Testing coated fabrics —

Part 13: Guide to the selection of methods for colour fastness to light testing

ICS 59.080.40

Committees responsible for this British Standard

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Foreword

This British Standard has been prepared by Technical Committee TCI/78, Coated fabrics, which has the responsibility to:

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 7 and a back cover.

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Introduction

This guide is intended to assist in the selection of procedures and apparatus for the colour fastness testing of coated fabrics to artificial light and also the subsequent physical testing of the coated fabric test specimens.

A number of different techniques and methods are available which each have advantages and disadvantages. The guide aims to highlight these and provide sufficient information so that the best and most appropriate testing can be carried out.

The guide has been written after a two stage information gathering process. The first stage was to survey the opinion of European suppliers of coated fabrics as to their testing requirements and current practices. This took the form of a questionnaire circulated to over 70 companies (see clause **10**). The second stage was to review the current test methods and to summarize and assess them.

The ultimate criterion for judging a light fastness test is how the results compare with the real life situation. The purpose of laboratory testing is to simulate real exposure to light but at an accelerated rate. For each individual material, the end-use may be different, so the recommendations of this guide should be heeded whilst at the same time considering experience of real life situations. Where more quantitative results are sought, this guide will be particularly useful since it is designed to make the testing procedures as standardized, consistent and repeatable as possible.

In the past, BS 3424 has recommended that either BS 1006 or BS 2782 is followed depending on which side of the coated fabric was being tested. Similarly, this guide makes significant reference to ISO 105.

1 Scope

This document describes the factors that need to be considered when assessing the colour fastness of coated fabrics to artificial light and when carrying out post exposure physical testing on the coated fabric test specimen. It is applicable to all forms of plastic and rubber coated materials.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 1006:1990, *Methods of test for colour fastness of textiles and leather.*

BS 2782-5:Method 540D:1995, *Methods of testing plastics — Part 5: Optical and colour properties, weathering — Method 540D: Methods of exposure to laboratory light sources. General guidance.*

BS 2782-5:Method 540E:1995, *Methods of testing plastics — Part 5: Optical and colour properties, weathering — Method 540E: Methods of exposure to laboratory light sources. Xenon-arc sources.*

BS 2782-5:Method 552A:1981, *Methods of testing plastics — Part 5: Optical and colour properties, weathering — Method 552A: Determination of changes in colour and variations in properties after exposure to daylight under glass, natural weathering or artificial light.*

BS EN 20105-A02:1995, *Textiles — Tests for colour fastness — Part A02: Grey scale for assessing change in colour.*

ISO 105-B02:1994, *Textiles — Tests for colour fastness — Part B02: Colour fastness to artificial light: Xenon arc fading lamp test.*

3 Light source

3.1 General

When testing colour fastness in general, it is vital that the test environment and conditions replicate real life or in-use conditions. Since this guide is concerned with light fastness as opposed to weathering, the light to which the test specimens are exposed should mimic daylight as closely as possible.

3.2 Xenon-arc light

Xenon-arc light (with the appropriate filters) is the source which best attains this goal. Over the wavelength range of 300 nm to 800 nm, which includes ultra-violet (UV), visible and infra-red (IR) radiation, the spectrum of filtered xenon light resembles that of sunlight. It may be that UV radiation is the primary cause of material degradation but the temperature of the test specimen is also very significant. Consequently the heating effects caused by the IR part of the incident radiation are also vital, especially for coloured test specimens. Although with some types of xenon lamps, the heating effects due to the IR radiation may be greater than those which occur in real life, appropriate filters can minimize this difference. An additional benefit of xenon lamps is that filters can be used whose output mimics that of daylight through window glass, a common in-situ application.

The specifications in BS 2782-5:Method 540E:1995, **4.1** regarding the xenon-arc lamp apparatus should be adhered to.

3.3 Filtered mercury vapour lamps

Filtered mercury vapour lamps with the addition of metal halide or tungsten are also able to give a similar spectrum to sunlight although the IR portion of its output is slightly lower than for solar radiation. The intensity of the light is also far lower than for xenon-arc and hence test exposure times will be longer.

3.4 Carbon-arc light sources

The light emitted by an arc between carbon electrodes was popular before the advent of xenon-arc light sources but, even with filters, carbon-arc light includes a significant amount of radiation between 350 nm and 450 nm which does not occur in natural daylight. Therefore the use of carbon-arc light sources is not recommended.

