INTERNATIONAL STANDARD

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Textiles — Tests for colour fastness —

Part J01:
General principles for measurement of surface colour

Textiles — Essais de solidité des teintures —

Partie J01: Principes généraux du mesurage de la couleur de surface

Reference number
ISO 105-J01:1997(E)

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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 105-J01 was prepared by Technical Committee ISO/TC 38, *Textiles*, Subcommittee SC 1, *Tests for coloured textiles and colorants*.

This fourth edition cancels and replaces the third edition (ISO 105-J01:1989), which has been technically revised.

ISO 105 was previously published in thirteen "parts", each designated by a letter (e.g. "Part A"), with publication dates between 1978 and 1985. Each part contained a series of "sections", each designated by the respective part letter and by a two-digit serial number (e.g. "Section A01"). These sections are now being republished as separate documents, themselves designated "parts" but retaining their earlier alphanumeric designations. A complete list of these parts is given in ISO 105-A01.

Annex A forms an integral part of this part of ISO 105. Annex B is for information only.

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Textiles — Tests for colour fastness —

Part J01:
General principles for measurement of surface colour

1 Scope

This part of ISO 105 is designed as a reference document to support the proper measurement of the colour of specimens by instrumental means as required in many parts of ISO 105. The document describes general concepts and problems associated with reflectance colour measurement.

Annex A specifies techniques and specimen handling procedures.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 105. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreement based on this part of ISO 105 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 139:1973, *Textiles — Standard atmospheres for conditioning and testing.*

CIE Publication No. 15.2, *Colorimetry,* 2nd ed. (1986)[1].

3 Definitions

For the purposes of this part of ISO 105, the following definitions apply.

3.1 colour measurement: A numerical representation of the colour of a specimen obtained by use of a colour measuring instrument; a single measurement may represent an average of multiple readings of a specimen.

1) Available from the International Commission on Illumination Central Bureau, Kegelgasse 27, A-1030 Vienna, Austria.

3.2 colour measuring instrument: Any device (such as a colorimeter or spectrophotometer) used to measure the relative amount of radiation reflected from a specimen in the visible region of the spectrum (comprising the wavelengths from 360 nm to 780 nm, and including as a minimum the region from 400 nm to 700 nm).

3.3 geometry (of a colour measuring instrument)**:** One of the following illumination/viewing conditions.

d/0	0/d	0/45	45/0

which describes the angle or manner in which a colour measuring instrument

1) illuminates the specimen:

d	0	0	45

2) views the resulting reflected light:

0(0°-10°)	d	45	0

d = diffuse; 0 = normal (0° to 10°); 45 (45° ± 2°) = tolerable range of the angle between the direction of illumination or viewing and the normal to the specimen.

NOTE — Instruments of different geometries may produce different colorimetric results on most textile materials.

3.4 area-of-view [optical aperture] (of a colour measuring instrument)**:** The dimensions (size and shape) of the surface area that a colour measuring instrument is capable of covering in a single colour measurement.

3.5 fluorescence: A phenomenon in which radiant flux of certain wavelengths is absorbed and re-emitted at other, usually longer, wavelengths.

3.6 reflectance: The ratio of the reflected radiant or luminous flux (light) to the incident flux in the given conditions.

3.7 reflectance factor: The ratio of the flux reflected from the specimen to the flux reflected from the perfect reflecting diffuser under the same geometric and spectral conditions of measurement.

3.8 specular reflection: The reflection without diffusion, in accordance with the laws of optical reflection, as in a mirror.

3.9 standardization (of colour measuring instrument)**:** The act of measuring one or more calibrated materials with a colour measuring instrument for the purpose of calculating a set of correction factors to be applied to subsequent measurements.

NOTE — Calibration is typically performed by an instrument manufacturer to ensure that the instrument meets the criteria as established by national standardizing laboratories.

3.10 verification standard: In colour measurement, any stable material which is used for the purpose of confirming (or verifying) the validity of an instrument standardization. Colour measurements, which are made immediately following a standardization, are compared to original measurements of the standard to detect improper standardization.

