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HUMIDIFICATION OF GLAZED COTTON FABRICS

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INTRODUCTION

Localized humidification treatments are commonly used by textile conservators to diminish wrinkles and creases in historic textiles, yet there have been very few formal studies documenting their effects. These treatments are especially useful for textiles which require some flattening but for a variety of reasons should not be fully immersed in water. Often textiles contain dyes or finishes which are unstable if fully wet; however, even the much less rigorous technique of humidification can produce unwanted changes in sensitive surface treatments.

The objectives of this project were three-fold:

1. To review existing literature on the interaction between cellulose and water, and on the history and application of glazed finishes.
2. To conduct an experiment assessing the effectiveness of localized humidification techniques in reduction of creases.
3. To evaluate any secondary visual changes that might occur in the glazed finish during the humidification treatments.

Six humidification treatments, all variations in methods using Gore-Tex¹, were studied. Because the Gore-Tex membrane is permeable to water vapour but not liquid water, it greatly reduces the risk of over-saturating the textile. The variations were as follows: using very light weights or heavier weights on top of the creased area after the textile is humidified and during drying; using pins around the edges of the textile to block it flat; and allowing the textile to dry without restraint by weights or pins. Usually when weights are used to aid in flattening a humidified textile, a blotter is placed between the surface of the textile and the weight. To determine if the presence of the blotter had an effect on the fabric surface, a second piece of smooth, inert Gore-Tex was placed between upper blotter and the textile surface for half of the treatments using weights.

It is hoped the information presented in this paper will assist conservators in their choice of humidification process when dealing with unstable surface finishes, in this case glazed surfaces on cotton textiles.

¹Gore-Tex is a porous film of expanded PTFE (polytetrafluoroethylene) heat-bonded to a 100% polyester spun-laced fabric (Purinton & Filter, 1992)

LITERATURE REVIEW

Before choosing a humidification treatment for a glazed textile it is useful to know both the mechanisms by which cotton fibres react to moisture, and also how the surface was achieved; therefore, a literature review was conducted on these topics.

Moisture Interactions with Cotton Fabrics

Effect of moisture on cellulose fibres

The interaction between cotton textiles and water is complex and can be discussed on various levels. Some of the reactions which have the greatest impact occur at the smallest submicroscopic level within the pores of cotton fibres. A network of tiny channels forms as the fibres grow on the cotton plant. When the fibres dry out, these pores shrink and collapse leaving small empty spaces which are associated with areas of irregular packing of the cellulose polymers. Water is able to penetrate these tiny spaces causing a gradual opening up of interconnecting passages (Rowland, 1977).

Morton and Hearle (1962) discuss several mechanisms for moisture absorption into textile fibres. When fibres come in contact with moisture, the first water molecules to enter the fibre form hydrogen bonds with hydrophilic groups on the molecular chains which make up the fibre. With increasing humidity, incoming water molecules can attach either to other exposed hydrophilic groups which become available for bonding as the structure loosens up, or may form layers on top of the directly held water. This secondary layer of molecules, called indirectly attached water, is somewhat restricted in its movement but is not as firmly fixed as the directly attached water. These layers are held to each other because of the high dipolar moment of water. Further increase in humidity results in the introduction of even less firmly attracted water. Kumar, Dave and Srivastava (1984) refer to these three layers as localized, intermediate and mobile water, ranging from firmly hydrogen-bonded to free moving water.

In addition to the surface adsorption theory described above, capillary condensation may also contribute to the manner in which water vapour reacts with the cellulose fibre. This theory is based on the idea that vapour pressure within a capillary increases with decreasing capillary radius, causing incoming water vapour to condense within the narrow confines of inner fibre capillaries (Christensen & Giertz, 1966).

As alluded to above, when a fibre is exposed to moisture, two processes occur. First, the hydrogen bonds within the fibre break and reform with the water molecules, causing an opening up, or swelling of the fibre. Secondly, stresses caused by increased extension and orientation, introduced to the molecular chains during processing are relaxed with the addition of water. Each of these processes is described more fully below.