3.5 Fluorescent UV light sources

Fluorescent UV light sources expose samples to the damaging UV portions of sunlight at controlled elevated temperatures.

4 Irradiance

Irradiance is defined as the amount of radiation energy incident upon a square metre of material. It is dependent upon the spectrum of the emitted radiation, the intensity of the radiation, the distance of the test specimen from the energy source and the orientation of the test specimen surface with respect to the incident energy.

The international colour committee, CIE, has compiled data which states that over the wavelength range 290 nm to 800 nm (UV, visible and IR radiation), an irradiance value of 550 W/m^2 is recommended when simulating solar radiation. When considering irradiance values caution is advised since it is easy to be misled. The energy of a radiation source is inversely proportional to the wavelength of the radiation (UV radiation is more "energetic" than IR radiation) so the same intensity of radiation can give different irradiance values depending on the wavelength range over which the measurements are made.

The importance of reproducing sunlight has already been emphasized but it is worth reiterating.

A radiometer is a device for measuring irradiance. In the context of the testing apparatus it should be mounted in the same relative position as the test specimen and in the same orientation with respect to the light source. The radiation energy is not evenly distributed over the entire wavelength range. The xenon-arc lamp (when new) should conform to the spectral distribution of UV radiation specified in BS 2782-5:Method 540E:1995, **4.1**.

NOTE 1 Although the lamps may be manufactured to conform to BS 2782-5:Method 540E:1995, **4.1**, there will be significant variation between the spectral distributions of the lamps.

Assuming that real life test experience has shown the need to mimic sunlight as closely as possible, the radiometer should measure over the wavelength range 290 nm to 800 nm and its output should be used to automatically adjust the intensity of the lamp so that an irradiance of 550 W/m^2 is applied constantly. The lamp burner should be discarded and replaced when this irradiance cannot be achieved.

NOTE 2 The output of an adjusted lamp will decrease in intensity over time.

ASTM D3424 [1] indicates that the average daily dose of radiation energy received in Miami and Arizona is 1 MJ/m^2 over the range 295 nm to 400 nm. An irradiance of 550 W/m^2 over the wider range specified earlier is equivalent to 60 W/m^2 over this narrower range. Correspondingly in 1 h a radiation dose of 220 kJ/m^2 will be emitted. Therefore the total daily Miami radiation dose will be received by the test specimen in less than 5 h. If it is also assumed that Miami sunshine is four to five times more severe than in Europe, then 1 h exposure at 550 W/m^2 is equivalent to the average daily dose of radiation energy in typical European sunshine.

This is not a very accurate statistic and it should only be considered as a rule of thumb. More data needs to be collected either by individuals or by the textiles/plastics/rubber industries to relate exposure time in a laboratory test to real life exposure.

NOTE 3 UV testing using lamp options span the range 295 nm to 400 nm.

5 Humidity/temperature control

It has already been stated that temperature is an important factor in any photochemical reaction that will occur within the test specimen. Humidity is also important, especially for the textile component of the test specimen. In each case, the critical area is at the test specimen itself. The temperature and humidity of the test specimen chamber influence the test but any measurements should be focused at the surface of the test specimen.

Although the mercury vapour lamp light can be made to resemble that of daylight, the test method which utilizes this light source, BS 1006:1990, Method UK-TN specifies quite simple apparatus. Some account is made for humidity and temperature control but not to a sufficient level for the method to be regarded as a quantitative test. Indeed the method states that it is intended for use as a quality control test.

It is recommended that a red azoic dyed cotton cloth is used to measure the "effective humidity", as defined in ISO 105-B02:1994, **4.1.3**, and the apparatus adjusted accordingly.

There is also a limit as to how accurately the apparatus can control the humidity within the chamber. Utilizing electronic control systems and sensitive water dispersal systems the relative humidity can be maintained at a given level within a ±2 % range. Using less sophisticated control systems will broaden the range and increase the inaccuracy of the humidity level within the test chamber.

The instrument used to measure the temperature of the test specimen is significant. Ideally, the temperature at the surface of the specimen would be measured directly but in reality the best that can be achieved is to position a measurement device so that it is exposed to the light source in the same manner as the test specimen. Two types of thermometer are commonly used in light fastness equipment: a black-standard and a black-panel thermometer. Differences in design means that typically the black-panel temperature indicated is significantly less than the black-standard temperature. Black-standard devices approximate the temperature of dark test specimens which have a low thermal conductivity. Since coated fabrics are poor conductors of heat, it is recommended that a black-standard thermometer is used. In order to make the temperature measurement more applicable to a range of coloured test specimens, a white-standard thermometer should also be used. Both the black-standard and white-standard thermometers are described in BS 2782-5:Method 540D.

