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Prepared by
Leslie K. Redman
Conservation Services Division
Canadian Museum of Civilization
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Supplementary to the TCN, Spring 1991

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INTRODUCTION

The use of spectrophotometry and colorimetry in textile conservation laboratories to match backing and in-fill fabrics with artifacts is becoming increasingly common. A variety of instruments and computer programmes are being developed in an effort to marry the information gained in the readings to the dye recipes and produce the "perfect match". But in every case, in order to replicate the designated match exactly the same fabrics must be used that were in the sample. Often this is not possible. Either the artifact itself requires some variation in weight or texture or the fabric is no longer available. The moment that a different fabric is used the recipe will no longer produce a match. Other than noting that this is so, very little has been done to document this visual variation. This study was an attempt to discover if the observed change was also recorded by the colorimeter/spectrophotometer or if it was a change being recorded only by the optical and neural pathways in the brain.

There were, of course, many variables involved. No two "white" fabrics are exactly the same "white". It is difficult to obtain a variety of weave variations in exactly the same weight of fabric and then there are the many variations of the dyeing process itself. It was essential that all the colorimeter measurements be done on the same machine and within the same time period to prevent any changes in settings or machine variables. Fabric has certain general properties which determine how it reacts with dyes and light. The first is fiber absorbency, that is the ability of the structure to absorb moisture. This relates directly to the chemical components and the degree of crystallinity. Secondly is fiber luster, the more orderly the arrangement and the longer the reflecting surface the greater the sheen. The greater the uniformity of both molecular and cellular structure the greater the uniformity of dye uptake and light reflectance. This also applies to the structural uniformity of the weave structure, which will be discussed further on. The fourth and final factor is fiber resilience, or the ability of the fiber to stretch and bend and then return to its original state. Fibers with poor resilience become "wrinkled" and result in uneven reflectance. (Lambert. 1986)

The substrates chosen for this project were all silks as these are one of the most common forms of fabric used in textile conservation which requires dyeing. Silk is composed of a protein, called fibroin, which like other protein fibers consists of many different amino acids and the -OOC and NH3+ reactive groups. Reactive hydroxyl groups are also present but only on one type of amino acid and are located in the crystalline and therefore less accessible sections of the fiber (Knutson 1986). Because silk is produced as an extrusion fiber it is generally much more crystalline than other protein fibers and therefore less accessible in general to the dye molecules. This means that less intense colours are produced. However, because silk has no protective covering (such as wool's cuticle) it reacts more quickly and at lower temperatures than wool. High temperatures not only are damaging to the silk (reducing the strength and luster of the fiber) but result in the dye molecule returning to the dyebath. This accounts for some of the poor washfastness of silk. Better washfastness is obtained with the 1:2 premetallized dyes than most others. Because repaired artifacts are usually drycleaned if cleaned at all this is of less concern than under other home conditions.

Each level of organization provides surfaces which reflect and absorb light and the shape of these surfaces decided both the total amount of light reflected and the direction. This, in turn decides the perceived value (lightness or darkness) of the colour. If the surface is very organized and light is reflected away from the viewer it is seen as "dark", if light is reflected towards the viewer, it is perceived as "light". A number of factors influence this, including the length of uninterrupted fiber, its diameter, cross-sectional shape and longitudinal shape. Because silk is a filament yarn it has a very even surface and straight longitudinal shape resulting in a high degree of reflectance and therefore a lighter colour. At the next level of organization, that is the weave, any deviation from a straight one to one alternation of warp and weft results in the production of a "float". This is a thread which crosses at least two other threads before interlocking. The longer the float the greater the degree of reflectance from the fabric. The orientation of these floats to the viewer also effects the perceived value. This is particularly evident in a fabric like damask, where floats are orientated at right angles to produce a particular colour pattern. Silk, being a fine fiber, also produces many even reflecting surfaces which also increases its sense of "lightness". Silk is slightly triangular or trilobal and this form subtly breaks up the surfaces of reflectance making it softer than a synthetic triangular form.

The surface texture of the fabric also plays its part in value determination. The "roughness" of the surface is determined by the number of fiber ends, amount of twist imparted in spinning (the greater the twist the smaller the reflecting surfaces and therefore the darker it will appear), the direction of any nap and the type of yarn. Silk tends to have few fiber ends, and therefore little "nap" and is generally a low twist thread.

The spacing of yarn in a weave produces its own effect. An even-weave is such that the same number of wefts and warps are found per square inch. In a closely woven fabric the warp ends are just close enough to allow the weft thickness to show. When more loosely spaced an open weave is created. Open weave fabrics produce a special effect called the "gauze effect". (Lambert, Patricia. 1986). This means that when light is reflected from the viewers side the fibers seem bigger than they are and appear to fill the spaces. When lit from behind there is less reflection and the fibers are seen closer to their normal size. The addition of extra warps, tightly packed and hiding the weft threads results in a warp-faced weave with horizontal ridges. If the weft thread is fine the ridges are small creating little texture and colour variation on the highly organized surface (broadcloth is an example of this). If there are at least twice as many wefts as warps a weft-faced fabric is created with vertical ridges. This is particularly well illustrated in tapestry fabrics.