4 Principle

Materials of an opaque or nearly opaque nature (but not translucent) are measured by reflectance methods in order to obtain a numerical representation of the colour of the specimen.

NOTES

1 Proper equipment set-up, standardization of the colour measuring instrument and proper presentation of the test specimens to the instrument are required to achieve consistent, reliable and meaningful reflectance measurement results.

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

5 Apparatus

5.1 Reflectance colour measuring instrument, for illuminating a specimen and measuring the amount of light which is reflected from the surface of the specimen. Illumination is usually polychromatic (white light); however monochromatic mode is acceptable for nonfluorescent specimens. Reflectance colour measuring instruments may be broadly divided into two groups:

a) 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). These data may be used to calculate the desired 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.

b) 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.

Within these two categories, the instruments are further defined by their geometry as defined in 3.3.

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° 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 permits the inclusion or exclusion of the specular reflectance.

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° and measures the amount of light reflected from the surface into the sphere.

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.

5.2 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.

5.3 Black standard, required for some instruments. It may be of zero reflectance (a light trap) or it may be calibrated, in which case the comments in 5.2 apply.

6 Procedure

6.1 General

a) Collect and prepare specimen, noting any special sampling and/or conditioning procedures that may be required as described in 6.3 (see also annex A).

b) Standardize instrument according to 6.2. Maintain a record of the procedure and the results of any verification standards measured.

c) Present specimen to colour measuring instrument following any special techniques required for the type of material being measured per section 6.4 (see also annex A).

d) Measure the colour of the specimen, obtaining the appropriate spectral reflectance factors (or tristimulus values if a colorimeter is used).

e) Calculate colorimetric values, if required, as described in clause 7.

6.2 Standardization

Proper standardization of any colour measuring instrument is necessary in order to achieve more precise and accurate results. While different types of instruments require varying methods of standardization, there are common principles which shall be observed.

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

The frequency with which this standardization is 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 h to 4 h is acceptable.

Once the standardization step has been performed, it is important to verify the success of the procedure by measuring some coloured 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 to 3 standards and an acceptance limit of 0,20 $\Delta ECMC(2:1)D_{65}/10$ units.

6.3 Sampling

All measurements taken on colour 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, dyelot, etc.) all play important parts in achieving meaningful and reproducible results.

NOTE — Refer to ASTM method E1345 and SAE method J1545 for techniques in establishing sampling procedures. A brief description of J1545 is given in annex A.

6.4 Specimen preparation

The ideal specimen to measure is a rigid, non-textured, inert, opaque specimen of uniform colour. 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 to acceptable levels the effect any specimen characteristics have on the instrumental colour measurement. Specific procedures and techniques for handling specimens which meet the following characteristics are presented in annex A.

a) 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 that do not have methods for calibrating the UV content. Example materials are white or lightly coloured materials treated with FWAs.

b) Moisture content of textile materials can affect their colour and appearance characteristics. The amount of conditioning time necessary to achieve a stable moisture state varies with fibre, fabric construction, dyes and surrounding conditions. Examples of materials the colour of which are typically affected by moisture content are cotton and viscose materials.

c) Non-rigid specimens tend to protrude (or "pillow") into the viewing port of instruments. 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 colour measurement which are non-reproducible. Examples of these materials are fibre, yarn, knits, and layers of lightweight fabric.

d) 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 results. Examples of these materials are knits, lightweight materials and fiber.

e) Sensitivity of the specimen to light (photochromism) and/or heat(thermochromism) results in nonreproducible results, depending on the degree of sensitivity and the amount of time the specimen is exposed to undesirable conditions.

   The photochromic properties of a specimen may be determined according to ISO 105-B05:1993.

f) Size of the specimen is important in obtaining a representative measurement by the instrument. When the specimen is too small for normal measurement, special techniques may be required to achieve a proper colour measurement.

g) Surface texture of the specimen (including pile lay, twill, gloss and lustre) affects the results of the colour measurement. The colour measurements of specimens with such physical characteristics are affected in different ways depending on the geometry of the instrument. Results between instruments of different geometries may be non-reproducible. Examples of these types of specimens are carpet, corduroy and wound yarn.

h) Variation in colour (non-uniformity) within the specimen, as related to the area-of-view of the instrument, can cause non-reproducible results. Examples are denim and leathers.

