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Dyeing and colouring tests for fabrics

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Abstract: This chapter discusses the types of tests undertaken to evaluate fabric colour. The chapter first reviews the assessment of colour and colour change with detailed information on the visual and automated assessment. The chapter then examines in detail the factors involving colour fastness testing. Tests examined include light fastness, wash fastness, fastness to environmental factors, fastness to manufacturing processes, and tests specific to printed materials.

Key words: colour assessment, light fastness, wash fastness, colour fastness, staining, shade change.

9.1 Introduction: key issues in the testing of dyes and colours

A myriad of factors can affect the performance of a colour in a textile fabric. Colour performance may be assessed in many ways. These include levels of fading, change of hue, change of saturation and staining of other items. Knowing the correct test to perform and the most accurate measurement system to adopt can put the colour performance of a fabric ahead of the competitors. This chapter looks at the measurement of colour and colour change. It is designed to show how to adopt the correct test method to evaluate coloured fabric. It examines each type of test that can be performed and provides a detailed overview of variations between test methods.

9.2 Assessing colour and colour change

The assessment of colour and colour change is the most important part of testing dyes and colours. Incorrect colour measurement wastes time and money and can result in a substantial claim for compensation from a customer. Colour is measured by measuring the reflected light from a sample over a variety of wavelengths. Each colour has its own reflectance fingerprint defined by the percentage of light reflected at a given wavelength. A reflectance curve is measured in the visible region for a colour and is plotted as percentage reflectance (%R) versus wavelength. To simplify the description of colour, The International Committee on Illumination
(Commission Internationale de l’Eclairage or CIE) set a formulated system for the definition of colour in terms of ‘tristimulus values’ X, Y, Z. The tristimulus values of a sample represent the amounts of red (X), green (Y) and blue (Z) primary colours which are necessary to produce the ‘colour’ of the sample. They are determined from the reflectance value \(R_\lambda\), spectral radiant flux per unit area for the source light \(E_\lambda\) and the tristimulus eye sensitivity functions of the CIE standard observer \((x_\lambda, y_\lambda, z_\lambda)\). The integration is usually performed over the wavelength \(\lambda\) range of 380–740 nm. A constant \(k\) is used to normalise the results. Equations 9.1, 9.2, 9.3 and 9.4 show the formulas for calculating the tristimulus values.

\[
X = k \int_{\text{min } \lambda}^{\text{max } \lambda} E_\lambda x_\lambda R_\lambda d\lambda \\
y = k \int_{\text{min } \lambda}^{\text{max } \lambda} E_\lambda y_\lambda R_\lambda d\lambda \\
Z = k \int_{\text{min } \lambda}^{\text{max } \lambda} E_\lambda z_\lambda R_\lambda d\lambda \\
k = \frac{100}{\int_{\text{min } \lambda}^{\text{max } \lambda} E_\lambda y_\lambda d\lambda}
\]

In 1976 the CIE introduced the \(L^*, a^*, b^*\) and the cylindrical \(L^*, C^*, h\) chromaticity coordinates and these parameters are now widely used. These values are derived from the original X, Y, Z tristimulus values using equations 9.5, 9.6, 9.7, 9.8 and 9.9. \(L^*\) is defined as the lightness of the colour, \(a^*\) is the axis that extends from red (positive) to green (negative), \(b^*\) is the axis that extends from yellow (positive) to blue (negative), \(C^*\) is the intensity of chroma, \(h\) is the angle of hue, and \(X_n, Y_n, Z_n\) are the tristimulus values for the relevant standard illuminant and observer. Each of these parameters and the relationship between them is shown using the CIE colourspace described in Fig. 9.1.

\[
L^* = 116(Y/Y_n)^{1/3} - 16 \\
a^* = 500[(X/X_n)^{1/3} - (Y/Y_n)^{1/3}] \\
b^* = 200[(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}] \\
C^* = \sqrt{(a^*)^2 + (b^*)^2} \\
h = \arctan\left(\frac{b^*}{a^*}\right)
\]
Dyeing and colouring tests for fabrics

Decomposition of dye molecules or physical removal of dye from the fibre are two mechanisms that cause colour change in a fabric. Where a single dye is removed or degraded, the result is generally a reduction of colour depth and/or a reduction of colour purity. The colour change in a commercial fabric can be a little more complex, as most dyes and dye recipes are made of a combination of dyes with different hues and concentrations. Each dye will behave differently under different environmental influences, therefore a change in colour could be caused by a change in hue as one dye is affected more than another.

