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Instrumental Color Measurement

Developed in 1995 by AATCC Committee RA36; reaffirmed 1996, 1997, 2003, 2008; reaffirmed and editorially revised 1998. Technically equivalent to ISO 105-J01.

1. General Description of Instrumental Color Measurement

1.1 Purpose

1.1.1 This evaluation procedure is a reference document to support the proper measurement of the color (or colored appearance) of specimens by instrumental means as required in many of the current AATCC test methods. The document contains three major subsections covering *reflectance measurement*, *transmittance measurement* and *related calculations*. In addition, an appendix is supplied which details specific techniques and specimen handling procedures.

1.2 Terminology

1.2.1 **area-of-view,** n.—*of color measuring instrument*, the dimensions of the surface area that a color measuring instrument is capable of covering in a single color measurement.

1.2.2 **color measuring instrument,** n.— any device, such as a colorimeter or spectrophotometer, used to measure the relative amounts of energy reflected from (or transmitted through) a specimen in the visible region of the energy spectrum (comprising the wavelengths from 360-780 nm, and including as a minimum the region from 400-700 nm).

1.2.3 **color measurement,** n.—a numerical representation of the color of an object obtained by use of a color measuring instrument. A single measurement may represent an average of multiple readings of a specimen.

1.2.4 **fluorescence,** n.—a phenomenon in which radiant flux of certain wavelengths is absorbed and re-emitted nonthermally at other, usually longer, wavelengths.

1.2.5 **geometry,** n.—*of a color measuring instrument*, one of the following terms (diffuse/0, 0/diffuse, 0/45 or 45/0) which describe the angle or manner in which a color measuring instrument:

(1) illuminates the specimen (diffuse, 0, 45).

(2) views the resulting reflected light (0 [0°-10°], diffuse, 45, 0).

Diffuse/0 and 0/diffuse geometry instruments contain a sphere used to diffuse the light illuminating [or reflected from] the specimen, while 0/45 and 45/0 geometry instruments generally use mirrors or fiber optics to direct the illumination [or viewing] at a 45 angle to the specimen.

NOTE: Instruments of different geometrics may produce different colorimetric results on most textile materials.

1.2.6 **reflectance,** n.—the ratio of the reflected radiant or luminous energy (light) to the incident energy in the given conditions.

1.2.7 **reflectance factor,** n.—the ratio of the light reflected from the specimen to the light reflected from the perfect reflecting diffuser under the same geometric and spectral conditions of measurement.

1.2.8 **specular reflection,** n.—the reflection without diffusion, in accordance with the laws of optical reflection, as in a mirror.

1.2.9 **standardization,** n.—*of color measuring instrument*, the act of measuring one or more standard materials with a color measuring instrument for the purpose of calculating a set of correction factors to be applied to all subsequent measurements.

1.2.10 **transmittance,** n.—the ratio of transmitted light to incident light under specified geometric and spectral conditions.

NOTE: Regular transmittance (of transparent materials) is the ratio of undiffused transmitted light to incident light.

1.2.11 **transmittance factor,** n.—the ratio of the light transmitted by a specimen and evaluated by a receiver to the light passing through the same optical system and evaluated by the receiver when the specimen is removed from the system.

1.2.12 **verification standard,** n.—*in color measurement*, any stable material which is used for the purpose of confirming (or verifying) the validity of an instrument standardization. Color measurements, which are made immediately following a standardization, are compared to original measurements of the standard to detect improper standardization.

1.3 Safety Precautions

1.3.1 Normal safe laboratory practices should be observed during sample preparation and color measurement procedures. The operation of color measuring instruments should be done in accordance with specific manufacturer's instructions and precautions concerning operation and maintenance procedures.

1.4 General Guidelines

1.4.1 In general, instrumental color measurement procedures are dictated by the type of specimen to be measured and the instrument with which it will be measured. Many types of color measuring instruments are available, differing in such features as area-of-view, illumination method and geometry. The user is cautioned that conflicting results may be obtained by comparing data acquired on instruments of different designs.