When the first water molecules enter the cellulose fibre, they bond to the oxygen atoms and the few hydroxyl groups not already participating in inter- and intra-molecular hydrogen bonding, (Kumar, Dave, & Srivastava, 1984). If carboxyl or carbonyl groups are present, they too will form bonds with water (Christensen & Giertz, 1966). This process gradually pushes the molecular chains in the amorphous regions apart, freeing up additional hydroxyl groups, and opening up more space for more water to enter; therefore it is this directly attached 'localized' water which has the greatest impact on the physical properties of the fibre, including swelling (Morton & Hearle, 1962). Because water is only absorbed in the amorphous areas of the fibre, the amount of swelling is limited by the presence of the crystalline regions which produces

internal stresses within the fibre (Morton and Hearle, 1962). Cotton fibres can undergo a 14% increase in diameter, and a 1.2% increase longitudinally due to swelling (Peters, 1963).

As the fibre swells, the forces between molecular chains become less restraining, allowing the molecular chains to revert into a more random, relaxed conformation which can result in a decrease in overall length of the fibre. Fibres with low modulus² undergo greater strain during production, and their subsequent retractive forces after wetting are low. These fibres, like rayon, tend to undergo progressive shrinkage because built in stresses cannot all be released with one wetting, but are released incrementally by successive wettings. Cotton has a high modulus, so undergoes less initial deformation during production and also has higher retractive forces. Stresses from the processing of a cotton fabric can usually be overcome after a single wetting (Gray, 1971).

Breakage of structural hydrogen bonds within the fibre results in plasticization of the fibre; however, to remove major surface distortions, it is necessary to break hydrogen bonds between fibres not merely those within them (Sugarman & Vitale, 1993). For these bonds to be broken additional water is required. 'Capillary water' is held in fibre surface pores and interfibre spaces by surface tension, and only occurs at very high humidity, over 99% (Morton & Hearle, 1962). This is why overall wetting is more effective in removing major deformations than humidification alone.

Effect of moisture on yarns and fabrics

Changes at the molecular level within fibres translate to visible changes in fabrics. The processes of yarn spinning and weaving add a series of factors to be considered. When discussing the effect of water on yarn and fabric structures, it is important to remember that the strain released all resides in the original fibre; however, yarn and fabric geometry are affected by these changes at the fibre level.

The amount by which a yarn changes dimension is determined by the amount of internal voids it contains. Cotton yarns inherently have some voids because of the irregular cross-section of the fibre, but are also usually highly twisted because cotton is a staple fibre. The fewer open spaces found in highly twisted structures results in greater dimensional change of these yarns. As the fibres swell, the yarn diameter increases. Within the twisted structure the fibres, in part, travel around the circumference of the yarn. To compensate for the increased distance the fibres must travel around the swollen yarn, the yarn twist increases, and the yarn length shrinks (Gray, 1971). Similarly in the woven fabric structure, the increased yarn diameter makes the distance the yarns must travel as they interlace with one another larger. The yarns are drawn closer together to compensate, thus increasing yarn crimp and decreasing the dimensions of the fabric. This type of fabric and yarn shrinkage is reversible because as the fabric dries the fibres de-swell and the original dimensions are restored (Gray, 1971).

While fibre is swollen however, the second process, relaxation, also occurs, especially with the first wetting of the fabric after processing. Relaxation results in permanent dimensional change of the fabric. Weaving and textile finishing processes build stress into the fibres. Loom tension on warp yarns and tentering of the finished

²The modulus of a fibre is the ratio of stress to strain at low loads, from which recovery from deformation is complete, and is related to the stiffness of a fibre (Kaswell, 1953, 17)

fabric cause molecules in the fibres to become more oriented and extended. The degree to which these stresses can be relaxed is affected by the modulus of the fibre and the degree of freedom for movement. Movement is restricted by tightly twisted yarns and high thread counts. Movement becomes even more restricted when the fibres swell; therefore much of the relaxation process actually occurs during drying. The water plasticizes molecular chains allowing them to shift and release stress, reverting into a less elongated, more random configuration which translates to a decrease in fibre length. As swelling diminishes upon drying, the fabric structure loosens, which allows further room for movement and relaxation (Gray, 1971).

Gray's article (1971) focuses on the effects of wetting on dimensional changes of fabrics. Less extreme, but significant dimensional changes can occur by increased humidity also, as demonstrated by du Pont Cornelius (1967). Canvas strips were cycled between 20% and 95% relative humidity, which caused an overall shrinkage of 8 1/3 % in the warp direction, the majority of which occurred during the first exposure to high humidity. Hedley (1988) recorded the change in length of free-hanging primed canvas strips as they were cycled from 15% to 98% relative humidity. His results indicated that as the strips absorbed water they gradually became slightly longer (0.2%) with increasing humidities up to 80%. When the RH was raised above 80%, shrinkage occurred suddenly, some of which was not recovered when the humidity was decreased. Similar to du Pont Cornelius (1967), Hedley (1988) also noted that the samples exhibited progressive shrinkage upon repeated exposures to high humidities (98%), with shrinkage diminishing upon each exposure.