The commonly used ASTM G26 [2] recommends a black-panel temperature of 63 ± 3 °C. The in-use exposure conditions, both in terms of humidity and temperature, will vary depending on the country of end-use. It is recommended that the exposure conditions specified in ISO 105-B02:1994, clause **6** (see Table 1) are followed. This will enable normal and extreme European conditions to be recreated as well as facilitating meaningful comparisons with American test results.

6 Post exposure testing

In addition to assessing the colour change of a test specimen material, it may be desirable to study the effects of light exposure on other properties such as surface texture or flexing resistance.

When conducting physical tests, test specimens may have to be reduced in size because of the geometric limitations imposed by the testing apparatus. This may mean that non-standard tests have to be carried out but in such a situation it is not definitive answers which are important, rather the change in the relevant property. Therefore the physical test should be performed using smaller test specimens which have not been exposed to artificial light as well as specimens which have been exposed to the light source. The procedures in BS 2782-5: Method 552A:1981, clause **4** and BS 2782-5: Method 552A: 1981, **5.2** are recommended. It is recommended that the operation of the light fastness equipment is not changed in order to accommodate test specimens, as this may introduce extra or unknown variables into the test.

It does not seem that post exposure testing is frequently carried out but if post exposure testing is of particular concern and larger test specimens must be accommodated, fluorescent UV apparatus can be more versatile than typical xenon-arc machines. Alternatively, large scale xenon-arc machines are available but these are considerably more expensive.

7 Blue wool standards

Blue wool standards are samples of wool which have been specifically dyed to give the fabric's known light fastness properties. A range of eight grades are produced and are commonly used in the testing of textiles.

The principle of operation is that the blue wool standards are exposed to the artificial light source simultaneously with the test specimen. The change in colour of the test specimen is assessed visually using grey scales. When a certain level of colour change has been detected, the test specimen is visually compared to the blue wool standards and the colour fastness of the test specimen is reported as being equal to one of the eight standards.

There are some variations in this technique which can be used but they are susceptible to the same inherent problems which are compounding the errors from two subjective and non-reproducible measurement techniques. The method of using grey scales for visually assessing colour is well known and frequently used but does not give very repeatable or reproducible results, particularly when the assessments are not performed by experienced personnel.

Two sources of error exist in the experimental procedure. First, within the method of grey scale assessment of the colour change of the test specimen and second, within the subjective comparison of the test specimen and the blue wool standards.

Table 1 — Recommended exposure conditions

Exposure condition	Effective humidity	Blue wool rating of humidity control fabric	Black-standard temperature °C
Europe: extreme	Low	6 to 7	Maximum 65
Europe: normal	Moderate	5	Maximum 50
Europe: extreme	High	3	Maximum 45
America	Low	6 to 7	63 ± 1 (black-panel)

In the past, blue wool standards have also been used when testing plastics and rubbers. Since there was a need to expose these materials to the light source for longer periods of time, a method of using a number of blue wool standards in a sequential manner was developed. However, even then doubt was expressed about the applicability of the fabric standard to plastic and rubber testing. Consequently BS 2782-5:Method 540E does not recommend their use.

Another problem is that the dyes used to produce blue wool standards have been outlawed by legislation. Work is under way to produce an alternative set of printed pigment standards. This is being carried out by Leeds University in association with the Society of Dyers and Colourists but at this time the standards are still at the development stage. The printed pigment standards are intended to be used in the same way as the blue wool standards but it is not known whether they will be adopted by the rubber and plastic industries.

It is concluded that the use of blue wool standards is subject to several significant inaccuracies, especially when used in conjunction with rubber and plastic coated fabric.

8 Instrumental colour assessment

Instead of relying purely on visual assessment it is possible to use instrumental techniques to quantify the colour of an object. This is desirable since it would lead to colours and colour changes being more precisely measured and better differentiation between objects would be possible.

The colour measurement system expresses colours using three numerical categories: hue, chroma and lightness. The difference in one or all of these quantities can be subsequently calculated.