1.5 Procedure

1.5.1 Operators who utilize Evaluation Procedure 6 as a reference for color measurement should generally conduct such measurements as follows:

1.5.2 Refer to the appropriate section (Reflectance or Transmittance) for specimen to be measured.

1.5.3 Standardize instrument according to section titled ***Standardization***. Maintain a record of the procedure and of the results for any verification standards measured.

1.5.4 Obtain and prepare specimen, noting any special sampling and/or conditioning procedures that may be required (see Appendix A.1.2).

1.5.5 Present specimen to color measuring instrument, again following any special techniques required for the type of material being measured (see Appendix A).

1.5.6 Measure the color of the specimen, obtaining the appropriate spectral reflectance or transmittance factors or colorimetric values.

1.5.7 Perform any appropriate numerical calculations as specified in Section 4 or as is required by the specific test method.

2. Measurement of Color by Reflectance Methods

2.1 Principle

2.1.1 Materials of an opaque or nearly opaque nature (but not translucent) are measured by reflectance methods to obtain a numerical representation of the color of the specimen. Proper equipment setup, standardization of the color measuring instrument, and proper presentation of the test specimens to the instrument are required to achieve consistent, reliable, and meaningful reflectance measurement results. In addition, calculation of the colorimetric values required for evaluating the results must be performed in the prescribed manner.

2.2 Uses and Limitations

2.2.1 This section is restricted to the measurement of the color of opaque and nearly opaque specimens by reflectance spectrophotometers or reflectance colorimeters. The use of special procedures and/or aids to the presentation of specimens is covered in the appendix.

2.3 Apparatus and Materials

2.3.1 Reflectance color measuring instrumentation illuminates a specimen and

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measures the amount of light which is reflected from the surface of the specimen. Illumination is normally done in a polychromatic manner (white light), however monochromatic mode is acceptable for nonfluorescent specimens. Reflectance color measuring instruments may be broadly divided between two groups: Spectrophotometers and Colorimeters.

2.3.2 Spectrophotometers (typically diffuse/0°, using polychromatic illumination) separate and measure the spectrum of light reflected from the specimen, relative to a reference, white at regular intervals (wavelength intervals of 5 nm, 10 nm, and 20 nm are most common). This data may be used to calculate the needed tristimulus values (X,Y,Z) for any given illuminant and observer. Some spectrophotometers (typically 0/diffuse) illuminate the sample with monochromatic light, and measure the amount of light reflected from the surface as the sample is illuminated at regular wavelength intervals.

2.3.3 Colorimeters measure the tristimulus values (X,Y,Z) directly through broadband filters which are designed to produce colorimetric values for one illuminant and observer (typically C/2°). Measurement of reflectance factors at specific wavelengths is not possible with a colorimeter.

2.3.4 Within these two categories, the instruments are further defined by their geometry. Two types of geometries are prevalent: Sphere (also referred to as diffuse/0° [d/0°] or 0/diffuse [0°/d]) and 45/0 or 0/45. The first term in each geometry type refers to the method (or angle) by which the sample is illuminated (ex: 45 degrees in a 45/0 instrument). The second term refers to the angle at which the instrument views the illuminated specimen (ex: 0 degrees in a 45/0 instrument).

2.3.5 Diffuse/0 (sphere) instruments illuminate the specimen indirectly when the specimen is placed against a port opening into a diffusely illuminated sphere, and view the specimen at an angle between 0 and 10 degrees from the perpendicular. This arrangement is designed to capture all light reflected from the specimen. Some sphere instruments with a viewing angle greater than 0 include a *specular port* which allows for the inclusion or exclusion of the *specular reflectance*.

2.3.6 0/diffuse (sphere) instruments are similar, but the path of illumination and viewing are reversed. This method illuminates the sample at an angle between 0 and 10 degrees, and measures the amount of light reflected from the surface into the sphere.

2.3.7 Instruments with 45/0 or (0/45) geometry illuminate the specimen at the first angle and view the specimen at the second. These two geometries can be either circumferential (viewing or illuminating at 45 to the specimen in a complete circle) or directional. For most textile samples, either 45/0 or 0/45 yield equivalent results.