The dyes often used within textile conservation for protein fibers are Ciba-Geigy's Irgalan series. They are particularly noted for their excellent wash and light fastness although they produce somewhat dull colours. They are included under the broad category of acid dyes, because they are applied in an acid bath and the active colour component is an anion. The presence of acid in the dyebath helps to sever the salt linkages between the molecular chains and thereby increases the number of positively charged sites. (Trotman. 1984) They are more specifically classified as 1:2 metal complex azo dyes. These dyes have one metal atom, chromium III, attached to two dye molecules (monoazo compounds). It is this inclusion of a metal ion which results in a bathochromic shift and a duller colour. (Gordon. 1983) These complexes are stable over a wide range of pH and can be applied from a neutral to weakly acidic dyebath. They contain no sulphonic acid groups (-SO3H) which makes them less sensitive to variations in surface fibers and therefore better at level dyeing. Ciba-Geigy also manufactures a series of sulphonated acid dyes designed to "brighten" the Irgalan dyes. These can be used in the same dye bath and under the same set of conditions. Observed colour is dependent on the integration of three factors, the nature of the light source, the light absorption qualities of the object and the response of the eye to the reflected light. Light sources are continuums of various wavelengths of light whose energy is dependent on the overall intensity and type of light source. When light strikes a dyed textile surface different wavelengths of the light are absorbed, and the remainder is reflected (or transmitted depending on the thickness of the fabric). Energy absorbed by the molecule results in the molecule being excited to a higher energy state. This energy is normally dissipated through vibration within the dye molecule and given off as heat. (If the energy cannot be effectively dissipated the dye molecule undergoes chemical attack and is altered resulting in a colour change or fading.) The reflected wavelengths are then "recorded" by the eye of the observer and "processed" in the brain with a "colour" then being identified. Over the years a number of systems have been devised in an effort to define individual colours and relate them to measurable reflectance spectra and a number of terms have developed which are frequently used to indicate a specific colour. Hue, is considered to refer to the basic colour type such as red, green or blue. Chroma or saturation refers to the difference between the colour in question and its closest primary hue. Lightness or value refers to the degree of lightness or darkness. By recording the reflected light from a coloured object in its various component wavelengths and then mathematically converting this information to a series of tristimulus values each colour can be plotted on a standardized cartesian system. This system known as the Hunter CIE L* a* b* system is used in most of the textile conservation labs to not only determine colour changes related to fading or cleaning but also to assist in matching dyed fabrics as mentioned. It has also greatly assisted in dealing with the problem of metamerism, where colours that match under one type of light do not under another because the actual wavelengths given off are not the same. (It is possible for two colours to have the same tristimulus values under a single light source but different reflective values.) A similar phenomenon in which exactly matching colours (done from the same dye lot) seem to change when moved into a different light is referred to as "flare" and is related to the wavelengths available from the light source. In this study the reflected wavelengths were compared to discern if there were actual changes in measurable colour occurring when different weave substrates were used.

EXPERIMENTAL PROCEDURE

The three dyes chosen were Irgalan Yellow 2GL, Irgalan Bordeaux EL and Irganol Brilliant Blue GL. The first two are monoazo, 1:2 metal complex dyes and the third was a monoazo dye. As mentioned earlier these Irganol dyes were developed to "brighten" the metal complex dyes. These specific colours were chosen because they had yet to be completely tried by the Canadian Conservation Institute (CCI) textile lab and there was considerable interest to see what the resulting colours would look like. They have similar fastness properties. It was decided to do the outer edges of a colour triangle using increments of 20%. This gave a total of 15 different colours to be tried on five different substrates, a total of 75 samples in all.

The five silk substrates chosen were of fabrics commonly used in the CCI textile lab and included an unbleached broadcloth, a bleached broadcloth, a shantung, a pongee and a satin. They were of similar warp thread count (approximately 25/quarter inch) although the wefts varied more (20 - 46). All of the fabric was washed in distilled water with a small amount of Orvus and then thoroughly rinsed. They were then dried and cut into 5 gram samples. Each sample was numbered.

It was decided that a 2% depth of shade (DOS) would be used and a 1% w/v stock solution of each dye was mixed with water to make for standard mixing of small amounts of each colour. Each combination colour was made up individually, into the small "launder-o-meter" pots and a number of small metal balls were added to facilitate even mixing. After being dyed each piece was rinsed well, air dried and ironed to provide an even surface.

Colorimeter readings were taken on the Minolta Chroma meter belonging to CCI for comparison readings only while the actual project readings were done on the Macbeth Colorimeter at Queen's. A CIE Illuminant D65 was used for calibration on both. For readings on the Macbeth the spectral component was excluded and the UV was in and the SAV out. The Macbeth provided the spectral analysis used in the comparison graphs as well as a CIE L*a*b* analysis, which describes the colours'position on a cartesian system. Each fabric was folded until it was opaque to the colorimeter (i.e. no light was visible through the fabric when tested). Sixteen layers was found to be satisfactory for all five fabrics. The spectra for each colour on all five fabrics were plotted on the same graph for ease of comparison. The undyed fabric samples were also compared.

CONCLUSION

The differences between each of the five samples for each colour, when graphed, were found to be quite small. This difference would seem to have more to do with the variations in original colour than anything else. This suggests that any difference seen in the weave variations has more to do with the eye of the perceiver and/or surface irregularities and gloss rather than any change in colour attributes alone. As only on reading was done on each fabric there is a possibility that some of the individual curves could show a greater or lesser degree of variation if more readings were done and then averaged. This would assist in showing any significant variance which might exist. It was interesting to note that a sharp peak existed on the undyed, bleached broadcloth readings in blue/ultra-violet range. I have presumed this to be due to the use of some form of optical brightener in the bleach. This aberration seemed to disappear as soon as the fabric was dyed.

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