There are two systems used for the assessment of colour change. These are visual assessment and computer aided assessment. Visual assessment has been in use since the performance of colour was first considered and is still used widely today. Visual assessment is a subjective measurement system and is significantly influenced by the person undertaking the assessment. The development of computer assessment systems and customers' requirement for repeatability and accountability are driving the shift to computerised measurement.

9.2.1 Visual assessment

The most well-known and used system of visual assessment is the grey scale. Grey scales are used as the rating system for most standard test methods.
as they are widely available, low cost and easily used. There are two types of grey scales. One set measures the change in shade of a coloured textile and the other measures the degree of staining in an adjacent fabric. The two grey scales are shown in Fig. 9.2. Grey scales have a rating of 1 to 5 with 1 being the worst colour performance and 5 being the best. Each rating can be split so that there are nine available ratings within the grey scale system.

The type of light used to illuminate the sample is important when visually assessing colour. Each light source produces a different emission spectrum and this influences the colour seen by the observer. Visual assessment of colour is normally carried out in a light box under a specified illuminant. The most common illuminants are artificial daylight, incandescent light, fluorescent light, horizon light, point of sale light and ultraviolet light. Each illuminant can then be broken down into individual types. An example is artificial daylight that has multiple source types including D50, D65 and D75. Most test methods specify the light source under which the samples should be rated. If the test method does not state the light source, a light source is agreed on and fixed by all stakeholders in the colour measurement.

The angle of the observer and the incident light are important in visual assessment. The illuminant light should hit the sample at 45°. This is achieved by resting the samples on a table set at a 45° angle to the light. This presents a perfect angle for the viewer to observe the samples perpendicular to the fabric surface. It is also important to exclude any light from external sources. Lights from external sources include room lighting or light from a window. Placing the light box in a dark room or placing a curtain around the light box will combat stray light.
The colour of the viewing surface is also important. Most standard test methods recommend a matt grey finish. The matt grey colour does not distract the viewer from the colour being assessed. It is important to keep the light box viewing surface clean and free of defects or imperfections. Damaged light box surfaces should be repaired with a paint that has the correct colour and gloss level.

9.2.2 Automated assessment

The use of spectrophotometers for fabric colour measurement has been adopted widely in the last 10 years. This technique has not changed much over the last 30 years; however, data collection and management of the spectrophotometer has. The development of low-cost high-powered desktop computers has allowed the quick acquisition, manipulation and quantification of colour information. Information obtained is both qualitative and quantitative, and can be efficiently stored for future reference or use. Information obtained using one spectrophotometer can be compared with results from another without any error. A spectrophotometer can provide a huge amount of measured and calculated information including $\Delta E^*$ values, multiple light source colour information, comparisons with measured or inputted standards, colour histograms of multiple batches, reflectance versus wavelength graphs and recipe advice.

CIELAB colour difference ($\Delta E^*$) is the most common system used in automated colour assessment for defining a difference in colour. $\Delta E^*$ is the difference in colour between two samples (1 and 2), with the coordinates $L^*_1$, $a^*_1$, $b^*_1$ and $L^*_2$, $a^*_2$, $b^*_2$, and is calculated using equation 9.10. A CIELAB $\Delta E^*$ value of one unit represents the smallest colour difference that can be visually detected. Subsequent experience has shown that the visual detection limit is more like 0.8 of a unit. $\Delta E^*$ is most commonly used in fabric testing to electronically specify the change in shade or degree staining of a sample or adjacent fabric after fastness testing. Grey scales have been assigned fixed CIELAB $\Delta E^*$ values by the standard boards. The CIELAB-assigned $\Delta E^*$ values for each of the grey scales are reproduced in Table 9.1.

$$\Delta E^* = \sqrt{((L^*_1 - L^*_2)^2 + (a^*_1 - a^*_2)^2 + (b^*_1 - b^*_2)^2)}$$ 9.10

Colour data management has improved markedly since the development of automated assessment. Databases attached to the computer colour measurement systems allow for the efficient storage of colour data without the need to store the physical test sample. Specialised computer screens allow on-screen reproduction of the test standard and are accurate enough for a person to perform a visual assessment. Results can be sent worldwide using the Internet and appraised visually by the customer immediately after the test is completed.
Table 9.1 CIELAB ΔE* assigned values for grey scales