Thus it would appear that humidity alone induces sufficient plasticization for molecular chains to relax and some permanent shrinkage to occur.

Glazed Finishes

The lustre of textiles is produced by the combination of diffused and specular light reflected off the fibre surfaces. Fibres appear most lustrous if viewed in the direction of the fibre axis (Kaswell, 1953). A smooth, uniform surface promotes lustre; therefore, it is important for the fibres on the textile surface to be as parallel to one another as possible if a glossy effect is desired. The lustre of cotton fabrics is often associated with the quality of the fabric. Cotton fibres have a natural lustre which varies from species to species, with pima cotton having the highest natural lustre (Prakash, Oka, & Iyengar, 1968). The irregular fibre cross-section, and the convolutions of cotton fibres cause disruptions in regularity which reduce lustre. Submicroscopic structural properties including molecular orientation and degree of crystallinity also contribute to lustre (Prakash, Oka, & Iyengar, 1968). The lustre of cotton fabrics can be increased through chemical means (mercerization) and by the application of mechanical finishes.

Nonpermanent glazed finishes

Application

Increased lustre can be imparted to a cotton fabric by passing the damp woven cloth through a calendering machine. The fabric is passed under pressure between two rollers (bowls), one of hot metal, the second of a soft material like wood, rubber,

compressed paper, or cotton called the 'pressed bowl' (Storey, 1978; Hall, 1957). Modern calendering machines generally have three, four or five bowls, different combinations of which can be used to produce different effects. A plain finished calender is produced by two pressed bowls on either side of a central heated metal bowl. Moisture and heat plasticize the cotton fibres, allowing them to be easily deformed. The plain calendered finish flattens the textile yarns, smoothing out the surface of the fabric thereby increasing lustre.

The effect can be greatly increased by first saturating the fabric with starch, waxes, or clays prior to calendering (Hall, 1957; Bogle, 1977). These substances fill in irregularities in the fabric surface, increasing flatness. Wheat starch is more effective than other starches in acting as a binder for inorganic fillers like china clay (aluminum silicate). It imparts a firm hand and high gloss when calendered, but can crack on the surface. Farina, or potato starch, lends a softer, more flexible finish, and when combined with borax or wax is capable of giving a highly lustrous finish which adds very little weight to the original fabric (Marsh, 1966).

A highly polished surface can be achieved by the use of a friction calender whereby one bowl rotates two to four times faster than the others (Marsh, 1966). Storey (1978) describes a friction calender as having a middle bowl of pressed cotton with an upper heated steel bowl and a lower one of cast iron. The polished cotton textiles produced by these machines are often referred to as 'glazed' or having a 'chintz finish'.

History

Ancient methods for smoothing cloth included rubbing the surface with rods, as was carried out in Egypt, and the use of pressure with wooden blocks or smooth stones. In Switzerland, a heavy marble ball was rolled over the taut fabric surface (Patterson, 1956). Ancient Andean cultures also developed a method for glazing cotton fabrics, possibly using smooth stones (Pettit, 1970).

Simple cloth screw-presses have also been used since antiquity. In the 18th century, these presses were still being used and were capable of imparting gloss to textile surfaces, especially when used with heat. The back of the cloth was sprinkled with a dilute gum arabic solution or water and was then carefully folded back and forth, interleaving with vellum, paste-board or wood. A very hot brass or iron plate was inserted every few folds, and the entire package compressed in a large screw press where it was left for ten to twelve hours. This process could be repeated several times (Patterson, 1957).

Beginning in the 17th century, brilliantly patterned cotton textiles, called variously 'chint', 'chints', 'chites' (from the Indian word 'chitta' meaning 'spotted cloth') were exported from India to Europe. From these cloths developed the glazed cotton fabrics often used for furnishings known as 'chintz' (Gittinger, 1982, Irwin & Brett, 1970). Cole notes the original Indian chintz is identifiable by its "quaint, old-fashioned patterns, coarse irregular threads, and its *entire freedom from dressing*" (p.100, italics added). Claburn (1988) also notes that Indian chintzes were without the highly polished surfaces which became associated with the term during the 19th century.

