to entry: For fluorescent media, the radiance factor is the sum of two quantities, to that from the perfect reflecting or transmitting diffuser, similarly irradiated and viewed.

[SOURCE: ASTM E 284]

3.17
reference material
material or substance one or more of whose property values are sufficiently homogeneous and well established to be used for the *calibration* (3.3) of an apparatus, the assessment of a measurement method, or for assigning values to other materials

[SOURCE: ISO Guide 30:2015, 2.1.1, modified — Notes to entry have been omitted.]

3.18
reflectance factor
ratio of the radiant or luminous flux reflected in the directions delimited by the given cone to that reflected in the same directions by a perfect reflecting diffuser identically irradiated or illuminated

Note 1 to entry: The industry commonly, but incorrectly, uses the term reflectance rather than reflectance factor.

Note 2 to entry: It is important to specify the geometry that establishes the given conditions of measurement. See CIE Publication 176.

[SOURCE: IEC 60050-845-04-64]

3.19
repeatability
<of results of measurements> closeness of the agreement between the results of successive measurements on that single specimen using a single instrument by the same operator, in the same location and in a short period of time

3.20
reproducibility
<of results of measurements> closeness of the agreement between the results of measurements of the same measurand carried out under changed conditions of measurement

Note 1 to entry: Reproducibility is distinct from repeatability. Conditions of measurement may include operator, specimen — including repositioning the same material standard, longer spans of time between readings — including hours, days, weeks, etc.

[SOURCE: ISO International Vocabulary of Basic and General Terms in Metrology]