<table>
<thead>
<tr>
<th>CIELAB colour difference for fading</th>
<th>Colour fastness grade</th>
<th>CIELAB colour difference for staining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>Tolerance</td>
<td>Value</td>
</tr>
<tr>
<td>0.0</td>
<td>&lt;0.40</td>
<td>0.0</td>
</tr>
<tr>
<td>0.8</td>
<td>0.40–1.25</td>
<td>2.2</td>
</tr>
<tr>
<td>1.7</td>
<td>1.25–2.10</td>
<td>4.3</td>
</tr>
<tr>
<td>2.5</td>
<td>2.10–2.95</td>
<td>6.0</td>
</tr>
<tr>
<td>3.4</td>
<td>2.95–4.10</td>
<td>8.5</td>
</tr>
<tr>
<td>4.8</td>
<td>4.10–5.80</td>
<td>12.0</td>
</tr>
<tr>
<td>6.8</td>
<td>5.80–8.20</td>
<td>16.9</td>
</tr>
<tr>
<td>9.6</td>
<td>8.20–11.60</td>
<td>24.0</td>
</tr>
<tr>
<td>13.6</td>
<td>&gt;11.60</td>
<td>34.1</td>
</tr>
</tbody>
</table>

### 9.3 Change in shade and staining tests

Change in the shade of a coloured fabric, or the staining of a fabric in the proximity of the coloured fabric, are performance problems associated with coloured fabrics. An example of change of shade is seen during light fastness testing of fabric. During exposure to light, most dyes degrade and change or lose their colour, causing a change of shade in the fabric. Staining of a fabric is seen during laundering when a white garment turns pink. This is due to migration of red dye from a garment that is also in the wash bath.

#### 9.3.1 Reversible colour change

Some colours undergo reversible colour change. The light-initiated version of reversible colour change is called photochromism. Photochromism occurs because the photons of light striking the coloured surface induce a structure change in the dye instead of degradation of the dye. A change in dye structure results in a change in colour. After duration of no exposure to light the structure reverts back to its original form and colour. This type of colour change can also occur due to exposure to heat or chemicals.

#### 9.3.2 Metamerism

Metamerism is the colour change seen in a coloured item because of different spectral emissions from different light sources. Each light source has its own emission spectrum (colour) so when a light source is projected onto a surface, the surface colour is influenced by the colour of the light. This produces a different colour to the observer for the same item when the light source type is changed. An example of this is the bluer tinge of a
coloured sample when observed under the fluorescent light TL84 compared to daylight. A standard light source is important when viewing, rating and specifying colour change to minimise the effects of metamerism.

9.3.3 Optical brightening agents

Optical brightening agents (OBAs) can cause serious error in the evaluation of colour and hence in the evaluation of colour fastness. OBAs are normally used to enhance the whiteness of a textile. They convert ultraviolet light into a wavelength in the visible spectrum. Most OBAs used for improving the white effect of a textile emit light in the blue spectrum, as most off-white colours reflect higher in the red/yellow end of the spectrum. The addition of blue to a white with a red/yellow base causes a flattening of the reflectance curve, resulting in the colour looking whiter. The addition of an OBA to a dyed colour will change the observed colour.

Most commercial laundry detergents contain an OBA to make whites washed in them look whiter/cleaner. All colours washed in these detergents adsorb OBAs, altering the colour even though the fabric’s dye may not have been affected by the washing process. Most wash fastness test methods stipulate if OBAs are to be present in the wash liquor to limit the associated colour measurement problems. The presence of an OBA is easily detected in a fabric or detergent by placing it under an ultraviolet light source. The blue ultraviolet light will be reflected from the surface in the colour of the OBA.

Light fastness testing can be influenced by the presence of OBAs. OBAs have poor fastness to light and generally fade at a higher rate than most dyes. The chemical bond structure of the OBA provides the mechanism that allows ultraviolet light to be converted to visible light. This bond structure is easily changed by the ultraviolet light rendering the OBA colourless. OBA-induced light fastness problems are normally seen in whites and pastels.

9.4 Test standards

There are many different standard test methods for colour fastness testing of fabrics. The key standard setters for textile colour fastness are the Society of Dyers and Colourists (SDC) and the American Association of Textile Chemists and Colorists (AATCC). These two associations have spent many years developing standards and provide excellent information and advice on their websites. Other standard test setters in this area are the International Organisation for Standardisation (ISO) and the International Wool Textile Organisation (IWTO). These organisations provide standards to cover all facets of textile processing. Their colour standards are quite often based on
the SDC or AATCC equivalent. There are some country-based standard organisations, such as the British Standard (BS), American Standard Test Method (ASTM) and Australian Standard (AS). These are generally based on the ISO, SDC or AATCC test method with slight changes made to account for cultural or environmental differences. For example, it is not suitable to light fastness test fabrics for an Australian market under European natural daylight as the incident angle and intensity are different.