Contrary to these statements, however, is the botanist William Roxburgh's eye witness account of the Indian chintz dyeing process of 1795, quoted at length by Schwartz as an appendix to Irwin and Brett's book *Origins of Chintz* (1970). Roxburgh reports the patterned cloth was prepared for market by "beetling, starching and chanking; this last is similar to calendering, which is performed with a smooth shell

rubbed backwards and forwards over the painted side of the chints, till it has acquired a very high gloss or polish". Rice starch was also used in the process. According to Beer (1970), the original 'chint' trade cloth which was produced in India expressly for export to the Spice Islands, Persia and the Near East, sometimes had a glazed finish. Irwin and Brett (1970) postulate that all of the cloths made for export may have originally been glazed. They also note that during the 17th century, chintz was sometimes mistaken for satin, as further evidence that the fabric had a highly lustrous surface.

Early printed cotton textiles produced in Great Britain after 1750 were given a glazed finish in a hand process called 'sleeking'. The fabric was treated with a thin coating of beeswax, and laid flat in a trough. A fist-sized smooth curved block of flint, agate, or glass was then passed across the surface to produce a polished effect. Calendering machines were also used (Robinson, 1969).

An early form of the calendering machine consisted of a large box filled with stones which could pass back and forth over two rollers onto which the fabric had been wound (Patterson, 1957). A detailed description, and illustration of this type machinery as it was known in 1788 is found in Montgomery's *Textiles in America 1650-1870*, which quotes from Howards' *New Royal Encyclopedia*. The machine was used to "press certain woollen and silken stuffs and linens, to make them smooth, even, and glossy, or to give them waves, or water them" (Montgomery, 1984, 184). Cole (1900) refers to this type of machine as a mangle³. He goes on to state that a calendering machine was introduced to England from Flanders in the 17th century. The machine he describes closely follows the equipment outlined by Storey (1978), whereby the fabric passes between cylinders made of cast iron, wood, paper or cotton. It was used for numerous purposes including glazed, watered (moire) and embossed finishes. In his encyclopedia, written in 1900, Cole states that "no material alteration or improvement has been made in the original machine; nor have any great advances been made in the practical application of it" (p. 58).

Baines' 1835 account of cotton production in England describes how cotton fabrics were given a glossy finish by passing them between several wooden and iron cylinders. Prior to calendering, the fabric was "usually passed through starch made of wheaten flour often mixed with porcelain clay and calcinated sulphate of lime" to make it appear more substantial (p. 252). In his *Practical Treatise on Dyeing and Callicoe Printing* (1815), Thomas Cooper gives instructions for the finishing of textiles: "glaze or calender them: if you glaze them use white wax for light colours and yellow wax for the darker ones; just enough to make the glass ball run smoothly and no more" (p.489). The glass ball may be a reference to the sleeking process described by Robinson (1969).

These early methods, popular throughout the 19th century were successful in producing a pleasing lustrous appearance to cotton fabrics; however, the finish could not withstand wet cleaning (Krup, 1961). Exposure to water made the fibres swell, causing them to lose their calender-induced flatness and return to their more rounded shape upon drying. In this way, the smooth flat surface so essential to the glazed appearance was destroyed (Hall, 1957). In addition, starch and other fillers could be removed by wet-cleaning.

³A mangle consists of a cylinder applied to a level surface, upon which it is rolled backward and forward over the stretched cloth until some degree of smoothness is attained." (Cole, 1900, 58).

Durable glazed finishes

History.

By the early twentieth century, efforts were being made at producing a more durable glazed finish. Early attempts included applying thin coatings of nitro lacquers, polyvinyl, polyacrylic, and hydroxyethylcellulose prior to calendaring (Knup, 1961). The publication *Staple Cotton Fabrics* from 1942 refers to a "cellulose type" permanent chintz finish (Hoye, 1942, 234), perhaps referring to the hydroxyethylcellulose coating. These coatings improved washfastness, but produced unacceptable stiffness, were not fast to solvents, and were heat sensitive (Knup, 1961). Other early finishing suggestions included the application of soap solutions to produce a finish able to withstand damp ironing (Smith, 1971). Phenol-formaldehyde was suggested as a means of improving the durability of schreiner finishes in 1915.⁴