7 Method of calculation

Most calculations of colorimetric nature are performed by the software being used to operate the colour measuring instrument. In normal cases of reference to this method it will not be necessary for the user to perform these calculations, however they are described here as a means of reference and standardization for those who may need to perform such calculations.

7.1 Tristimulus values

The tristimulus values (X,Y,Z) are derived from spectral data and are the basis for all colorimetric calculations. The exact (X,Y,Z) values derived from a set of spectral data depend on several factors including the wavelength range and interval of measurement and the user's choice of illuminant/observer functions used in the calculation.

NOTES

1 In order to obtain results that are compatible between users the tristimulus values should be calculated according to ASTM E-308-96. Most calculations of tristimulus values are performed by computer programs and a user should therefore verify with the instrument/software supplier that they are thus calculated.

2 One method to verify that the correct calculations are being made is to enter 100 % reflectance values into the computer program and have the system calculate the tristimulus values. These values should agree with the values in table 1 (from ASTM E-308-96) to the second decimal place for the illuminant being checked.

7.2 CIE 1976 L^*, a^*, b^* C_{ab}^* and h_{ab}

Calculate the L^*, a^*, b^*, C^*_{ab}, h_{ab} values from the X,Y,Z tristimulus values for both the standard and sample as follows:

$L^* = 116\,(Y/Y_n)^{1/3} - 16$ if $Y/Y_n > 0{,}008\,856$

$L^* = 903{,}3\,(Y/Y_n)$ if $Y/Y_n \leqslant 0{,}008\,856$

$a^* = 500\,[f(X/X_n) - f(Y/Y_n)]$

$b^* = 200[f(Y/Y_n) - f(Z/Z_n)]$

where:

$f(X/X_n) = (X/X_n)^{1/3}$ if $X/X_n > 0{,}008\,856$

or

$f(X/X_n) = 7{,}787\,(X/X_n) + 16/116$ if $X/X_n \leqslant 0{,}008\,856$

$f(Y/Y_n) = (Y/Y_n)^{1/3}$ if $Y/Y_n > 0{,}008\,856$

or

$f(Y/Y_n) = 7{,}787\,(Y/Y_n) + 16/116$ if $Y/Y_n \leqslant 0{,}008\,856$

$f(Z/Z_n) = (Z/Z_n)^{1/3}$ if $Z/Z_n > 0{,}008\,856$

or

$f(Z/Z_n) = 7{,}787\,(Z/Z_n) + 16/116$ if $Z/Z_n \leqslant 0{,}008\,856$

$C_{ab}^* = (a^{*2} + b^{*2})^{1/2}$

$h_{ab} = \arctan(b^*/a^*)$ expressed on a 0° to 360° scale with the a^* positive semi-axis being 0° and the b^* positive semi-axis at 90°.

Thus

if $a^* > 0$ and $b^* > 0$, $0° < h_{ab} < 90°$

if $a^* < 0$ and $b^* > 0$, $90° < h_{ab} < 180°$

if $a^* < 0$ and $b^* < 0$, $180° < h_{ab} < 270°$

if $a^* > 0$ and $b^* < 0$, $270° < h_{ab} < 360°$

for these equations, X_n, Y_n and Z_n are the tristimulus values of the illuminant. For daylight the preferred illuminant/observer combination is $D_{65}/10$.

Table 1 gives the values for all combinations in ASTM E-308-96.