Consumers are increasingly looking for textile products that are environmentally friendly and have neutral health effects. Standard setters are creating new test standards to measure this. The Oeko-Tex Association has followed this theme and developed the Oeko-Tex 100 standard that is based around a human and environmentally friendly product. This standard looks at reducing harmful processing methods such as formaldehyde-based finishes. It also looks at minimising the environmental impact of textile processing by reducing environmentally harmful chemicals, waste and processes.

9.5 Light fastness

There are a large number of different light fastness tests available on the market. Each has its advantages and disadvantages. The most commonly used are the xenon arc and MBTF lamp; however, carbon arc and natural sunlight are also used. A fabric exposed to light is influenced by its depth of shade, the intensity of the light, the wavelength profile of the light, the temperature of the fabric, contaminants within the fabric, and the moisture content of the fabric. Other factors such as exposure cycling, exposure time and substrate colour change are also influential.

The light fastness rating system is based on the rate of fading of eight blue-dyed wool samples (blue chips) which are rated from 1 (poor) to 8 (excellent), with each successive standard dyeing taking twice as long to fade as the previous one in the series. The blue chips are placed into the light box with the samples to be tested and faded in parallel with the test samples. This is done as the light output of the light source can vary from test to test. Most test methods assess the light fastness when the fabric being faded exhibits a change in shade equal to 4 on the grey scale for colour loss.

9.5.1 Depth of shade

The depth of shade of a colour has a significant effect on the light fastness of a product. Light fastness is the degradation of a fixed number of dye molecules per exposure to a fixed intensity of light. A deeper shade is
affected less than a pale shade, as a smaller percentage of the overall dye molecules are degraded per light exposure. Figure 9.3 represents this.

9.5.2 Intensity

Most accelerated tests for exposure to light fastness use high-intensity light to minimise the test time. High-intensity light can reduce the amount of time to undertake the test, though it can also influence the result. Higher-intensity light generally results in higher sample temperatures, causing the reaction rate of dye degradation to increase. The rate of dye degradation with respect to temperature is not linear. At elevated temperatures one dye may fade at a quicker rate than another, giving a hue change not seen at lower temperature fading.

Most high-energy light sources have varying intensity depending on the age of the light source. Most have a run-in time before they can be reliably used and most have a set number of hours of use before they should be replaced. Most standard test methods have details of the run-in times and maximum number of running hours of a light source.

9.5.3 Wavelength

Different light sources have a different wavelength profile. Some are close to natural daylight; however, the majority have wavelength peaks of high intensity that are different from natural daylight. Daylight itself varies depending on the latitude of the viewer and the time of the year. The wavelength of the incident light on the dye bonds significantly influences the rate of degradation of those bonds. A wavelength profile different from
natural daylight could show an increased or decreased fastness rating, depending on the dye tested.

9.5.4 Temperature
The temperature of the test sample will influence the rate of light-induced degradation of a dye. Most light fastness tests have black body temperature measurement and a method of sample cooling so that temperatures do not become too high. High-intensity light sources produce increased sample temperatures, so increased cooling capacity is required to lower test temperatures. Tests for automotive fabrics are conducted at higher test temperatures, as the fading environment within a car interior can involve elevated temperatures not normally seen in the fading environment for clothing.

9.5.5 Moisture
The level of moisture in the fabric can influence the rate of colour degradation. The presence of moisture during a light fastness test can lead to the generation of peroxide radicals that significantly influence the results of the test. Moisture content is hard to control as the heat from the light source tends to decrease the moisture content of the fabric. Moisture levels can be monitored during a test by using azoic-dyed cotton with specified fading properties which vary with the amount of relative humidity. Some tests involve starting the test samples wet to simulate line drying of fabrics. Some tests involve intermittent jets of water to simulate rain on an exterior fabric. Tests that involve the use of water sprays are generally referred to as weathering tests.

9.5.6 Contaminates
Some fabrics are exposed to chemical contaminates when they are in use. These contaminates can include salt and chlorine. Tests have been developed to intermittently spray the fabric with chemical-contaminated water during the test. Like water, chemical contaminates can become involved in the chemical degradation of the dye molecules.

9.5.7 Test cycling
Sometimes exposing the fabric to a light source for a fixed duration is not enough to see the behaviour of the colour. Cycling of the light source on and off is sometimes used to simulate night and day. Some dyes can degrade to a certain point and degrade no further with continuous exposure to light.
Switching the light off for a period of time allows the energies within the dyes to return to their ground state. This can initiate a second round of fading when the light is restarted.