There are two types of instrument available: tristimulus colorimeters and spectrophotometers. In general terms, the colorimeter works by measuring the reflectance of three distinct light sources from an object whereas the spectrophotometer measures the reflectance across the whole visible spectrum.

Recent advances in technology have meant that portable hand-held spectrophotometers have become available at relatively low cost. This is a significant advance because they are more accurate and reliable than colorimeters.

The technology is still far from perfect because different pieces of equipment can still give different colour values for the same object. Calibration of the devices is also critical. Even the same instrument, if calibrated differently or using different calibration tiles will give erroneous results.

The colour difference between the exposed and unexposed areas of the test specimen can be expressed as numerical differences in hue, chroma and lightness or alternatively these values can be converted, by way of mathematical formulae, into grey scale values (see BS EN ISO 105-A05).

This creates another possible source of error — differences between visual and instrumental grey scale ratings. One of the points highlighted by the questionnaire replies concerned problems encountered in this area.

9 Colour vision deficiency

9.1 General

Two people who view the same object, from the same direction, under the same source of illumination may not perceive the object colour as being the same. This is due to inherent differences in human vision which exist between individuals. As such, normal colour vision can only be defined by using average characteristics of colour vision derived from a representative population.

Consider the situation where a person (observer) is asked to match a mixture of the three primary colours (red, green and blue) with a reference light or spectral colour.

Observers with normal colour vision will use a mixture of the three primaries to achieve a match within accepted tolerances. An observer with anomalous trichromacy will use the three primaries but the perceived colour match will be outside the "normal" tolerances. When only two of the primaries are used to achieve a match, a condition of dichromacy is diagnosed. In both these cases, the observer will perceive reds, greens and blues but they will be different to those seen by normal observers. Therefore these observers are said to have vision which is colour deficient. Whereas a person with monochromatic vision would require only one primary colour to match the reference and would see objects in shades of grey. The term colour-blind can be correctly used in this instance.

These deficiencies in colour vision can be inherited or acquired. Within Europe, approximately 8 % of men and 0.4 % of women have inherited colour vision defects while around 2 % of the population have acquired defects.

A detailed laboratory examination would require sophisticated optical instruments and a significant amount of time both to perform the test and analyse the data.

Four categories of more simple, practical tests are available and are described in **9.2** to **9.5**.

9.2 Colour matching tests

The principle of these tests is for the candidate to match a reference light with an added primary colour using a mixture of the two other primaries. This type of test is considered the reference standard by which other tests are judged. The equipment used is called an anomaloscope and is capable of detecting virtually all cases of defective vision.

Two statistics from the test data are particularly significant: the range of colours over which a match is perceived and also the mid-point of the match. For a given person, the test data will be compared to that pertaining to average "normal" vision. In addition to identifying the vision defects already described, the anomaloscope can be used to highlight variations within nominally "normal" colour vision. If the mid-point is displaced but the magnitude of the colour range is normal, the observer is classed as "deviant colour normal". This applies to approximately 4% of normal observers. If the mid-point is within tolerance but the range is wider than normal, the observer is said to be "colour weak" and this is true of around 20 % of the normal colour vision population.

9.3 Colour confusion tests

The most common type of test is of a pseudo-isochromatic nature (Ishihara tests belong in this category). For these tests, the candidate looks at a page which contains some coloured designs. Specific patterns within the design may be seen by normal observers but not by people with colour vision deficiencies, or vice versa.

The test is designed to give a pass/fail rating only. The candidate is considered as having normal or defective colour vision but with an uncertainty level of around ±9 %.

Another colour confusion test is the Farnsworth dichotomous D15 test which is not pseudo-isochromatic. This is designed to differentiate between severe colour deficients and observers with normal vision or mild colour deficiencies. As such, the test fails around 60 % of all colour deficients. The test can also give an indication of the nature of the vision problem.

9.4 Colour discrimination tests

One such test which is popular and gives good correlation with analytical results is the Farnsworth-Munsell 100 Hue test (FM 100 Hue). It utilizes 85 discs of different hues but constant chroma and lightness which the observer has to rearrange to minimize the colour difference between the discs.

A feature of the test is that the results are not judged against an averaged standard. It can be used to differentiate between normal colour vision and the three specific types of deficiency but not between anomalous trichromacy and dichromacy.

9.5 Specialist tests

For some occupations classifying colour vision as normal or defective is insufficient. It is more appropriate to test whether colour vision characteristics of the individual are suitable for the job. Tests designed to replicate a real work situation can be beneficial in these circumstances.