More successful permanent glazed finishes were possible with the discovery of thermo-setting resins which limited the swelling of cotton fibres by reducing the amount of water the fibres were capable of absorbing (Knup, 1961). Urea-formaldehyde resins were first discovered in 1918 and were originally suggested as a treatment for airplane wings. An early method of using the urea-formaldehyde resin for glazed cotton fabrics involved first producing the glaze in the traditional manner with starch, heat, and calendaring. The resin was then spread on the fabric in a very thin coating. The resin was prevented from penetrating the fabric by the starch which filled yarn interstices. After the resin was dry, the fabric was again calendared with heat. An enzyme was used to convert the starch to sugar, which was then easily removed by washing. The discontinuous film produced in this manner allowed the fabric to be soft and flexible, but with a high surface gloss (Marsh, 1960). Another method involved applying urea-formaldehyde and casein-formaldehyde which was said to be flexible as well as spot-proof. (Marsh, 1966).

The era of modern chemical finishes began with the crease-resistant finish patents of the Tootal Bradhurst Lee Co. Ltd in 1926. Their process stressed the importance of the phenol-formaldehyde and urea-formaldehyde resins being formed within the cotton fibre. From their original premise, other durable finishes quickly followed including shrink-free cottons, durable press garments, and durable glazed and embossed surfaces (Smith, 1971).

Urea-formaldehyde resins were replaced by melamine-formaldehyde resins in the early 1940's, because these newer finishes had improved washfastness (Smith, 1971). Melamine finishes became widely used in America, while urea resins remained more popular in Britain (Hall, 1966). One trade name for melamine finishes was "Everglaze"⁵, a durable glazing process introduced in 1946 (Marsh, 1962). With this new technology many variations in surface treatment became possible including printing the resin onto the fabric to produce a glazed or embossed pattern (Smith, 1971). Detailed descriptions of the processes involved in producing durable glazed, embossed or schreinered effects can be found in Marsh (1962).

Even after the advent of chemical finishes, non-permanent finishes continued to be produced. In a 1952 issue of the *CIBA Review*, Weibel states "the lustre imparted to a

⁴Schreiner is a mechanical finish introduced in the late 19th century. The calender rollers were engraved with fine diagonal lines, corresponding to the twist of the yarns, which were embossed onto the fabric surface producing a highly lustrous effect (Marsh, 1962).

fabric by calendering or a starch finish soon disappears during laundering, and finishers are increasingly concerned with the production of permanent finishes" (p. 3431). Commercial interest in permanent mechanical finishes reached a peak from 1950 to 1955 when thermosetting resins were put to many innovative uses including deeply embossed 'sculptured' fabrics, and 'tutored' or 'ruffled' finishes which combined the use of resins with mechanical shrinkage treatments (Smith, 1971). Detailed instructions for localized permanent chintz and sculptured effects are given in the 1961 issue of CIBA Review (Knup, 1961). Thereafter, changes in fashion resulted in a declining demand for glazed and embossed fabrics.

Application.

In order to reduce the negative impact thermo-setting resins can have on the strength and flexibility of fabrics, it is necessary the resin be formed within the fibre, rather than merely coating the surface. This is achieved by impregnating the fibre with a resin precondensate in an aqueous solution. The precondensate is formed by partially reacting the monomers (ie. urea and formaldehyde) which will eventually polymerize and cross-link to form the resin. The precondensate molecules are small enough to be soluble in water which also acts as a swelling agent for the fibres, allowing the precondensate to enter fibre pores (Hall, 1966).

The precondensate solution is padded onto the fabric along with a catalyst to speed up the polymerization process. Other additives, including softening agents, filling agents, or gloss-imparting agents may also be included. The fabric is then passed through the calendering machine, which imparts polished smooth surface as previously described (Storey, 1978). The glazed fabric is dried and then is cured at a temperature up to 150°C during which the precondensate polymerizes and cross-links with itself to form an insoluble resin. The fabric is washed to remove any residual resin clinging to the surface of the fibres and residual byproducts of the polymerization process (Hall, 1966). It is believed that urea and melamine formaldehyde resins (aminoplasts) also form occasional cross-links with the cellulose itself, thus improving their durability. If the resin were merely deposited within spaces in the amorphous fibre regions, it would eventually rinse away with repeated laundering, especially in combination with hot water and detergent. Other classifications of resins cross-link more strongly and frequently to the cellulose, and react less with themselves. Hall (1966) lists many of the resins in use today.