9.5.8 Substrate colour change

Substrate colour change is quite common in pastel wool colours. Wool initially photo-bleaches when it is first exposed to light; however, it yellows quite rapidly with continued exposure. The colour of the dye might not be affected by the incident light, though the change of the substrate colour will result in a change in the fabric shade.

9.5.9 Photochromism

Photochromism is commonly caused by exposure to light. The level of photochromism can be determined by placing a colour in an intense light source for a short period of time and then immediately rating it for colour change. If subsequent return to normal colour occurs after conditioning in the dark then the colour is photochromic. Some colours require a period of time to condition in the dark after light fastness testing before colour assessment can be conducted to avoid any photochromic effect.

9.6 Wash fastness

Consumers launder their fabric at some time in the lifespan of the textile. Change of colour or staining of another garment during laundering is generally immediately evident to the consumer and has a high impact on consumer satisfaction. Like light fastness testing there are a huge number of different iterations of the wash fastness test. The wide variety of test methods have mostly arisen due to the variety of washing methods available, cultural practices, the material being washed, and the end use of the product. The development of detergents and bleaches has influenced the development of new wash fastness test methods.

It is important when selecting a wash fastness test method to choose one that best simulates the washing environment of the fabric’s end use. If no end use has yet been selected then it is important to clearly label the level of wash fastness testing that has been conducted on the fabric. The most common washing methods in use today are dry cleaning, hand washing, gentle machine washing, machine washing, permanent press and industrial laundering. Each of these methods has one or more wash fastness tests to determine fabric colour suitability. Table 9.2 shows the variety of conditions in the first five ISO wash fastness tests for domestic and commercial washing.
Table 9.2 The first five ISO wash fastness test conditions

<table>
<thead>
<tr>
<th>Test</th>
<th>Temperature (°C)</th>
<th>Time (min)</th>
<th>Number of steel balls</th>
<th>Chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 1</td>
<td>40</td>
<td>30</td>
<td>0</td>
<td>Soap</td>
</tr>
<tr>
<td>ISO 2</td>
<td>50</td>
<td>45</td>
<td>0</td>
<td>Soap</td>
</tr>
<tr>
<td>ISO 3</td>
<td>60</td>
<td>30</td>
<td>0</td>
<td>Soap + Na₂CO₃</td>
</tr>
<tr>
<td>ISO 4</td>
<td>95</td>
<td>30</td>
<td>10</td>
<td>Soap + Na₂CO₃</td>
</tr>
<tr>
<td>ISO 5</td>
<td>95</td>
<td>240</td>
<td>10</td>
<td>Soap + Na₂CO₃</td>
</tr>
</tbody>
</table>

Each of these tests would be carried out at a 50:1 liquor ratio in a 2.0 litre wash wheel vessel with 5.0 g/l standard soap solution.

9.6.1 Equipment

Most wash fastness tests are carried out in enclosed 2000 ml vessels that are rotated at a constant speed and at a constant temperature in a wash wheel. An Atlas laundrometer is the most common make of equipment used for undertaking this test. The wash wheel is commonly referred to as a laundrometer. The fabric, adjacent material and wash liquor are placed into the test vessel before it is sealed. Some tests require the addition of stainless steel balls or discs to the wash liquor to increase the severity of the test.

9.6.2 Soaps and detergents

In a wash fastness test the soap or detergent is used to remove unfixed dye from the fabric. The use of a soap or detergent can also cause a breakage of bonds that hold the dye on the fibre. The pH of the soap or detergent has a major influence on the movement of dye from the fabric into the wash liquor and from the wash liquor to adjacent fabrics. Since the invention of detergents, the blend of chemicals used for domestic and commercial laundering has become quite complex. Most detergents contain mild oxidising agents, softeners, optical brightening agents, salts and other fillers. These detergent auxiliaries can increase the amount of dye removed from the fabric and in the case of oxidising agents cause degradation of the dye molecules. The dispersing nature of different detergents can also reduce the level of cross-staining to an adjacent fabric as the dye is held in the wash liquor by the detergent and is not allowed to redeposit. Some test detergents are specifically designed to contain bleaches and bleach activators like sodium perborate tetrahydrate and tetraacetylene diamine (TAED).
9.6.3 Test fabrics

Cross-staining of a third-party fabric is assessed using an adjacent fabric fixed to the fabric test sample. Adjacent fabrics come in many types and many forms, including single-component woven fabrics and multifibre woven fabrics. The single-component adjacent fabrics commonly used are cotton, wool, polyamide, acrylic, viscose rayon, polypropylene and polyester. Tests involving single-component adjacent fabrics have the adjacent fabric fixed to one or both sides of the fabric test sample. Sometimes a different adjacent fabric composition is used for each side to show staining on two fabric types. Nylon 6,6 is commonly used in staining tests as it tends to scavenge any free dyestuff from the wash liquor better than any other fabric composition.