2.3.8 All color measuring instruments require a white calibrated standard with which to standardize the instrument. The colorimetric values for this calibration standard are stored in the instrument or the software and require only that a specific standard be used to standardize the instrument. The correct white standard is usually identified with a serial number.

2.4 Standardization

2.4.1 Proper standardization of any color measuring instrument is absolutely necessary to achieve uniform, accurate results. While different types of instruments require varying methods of standardization, there are common principles which must be observed.

2.4.2 In general, an instrument standardization involves measuring a clean white surface of known reflectance factors (referenced to a perfect reflecting diffuser) and calculating (through software built into the instrument or computer program) a series of correction factors which will be applied to all subsequent measurements. Some instruments also require a black tile (or light trap), and possibly a gray tile. Each of these materials must be maintained in its original clean, unscratched condition. Refer to manufacturer's recommendations for cleaning instructions.

2.4.3 The frequency with which this standardization must be performed depends on many factors including the type of instrument, the environmental conditions in which the instrument operates, and the required accuracy of the results. For most applications, an interval of 2-4 h is typical.

2.4.4 Once the standardization step has been performed, it is important to verify the success of the procedure by measuring some colored materials (**verification standards**) and comparing the resulting colorimetric values to the original values for these materials. If the measured values do not fall within an acceptable variation from their original values, the standardization is not considered valid. The number of **verification standards** and the acceptability limits depend on user requirements, but are typically 1-3 standards and an acceptance limit of 0.20 ΔE_{CMC} (2:1) (D_{65}/10°) units.

2.5 Sampling

2.5.1 All measurements taken on color measuring instrumentation involve "**sampling**." The area-of-view of the instrument, the number of presentations averaged to produce a single measurement, the difficulty of presenting the specimen to the instrument, and the accuracy with which the sample represents the object of concern (garment, roll, dye lot, etc.) all play important parts in achieving meaningful and reproducible results. Refer to ASTM E1345 (see 7.1) and SAE J1545 (see 7.3) for techniques in establishing sampling procedures.

2.6 Specimen Preparation

2.6.1 The ideal specimen to measure is a rigid, non-textured, inert, opaque specimen of uniform color. Such ideal specimens do not exist in textiles, so it becomes necessary to employ techniques and practices when measuring most textile materials which eliminate or reduce the effect any objectionable characteristics have on the instrumental color measurement. Specific procedures and techniques for handling specimens which meet the following characteristics are presented in the Appendix.

2.6.2 *Fluorescence* of the specimen (from dyes or fluorescent whitening agents [FWAs]) will influence the results depending on the amount of fluorescing material present and the amount and quality of ultraviolet and visible energy in the instrument light source. Results may be particularly hard to duplicate between instruments. Example materials are white or lightly colored materials treated with FWAs.

2.6.3 *Moisture Content* of textile materials can affect their color and appearance characteristics. The amount of conditioning time necessary to achieve a stable moisture state varies with fiber, fabric construction, dyes and surrounding conditions. Examples of materials which are typically affected by moisture content are cotton and rayon fabrics.

2.6.4 *Non-Rigid* specimens tend to protrude (or "pillow") into the viewing port of instruments which contact the specimen at the measurement port. The amount of intrusion may vary depending on number of layers, softness of material and the backing pressure applied to mount the specimen. Variations in the amount of intrusion will result in significant deviations in the resulting color measurement which are both unpredictable and non-reproducible. Examples of these materials are fiber, yarn, knits and layers of lightweight fabric.

2.6.5 *Non-Opaque* specimens allow some light to pass through the material during measurement. Most textile materials, by nature of their structure, fit this category. During measurement, any light which passes through the material to reach the backing plate (or escape from the instrument) will yield false and unpredictable results. Examples of these materials are knits, lightweight materials, and fiber.

2.6.6 *Sensitivity* of the specimen to light (photochromism) and/or heat (thermochromism) will result in unpredictable and nonreproducible results, depending on the degree of sensitivity and the amount of time the specimen is exposed to objectionable conditions.

2.6.7 *Size* of the specimen is important

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