Other tests for unique properties include the colour aptitude test from the Inter-Society Color Council and the Burnham-Clark-Munsell memory test.

In the case of (dis)colouration of textiles, good colour discrimination and representative colour matching ability would be ideal attributes.

As stated earlier, there is an inherent variation between people's perception of colour. Therefore in a situation where colour grading of a product is important, a number of observers should judge the product before a final decision is taken.

10 Summary of questionnaire results

The majority of companies used a xenon-arc light source for their testing while UV fluorescent tubes were used to a large extent for comparative testing. All but one of the users of xenon-arc followed ISO 105-B02 and all utilized blue wool.

It appears that very little consideration had been given to the applicability of the ISO test method and exposure standard to coated fabrics.

In most cases the humidity within the test chamber was controlled although the techniques for achieving this were evenly distributed between a humidity meter, hair hygrometer and humidity control fabric. The air temperature was considered less significant with less than half the number of companies carrying out monitoring. Whereas most of the respondents obtained a measurement of the approximate surface temperature of the test specimen, using a black panel thermometer in nearly every instance.

Visual assessment using blue wool standards and grey scales were the most popular method of determining light fastness. Nevertheless, some companies did report problems with these assessment techniques.

Comments were received from a small number of companies who believed their testing apparatus gave repeatable results, although no mention was made of the correlation with the performance of the test material in wear. One company which followed BS 1006 found that when testing PVC (polyvinyl chloride) coated fabric the correlation with in-situ performance was poor.

Only a third of the respondents performed post exposure testing, the properties tested being tensile strength, flex resistance or abrasion resistance and no deviations from the standard light fastness test method were reported. Additionally, 10 % of the companies performed visual assessment for signs of damage after light fastness testing.

11 Overall recommendations

In order to assess the colour fastness of coated fabrics to sunlight using an accelerated laboratory test in as quantifiable, repeatable and meaningful way as possible the following recommendations should be followed.

a) The light source used should be of the xenon-arc type as specified in BS 2782-5:1995, Method 540D, **4.1**.

b) The temperature within the test chamber should be monitored using a black-standard thermometer and a white-standard thermometer as specified in BS 2782-5:1995, Method 540D, **5.1.5**.

c) The effective humidity within the test chamber should be monitored using red azoic dyed cloth as described in ISO 105-B02:1994, **4.1.3**.

d) The relative humidity within the test chamber should be controlled as accurately as possible. It should be possible to maintain a given relative humidity level within a ±2 % range.

e) The exposure conditions should be selected from those detailed in ISO 105-B02:1994, clause **6**.

f) The irradiance of the light source should be 550 W/m^2 over the wavelength range 290 nm to 800 nm and should be monitored using a radiometer.

g) The exposure duration should be controlled by time only. A guide to testing time is that 1 h exposure to xenon-arc light is equivalent to the average daily dose of radiation energy received in European sunshine.

NOTE More precise data needs to be collected to aid selection of testing time.

UV testing is an acceptable comparable test (ideal for polymer degradation and strength loss evaluations) but recognizes the limitations of wavelength (UV only) and humidity control.

h) The use of blue wool standards to determine the exposure duration is not recommended. When finalized, printed pigment standards may be more applicable to use with coated fabrics. If blue wool standards are used to grade the colour change of the test specimen, the most accurate method is to use a spectrophotometer to quantify the colour change of the standards and the test specimen.

i) The colour change of the test specimen should be assessed using a spectrophotometer and checked visually. If this is not possible grey scales should be used to assess the colour change (ISO 105-A02) but only by using the opinion of a number of experienced personnel.

j) Colour assessors should be selected having undergone tests to check for defective colour vision. Ideal candidates should have good colour discrimination and representative colour matching ability.

k) If additional tests need to be carried out to assess changes in other properties of the test material, the procedures in BS 2782-5:1981, Method 552A, clause **4** and BS 2782-5:1981, Method 552A, **5.2** should be followed.

Bibliography

[1] ASTM D3424 *Weatherability of printed matter.* Annual Book of ASTM Standards, Vol 06.01.

[2] ASTM G26-90 *Standard practice for operating light-exposure apparatus (xenon-arc type) with and without water for exposure of non-metallic materials.*

[3] BS EN ISO 105-A02, *Textiles — Tests for colour fastness — Part A02: Instrumental assessment of change of colour for determination of grey scale rating.*

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