Multifibre adjacent fabrics allow staining exposure to a range of different fabric types during one test. The most common supplier of multifibre fabric is the Society of Dyers and Colourists (SDC). The SDC produces two multifibre fabrics; one contains wool and one does not (Table 9.3). Multifibre fabric is affixed to one side of the test specimen and the other side is normally a polypropylene fabric in a staining test.

9.6.4 Agitation time

The agitation time of a laundering test can significantly affect the test results. Short test times limit the dissolution of unfixed or poorly fixed dye into the liquid or onto the adjacent fabric. The dye has more time to escape from the fibre and to migrate onto the adjacent fabric in longer tests. Longer test times can allow the dye to deposit on and migrate into the fibres of adjacent fabrics following a mechanism similar to dyeing, leading to an increase in the level of staining.

9.6.5 Temperature

The results of a wash fastness test are significantly influenced by the test temperature. Lower test temperatures are used where the end-use fabric
requires low-temperature washing. Low-temperature washing is normally seen for delicate fabrics like wool, silk and viscose. Low test temperatures limit the migration of dye from the fabric surface and generally cause low levels of staining on adjacent fabrics. There is not as much energy available at low temperatures, and energy is needed for the dye to attach and penetrate the adjacent fibre. High test temperatures should be used for fabrics that could be warm or hot washed during their lifetime. Higher test temperatures provide the energy required to swell fibres and migrate dyes. At higher temperatures adjacent fabrics are more likely to be stained by any free dyes in the wash liquor. Fabrics that are going to be used in a product destined for industrial laundering are generally tested at higher temperatures than normal, as industrial laundering temperatures are generally higher.

9.7 Fastness in relation to environmental factors

Wash fastness testing looks at the loss of colour or staining of adjacent fabrics due to laundering. However, there are numerous other environmental influences that may cause colour performance problems, most commonly perspiration. Perspiration from the human body is a complex chemical containing large quantities of salts; depending on the human metabolism, it can be either acidic or alkaline. Most of the tests for perspiration fastness are based on a solution containing the chemical histidine.

The fabric and adjacent fabric are generally soaked in the test solution before being placed under pressure in a perspirometer and incubated at body temperature for a period of time. Figure 9.4 shows an illustration of the general layout of a perspirometer. The test fabrics with adjacent material attached are sandwiched between Perspex plates under a fixed mass.

![Perspirometer diagram](image)
The perspirometer is also used for other tests including testing for fastness to water and seawater. Fastness to water testing simulates the effect of leaving washed fabric sitting in a wet pile after laundering. The staining assessment is the most important part of this test, as the colour can easily transfer from article to article under wet pressurised conditions. Fastness to seawater looks into the same effect as fastness to water but includes sodium chloride in the test solution, as salt can cause increased migration of dyes.

Fastness to chlorinated water is used to evaluate the colour fastness of swimwear, towels, deck furniture webbing or other articles that may be exposed to large amounts of chlorinated water. The test is normally carried out using a wash wheel under similar conditions to a wash fastness test; however, the temperatures used are selected to reflect pool water. It is important to check the active chlorine levels of the test solution before the test, as chlorine can reduce in strength over time.

Spot testing is used to determine the effects of spotting chemicals onto a fabric to remove a point stain or to simulate spot staining. An adjacent fabric can be fixed behind the spot to assess staining; however, the test is normally used to assess spot migration of the dyes within the fabric. Spotting tests include fastness to water, acid, alkali, dry cleaning fluid, and white spirits.

Fastness to rubbing is used to ensure that fabrics do not transfer their colour when rubbed against another layer of fabric. This test is also known as crocking and is carried out using a crockmeter. A crockmeter is a piece of equipment that applies a constant force on the test fabric against the tested specimen as it is rubbed back and forth. Rub fastness is carried out with either a dry or wet cotton fabric that is rubbed against the surface of the dyed fabric to remove unfixed dyestuff. Rub fastness using a wet test fabric tends to show higher colour transfer than when using a dry test fabric.