Effects of mechanical finishes on fabric properties

In addition to imparting increased durability to glazed finishes, the use of thermosetting resins also affects other fabric properties. Because the resins work by reducing water absorption of the fibres, it is not surprising that fabrics with permanent glazed finishes are also dimensionally stable. A 1947 publication by the Cotton-Textile Institute states their glazed fabrics have shrinkage of less than 2% after washing (1947). They also state the fabric is resistant to weathering and sun, and that 'the finish is in every respect as soft, smooth and crisp as an ordinary glazed chintz, and draping qualities are not in any way impaired' (Cotton-Textile Institute, 1947, 35).

The addition of thermosetting resins, plus friction calendering, reduces the stretch and elastic recovery of the textile, and can lower tensile strength (Knup, 1961). The

⁵A fabric swatch displaying this finish is included in the 1947 publication by the Cotton-Textile Institute *Cotton from Raw Material to Finished Product*. The Everglaze finishing system was still in common use at the time of Marsh's writing, 1962.

fashionable glazed fabrics of the 1950's were often brittle enough to tear along seam-lines when worn (Storey, 1978, 177). Low tear strength can be partially caused by excess resin coating the exterior of the fibres (Hall, 1966, 177). The resin and catalysts used can also affect the fabric's reaction to chlorine bleach, and can cause fabrics to yellow over time (Hall, 1966). Decreased strength is not a function only of modern finishing methods. Cooper (1815) stresses that the use of too much wax and starch produce glazed fabrics that "are stiff and brittle enough to tear very easily" (p. 469).

MATERIALS AND METHODS

Rationale

Localized humidification treatments using Gore-Tex were chosen for this study because they allow an artifact to be humidified in a slow, controlled manner which is especially important for materials with moisture sensitive surfaces. Purinton and Filters (1992) recommend humidifying paper from both top and bottom by sandwiching the artifact between Gore-Tex and damp blotter layers, but also mention that humidification from just one side is also possible. Mulhall (1989) humidified a mandala with unstable water soluble paint layer by introducing water vapour through Gore-Tex beneath the textile. Similarly, in this study, moisture was introduced from the back only, allowing the surface to be easily monitored throughout the procedure. Dwan (1992) used Gore-Tex to preserve the calendered finish of papers during drying by placing Gore-Tex next to the smooth paper surface, followed by a dry blotter, felt and a glass plate for weight. Following a similar procedure, some of the treatment groups in the current study were allowed to dry with Gore-Tex, dry blotters, and weights on top of them.

Analysis of Selected Glazed Fabrics

Six glazed cotton fabrics representing a variety of time periods and origins were acquired for the study. The fabric coatings were characterized using an iodine starch test, FTIR microscopy, and electron probe analysis.

The starch indicator test utilized the iodine solution described by Browning (1969, 84). 0.13 g of iodine was dissolved in a solution of 2.6 g potassium iodide in 5 ml of water. A thread from each fabric was placed in a drop of deionized water on a glass microscope slide, where it was allowed to sit for a few moments. A drop of the yellow iodine solution was added. A dark blue/black colour change in the fibres and/or surrounding solution was a positive indication of the presence of starch.

FTIR microscopic analysis was carried out using a Nicolet FTIR with Nic-Plan IR Microscope. Fibre samples were evaluated to identify any resin components. Residues of fabric components soluble in deionized water were also analyzed. A Cameca MBX Electron Beam Microprobe was used to identify inorganic coating components including clays and fillers.

Table 1

Characterization of Fabrics

#	Origin	Description	Glaze	Starch test	FTIR	Electron probe
1	India, trade cloth	brown discharge print, overall small motifs	light, irregular, crisp handle	+	starch	aluminum silicate (china clay) calcium carbonate
2	India, trade cloth	red, small overall printed pattern	very light irregular	+	starch	aluminum silicate (china clay)
3	19th c. dress lining	purple, no pattern	heavy glaze, but soft worn handle	+	starch	very few particles present, some aluminum silicate, calcium carbonate
4	1800-1850 English	white, with brown and red printed pattern	very heavy glaze, high gloss, stiff handle	+	starch	calcium sulphate
5	?	large multi-coloured paisley print	soft, even glaze	-	inconclusive	calcium carbonate
6	20th c.	curtain red and white stripes	even regular glaze, crisp handle	-	inconclusive	very few particles inconclusive

The results from these analyses are summarized in Table 1.