Table 1 — Tristimulus values for illuminant/observer combinations

Illuminant/observer combinations	Tristimulus values		
	X_n	Y_n	Z_n
Ten degree observer			
A/10°	111,146	100,000	35,200
C/10°	97,285	100,000	116,145
D_{50}/10	96,720	100,000	81,427
D_{55}/10	95,799	100,000	90,926
D_{65}/10	94,811	100,000	107,304
D_{75}/10	94,416	100,000	120,641
F2/10° (cool white fluorescent 4 230 K)	103,279	100,000	69,027
F7/10° (daylight fluorescent 6 500 K)	95,792	100,000	107,686
F11/10° (ultralume 4 000 K and TL84)[2)]	103,863	100,000	65,607
Two degree observer			
A/2°	109,850	100,000	35,585
C/2°	98,074	100,000	118,232
D_{50}/2	96,422	100,000	82,521
D_{55}/2	95,682	100,000	92,149
D_{65}/2	95,047	100,000	108,883
D_{75}/2	94,972	100,000	122,638
F2/2° (cool white fluorescent 4 230 K)	99,186	100,000	67,393
F7/2° (daylight fluorescent 6 500 K)	95,041	100,000	108,747
F11/2° (daylight fluorescent 4 000 K and TL84)[2)]	100,962	100,000	64,350

8 Test report

The test report shall include the following information:

a) reference to this part of ISO 105, i.e. ISO 105-J01:1997;

b) the instrument geometry type that was used to measure the specimen(s);

c) whether the specular component was included or excluded;

d) area of view;

2) Both are trademarks of Phillips.

e) UV energy included or excluded;

f) make and model of the spectrophotometer (including wavelength range and interval used) or colorimeter;

g) the illuminant(s)/observer(s) used to calculate the colorimetric values;

h) date of test;

i) identification of specimen(s);

j) specimen presentation, e.g. number of thicknesses, orientation, conditioning of samples;

k) number of readings per sample measurement;

l) any relevant results.

Annex A
(normative)

Measurement problems and guidelines

A.1 Fluorescence

For colour measuring instruments which do not have the ability to accurately control the amount of UV energy illuminating the specimen, the operator may insert a UV-absorbing filter between the light source and the sample, effectively eliminating the UV-induced fluorescence. Note that this technique may result in disagreement with visual results. Note also that this technique is only applicable in those cases where the fluorescence is caused by absorption of ultraviolet radiation. Instruments which can control the UV energy will produce results more consistent with visual observation, but these results may be harder to reproduce on other non-similar instruments. In either case when specimens are fluorescent, all specimens to be compared shall be measured during the same time interval (within 1 h), and in no case may previously measured data (standards, controls, etc) be used for comparison. In general, sphere-design instruments introduce a small error to the measurement due to the change in specimen illumination caused by the fluorescent emission. This error does not occur in a 0/45, 45/0 (circumferential or bidirectional) type measuring instrument. (See CIE 15.2:1986, section 1.4, note 8).

A.2 Moisture content

If the presence of moisture affects the measurement of colour it is necessary to "condition" the specimens to allow the moisture content to stabilize. This conditioning shall take place in a room or chamber where the temperature and humidity are constant, and enough time shall be allowed for the moisture regain of all related samples to be identical. This is typically several hours for most specimens containing cotton or hydroscopic fibre, but can vary significantly with different ambient conditions. The condition of the specimen should be maintained as much as possible during measurement. Standard laboratory conditions are specified in ISO 139.

A.3 Non-opaque

Most textile samples are non-opaque to some extent. All specimens should be measured using the same procedure. If sufficient quantity of material is available, it is desirable to layer the material until light will no longer penetrate through the layers. If the measurement of the specimen backed with a white tile is not significantly different to the measurement of the same specimen backed with a black tile, then the number of layers is considered sufficient. Note that many layers of soft material can cause other problems (see A.4) and may require a compromise. In such cases it may be necessary to use a nominal number of layers (always the same number for each specimen measured) backed by a white material or tile that contains no fluorescent whitening agents. Always use the same backing material.