9.8 Fastness in relation to manufacturing processes

There are a range of tests that are based around the mechanical processing of textile fabrics during and after the manufacturing process. The tests are described only briefly here as books on processing, product circulars and test standards describe these test methods more specifically. The tests for processing are based around three main concepts: the application of heat, gases and chemical processes.

9.8.1 Colourfastness to heat

Heat-based tests look at the change of colour due to heat. Some dyes sublime under extreme heat and can be evaporated from or heat-transferred
from the fabric. Some dyes are degraded by extreme heat and can change
or lose their colour. The presence of moisture during heating can increase
swelling of the fibre and thus increase the transfer of colour into an adjacent
fabric. Heat can be applied in various ways, so the test selected must reflect
the way in which the heat is applied. The four ways in which a heat can be
applied are dry heat without pressure, steaming without pressure, dry heat
with pressure, and steaming with pressure. The test for dry heat without
pressure is used to simulate drying of fabrics. The test for steaming without
pressure looks at the colour change due to steam relaxation or steam
setting. The test for dry heat under pressure is a test to simulate hot pressing,
ironing and calendaring. The test for steaming with pressure is used to
replicate steam pleating, steam pressing and decatising.

9.8.2 Colourfastness to chemical processing

There are a large number of chemical processes that expose coloured
fabrics to chemicals. Most chemical processes in manufacturing involve
chemical finishes applied to the fabric after dyeing. A large number of
these finishes have specific tests defined by the company that look at the
level of colour change occurring during the finishing process. Chemical
finishes can also affect light fastness and rub fastness results. Therefore for
some fabrics these parameters should be measured after the finish has been
applied.

During manufacture a dyed fabric may be exposed to a number of
chemicals. Standard test methods have been developed to assess the changes
that these factors can cause. Testing includes bleaching with different
bleaching agents including chlorite, hypochlorite and hydrogen peroxide.
Wet processing of fabrics such as milling, carbonising and crabbing can also
affect fabric colour. The test for crabbing is also referred to as potting, as it
involves boiling the fabric under tension for a period of time.

9.8.3 Gas exposure

There are a whole range of tests that are based around drying fabrics. The
tests for oxides of nitrogen and burnt gas fumes are used to evaluate the
effects of inefficient and badly regulated direct-fired drying equipment.
Ozone is also a chemical that is generated in the environment or during
combustion. Ozone can rapidly break down dye, so there are a number of
standards that relate to the effects of ozone in the presence of a textile
fabric.

There are also tests that look at the influence of residual chemicals in the
fabrics during drying. The most common of these tests look at the presence
of residual hardness salts, acid and alkali. Specific tests can also be conducted
to look at the effects of aftertreatments applied during or subsequent to the drying process.

9.9 Printing tests

The colour fastness of printing is slightly different from that of dyeing, as most printing techniques use a pigment to colour the surface of the fabric generally by forming a pattern on the fabric. The pigment is bound to the fabric surface using a polymer binder, most commonly acrylic. The main problems associated with prints are poor registration of the pattern, wicking of some or all of the colours and poor rub fastness. Printing is commonly done over the top of a previously dyed fabric and the printing process and chemicals can have an effect on this colour. The printing process can also affect fabric properties other than colour and these should also be measured. Most of the standard tests used for assessing colour in dyed goods are also used for printed goods.

9.9.1 Registration

Registration refers to the alignment of a single print colour on the fabric with reference to the fabric and other colours in the print. A malfunction or poor setup of the printing process can result in poor registration of a print. This will be seen in the final product as a misalignment of part or all of the individual colours of the print. Testing for registration can be conducted visually with deviation from registration measured with a ruler or callipers. The development of image processing software has resulted in several good automated print registration test apparatus being available in the market.

9.9.2 Wicking

Wicking is the transfer of some or the entire print colour along the fibres in a fabric due to a capillary action. Wicking can be seen as a reduction of sharpness of a printed edge and can be assessed visually or with the same software as is used for the testing of print registration. Sometimes the printing ink can cause bleeding of the fabric base colour. Bleeding of the base colour looks blotchy along the edge of the print or, when printing is done in a garment, a transfer of dye onto the fabric occurs adjacent to the print face.

9.9.3 Rub fastness

Rub fastness is of significant importance to prints, as the colour is provided by a pigment that is fixed to the exterior of the fibre. The pigment on the
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surface of the fabric is the first component to come under attack when a fabric is rubbed or abraded. Crocking is a simple method for determining fastness to rubbing. The standard 10 cycles employed in the crocking test may not be enough to break down a faulty pigment binder system, so some rub fastness test methods involve an increased number of rubbing cycles. There are test methods and testing equipment developed that have an increased abrasive effect on the fabric surface. These include oscillating drum, wire mesh and emery abrasion testers. Each of these testers abrades the surface more than the crock meter and they are used for textiles that require high resistance to abrasion such as military fabrics.