Results from the FTIR microscopic analysis of the residues generally reinforced those of the starch test. Analysis of the residues yielded no further information for fabrics 5 and 6, as any resin present in them was not extracted in water. Unfortunately, the spectra of whole fibres were not useful in determining the presence of resins, as the cellulose content obscured any differences in coating composition.

The spot test described in by Van Loo, Salisbury, and Andrew (1956) would be useful to determine the presence of thermosetting resins, especially those which tested negatively for starch (fabrics 5 and 6). FTIR analysis on extractions from 1,1,1-trichloro-ethane, hexane and hydrochloric acid, in which the resin and wax components may be soluble would also be useful, as would the other analytical procedures described in AATCC test method 94-1987 (1991). Further work to more completely document the test fabrics would include a more precise identification of date and origin through

historical references.

Humidification of Selected Glazed Fabrics

The fabrics were cut into 21 test specimens each measuring 2" x 2 1/4". Because of the small quantity of fabric 2, only 14 specimens were cut, each measuring 2" x 1 3/8". The specimens were randomly assigned to the 7 treatment groups briefly summarized in Table 2.

Table 2

Group	Type of Humidification Treatment
Group A	light weights with upper blotter
Group B	light weights with Gore-Tex between blotter and fabric surface.
Group C	heavier weights with upper blotter
Group D	heavier weights with Gore-Tex between blotter and fabric surface
Group E	pinned around edges to hold flat
Group F	no restraint by weights or pins
Group G	control (not humidified)

Description of Treatment Groups

Identical creases were then artificially placed down the centre of each specimen by folding it in half, and placing under heavy weights and plexi for 2 hours.

All the specimens for each fabric were humidified together (except the controls in group G) within a single package layered as follows:

- clear polyethylene
- test specimens
- Gore-Tex: film-side up
- damp blotter paper
- clear polyethylene
- Fome-Cor (as a pinning surface)

The edges of the humidification package were weighted down and the specimens allowed to humidify for 1/2 hour. The top layer of polyethylene was removed and the creases gently flattened with the fingers. The underlying damp blotters were then exchanged for dry. Blotter paper was placed over specimens in groups A and C. Specimens in groups B and D had Gore-Tex placed against the glazed surface film side

down, followed by a dry blotter. Those in group E were held flat by pinning the edges down through the underlying Fome-Cor. The top layer of polyethylene was then replaced. Groups C and D were weighted with a light plexi weight, plus a heavier weight, while groups A and B were weighted with plexi alone. The treatment groups were allowed to remain in this state for 1/2 hour, after which the package was re-opened and new dry blotters placed beneath the samples. The same weights, or pins as used during humidification were then replaced and the specimens allowed to dry overnight in the unsealed package. This procedure was repeated for each fabric.

Visual Evaluation and Statistical Analysis

Five observers compared each of the 21 specimens for each fabric to standards which defined levels of creasing on a scale from 1 to 20. The fabric standard at #1 on the scale had no evidence of a crease, and that at #18 was deeply creased. Standards were placed along the scale at # 2, 4, 6, 8, 10, 12, 14, and 16 in between these two extremes. New random numbers were assigned to the specimens so observers did not know which specimens had undergone which treatment.

The scores for each treatment group within each fabric were then pooled for a total of 15 scores per group; there were 5 observations of each of the 3 specimens per group for each fabric. The data were then analyzed using one-way analysis of variance (ANOVA) to determine if there were any statistically significant differences between the treatment groups. Statistical calculations were made by inputting the data into the Works for Windows spread-sheet package. The total sum of the squares, and the sums of the squares between groups and within groups were calculated, and from these, an F statistic was computed. If this value exceeded a corresponding value in the F distribution, this indicated that there was at least one statistically significant difference somewhere among the treatment groups (Hinkle, Wiersma & Jurs, 1982).

Because the treatment groups for each fabric were of equal size, the Tukey Test (or HSD 'honestly significant difference' test) was then used to calculate a Q statistic for each pair of the treatment group means. When the Q score exceeded a corresponding value in the studentized range distributions (at a confidence interval of 0.05), a statistically significant difference existed between those two treatment groups. This means that there was a 95% chance that the difference between the means of these treatment groups was real, and not merely due to chance variation (Hinkle et al, 1982).