A.4 Non-rigid

To avoid intrusion of soft specimens into the measuring port of the colour measuring instrument use one of the following procedures:

a) Winding, fastening or mounting to a card or other sufficiently rigid material. The backing material shall be of a neutral (white, grey or black) colour, reproducible for all specimens to be measured, and the opacity rules (see A.3) shall be observed. When yarn specimens and continuous filament specimens are wound onto cards it is necessary to control the tension, orientation and thickness of the material to achieve reproducible results.

b) A few instruments are designed to measure specimens without contacting their surfaces. Specimens to be measured must be flat, backed by a rigid structure, and have sufficient thickness to eliminate any effects from non-opacity.

c) Measurement of some specimens behind glass increases repeatability of colour measurement for spectrophotometers, particularly on fibre and yarn specimens. The amount of material and the pressure used to press the material against the glass shall be controlled and the glass cleaned between readings if necessary. The effects of the glass may bias the results. The resulting reflectance measurements can be corrected by the following equation:

$$R_\lambda = \frac{(R_g + T_c - 1)}{[R_g + T_c - 1 - (T_d \times R_g) + T_d]}$$

where

R_λ is the corrected percentage reflectance without glass;

R_g is the measured percentage of R behind glass;

T_c is the transmittance of glass to collimated light (nominally equal to 0,92 for specular-included type measurements, for glass with a refractive index of 1,50 and no absorption);

T_d is the transmittance of glass to diffuse light (nominally equal to 0,87 for glass as described above).

NOTES

1 All R and T values are expressed in decimal fraction form.

2 If it is not possible to apply this glass correction to the measurement, then measurements should be made with the specular component excluded.

A.5 Sensitivity to light or heat

Specimens which are sensitive to light and/or heat are best measured in a colour measuring instrument which exposes the specimen to light for only a brief moment during the actual measurement. Flash illumination instruments and instruments with automatic shutters provide mechanisms for limiting the amount of time that the sample is exposed to light. Instruments which scan the visible spectrum (taking several seconds to perform a single measurement) should not be used for these specimens. In all cases, sample preparation shall include keeping the specimens in the dark (minimizing exposure to light) prior to measurement. Instruments which illuminate the specimen monochromatically are also acceptable for measuring these types of specimens.

A.6 Small specimens

Specimens which are small enough to require the use of an SAV (small area view) option on the colour measuring instrument shall be read a multiple number of times and averaged to improve the repeatability of the measurement. Specimens smaller than the area of view of the instrument cannot be measured reliably.

A.7 Surface texture

The difficulty in measuring specimens with pronounced physical surface characteristics first lies in the decision as to what physical attribute interests the user. The ability of an instrument to separate colour from *appearance* is an advantage in some situations such as colourant formulation, and a disadvantage in others such as quality control applications. For example, it is desirable to measure only the *colour* of pile type specimens, the most effective means is to mount the specimen behind glass and apply enough pressure to eliminate any texture differences. The same precautions and requirements apply as in the use of glass for non-rigid samples above. When the texture of the surface results in *directionality variation*, the specimen may be measured in multiples of four, rotating 90° after each measurement. All measurements are then averaged to produce a single set of colorimetric values.

NOTE — An example of such a procedure developed for automotive fabrics is SAE J1545.

A.8 Variation in colour

When the specimen to be measured is not uniform in colour, measurement averaging (of spectral data from a spectrophotometer or tristimulus-value data from a colorimeter) is necessary to achieve repeatable measurements. This requires determining the number of readings necessary for the area-of-view employed which, when averaged (arithmetic mean) to produce a single result, can be reproduced by repeating the procedure at random locations on the specimen (see SAE J1545).

Annex B
(informative)

Bibliography

[1] ISO 105-B05:1993, *Textiles — Tests for colour fasteners — Part B05: Detection and assessment of photochromism.*

[2] *ASTM Standards on Color and Appearance Measurement,* Fifth Edition 1996, ASTM, Conshohocken, PA[3].

[3] ASTM E1345:—[4], *Standard Practice for Reducing the Effect of Variability of Color Measurement by Use of Multiple Measurements.*

[4] SAE J1545:1986, *Instrumental Color Difference Measurement for Exterior Finishes, Textiles and Colored Trim.*

[5] ASTM E-308-96, *Computing the Colors of Objects by using the CIE System.*

3) Available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19426, USA.

4) Withdrawn.

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