After rub fastness testing the rubbed surface is often appraised for colour change or frosting. Frosting is common in prints and is the pigment rubbing away from the surface of the fabric exposing the natural fibre colour below. This can also be called fibrillation, as single fibres poke through the surface of the print. Frosting is easily identified in a loss of depth of shade of the print.

9.9.4 Fastness to steaming

Most prints are steamed to improve penetration into the fabric or to assist in fixation of the dye or binder system. It is important that dyes or pigments used in the printing industry are fast to steaming. The test should not just be limited to the effect of the steaming on the print but should be expanded to include the fabric base colour. A change in fabric base colour can occur even though the print is unaffected. The tests undertaken for steaming are generally the same as the tests explained earlier for steam without pressure.

9.9.5 Light fastness testing

When testing light fastness it is important to assess all of the colours in the print. Light fastness test samples should be selected to maximise the area of each of the colours within the print, and more than one light fastness sample per print may be required to achieve this. Pigments generally have better light fastness than dyes, as the chromophore does not need to be selected to fit into the fibre matrix or to have specialised bonding and solubilising groups.

9.9.6 Plastisol prints

Plastisol prints pose their own unique fastness problems. Inaccurately cured pigment can result in cracked and peeling prints or bleeding of the colour into other fabrics. Prints can be tested for curing by a simple domestic
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washing followed by a tumble dry. Other curing tests can involve the use of solvents and pressure. The print is spotted with small amounts of solvent and then pressed against a fabric to assess the colour transfer. Dry heat is normally used to apply a plastisol print, so fabrics should be evaluated for dry heat in pressing to ensure that there is no colour change to the fabric base colour.

9.10 Applications

There are many different applications for the testing of coloured fabrics. The textile colourist utilises colour testing to confirm a colour matching formula before it is used in manufacture. Most textile mills will implement quality control testing of colours during manufacture to reduce the chance of faulty work being processed further than it needs to be. It is hard to improve the wash fastness of a fabric that has been cut into a garment.

It is important to measure the colour fastness properties of a dyed fabric after manufacture. Most customers require a quality control certificate for the fabric that they are purchasing to confirm that it meets their target limits. Testing will highlight possible problems and avoid despatch of under-specification fabric. A manufacturer should measure a fabric that has come from a supplier or commission dye house if the fabric does not already have a set of test statistics. When a fabric does come with test results, it is advisable to double-check test results for the first few deliveries from a new supplier and then randomly audit deliveries as purchases continue. Suppliers that have their own test laboratories can be production-biased when rating fastness results and can pass samples that have not met the testing requirements. Double-checking the results will give confidence in the skill and accuracy of the supplier’s test house.

Quite often a manufacturer will be interested in replicating a competitor’s product. Careful testing of the product can reveal the type of colouration method used and the level of fastness required to duplicate the product. Testing results of a product can be used to exploit the marketing potential of a product. The development of machine wash fast colours was originally a strong selling point for a textile product. Proof of meeting Oeko-Tex 100 environmental and health standards is an example of a new selling point that can be confirmed by accurate product testing.

9.11 Future trends

In the future we will see increased use of electronic measurement of colour and colour fastness test results. The development of data handling, transfer and storage has revolutionised the way in which test results are measured and conveyed within the mill and to the customer. The Internet
transfer of colour and colour details is becoming adopted by more processors and customers, and speeds up the test path as a customer can approve a colour test just minutes after it has been conducted. The use of fuzzy logic mathematics helps to analyse all of the testing data and enables the manufacture to optimise processing and reduce reject rates.

Consumer requirements for environmentally friendly, neutral health effect and neutral environmental impact textiles will increase. Some companies are leading the way by meeting standards like Oeko-Tex 100; however, more stringent standards will be developed. Environmentally friendly coloured textiles will see significant development in test methods and accreditation over the next decade.

9.12 Sources of further information and advice

Society of Dyers and Colourists, www.sdc.org.uk
American Association of Textile Chemists and Colorists, www.aatcc.org
Pantone, www.pantone.com
Oeko-Tex Association, www.oeko-tex.com
International Organisation for Standardisation, www.iso.org
Ecological and Toxicological Association of Dyes and Organic Pigment Manufacturers, www.etad.com

9.13 Bibliography

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