RESULTS

Reduction in Creases

Analysis of variance was run separately on each fabric. As shown in Table 3, the only clear trend common to all the fabrics was that all the humidification treatments caused a statistically significant lessening of the crease when compared to the unhumidified control. These results indicate that the water vapour absorbed by the fibres was the largest factor in reducing the creases. Slight improvements were found in three of the six fabrics through the use of weights, but these improvements were small compared to the action of humidity alone. For example, as shown in Table 3, the creasing in Fabric 3 dropped from an initial crease of 18.5 (group G) to 6.8 (group F) without the use of substantial weights or restraint. The specimens in group F were smoothed slightly with the fingers after humidification, and had only the weight of the upper layer of polyethylene on top of them. The use of a heavy weight improved the crease to between 3.9 and 2.5 (groups C and D); this is a notable difference but is not nearly as great as between group F and the control. These differences can be more easily seen in Figures 1,

2, and 3 which depict the data in graph form.

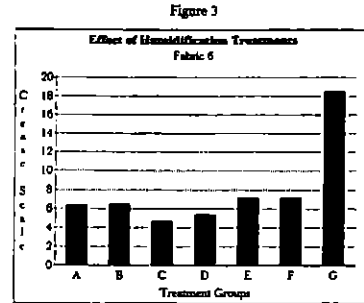
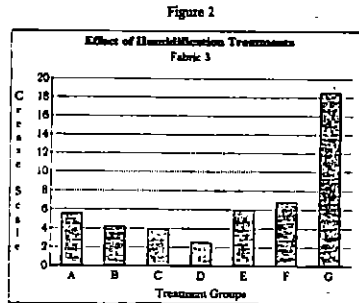
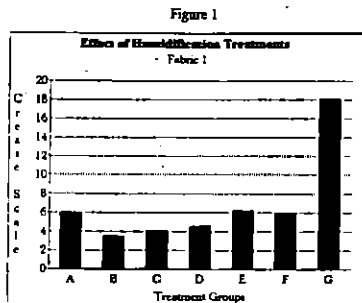
Table 3

Degree of Creasing in Glazed Fabrics After Humidification

Fabric	Treatment Groups						
	A	B	C	D	E	F	G
1	6.0	* 3.5	4.1	4.6	6.2	6.0	*18.1
2	2.6	3.2	3.9	3.5	3.6	3.5	*18.4
3	*5.6	*4.2	3.9	*2.5	*5.9	*6.8	*18.5
4	4.4	5.2	3.5	4.3	4.1	6.3	*18.5
5	4.7	5.3	5.1	4.2	5.7	5.9	*19.1
6	6.4	6.5	*4.7	*5.4	7.2	7.2	*18.5

20 point crease scale (1 = no crease, 20 = very deep crease)

*denotes a statistically significant difference from at least one other group (95% confidence) as determined by the Tukey Test n=15 except fabric 4 where n=10



For fabrics 2, 4, and 5 no statistically significant difference was found between the 6 variations on the humidification treatment. Those samples left unweighted and unrestrained (groups E and F) were visually no different from those with heavy weights or pins. A Gore-Tex layer between the upper blotter and the fabric surface (Groups B and D) had no effect on the flattening of the crease. These 3 fabrics had virtually nothing in common: fabric 2 was an Indian print with a very light glaze; fabric 4, an English print with a heavy stiff glaze; and fabric 5 appeared to have a thermoplastic resin durable glaze. All contained different types of fillers.

Fabric 1 was an Indian printed cotton of similar provenance to Fabric 2. In this case, treatment B, using light plexi weights and a layer of Gore-Tex between the fabric surface and upper blotter was statistically better at flattening the creases than the same treatment lacking the upper Gore-Tex (treatment A). Figure 1 shows that the use of

light plexi weights (treatment B) was also more effective than allowing the fabrics to dry without weights (treatment F) or by restraining with pins (treatment E), but could not be differentiated from those dried under heavy weights (treatments C and D).

Fabric 6 was a modern red and white striped curtain purchased at a second-hand store. It appeared to have a durable glazed finish, as it contained no starch and the finish was not soluble in water. For this fabric, treatment C was most effective, as shown in Figure 3. This treatment, using heavy weights and no upper Gore-Tex layer, was statistically significant from those groups using light weights, pins, or no restraint (groups A, B, E, and F). It was not significantly different from the same treatment with the inclusion of the second Gore-Tex layer (treatment D). Treatment D (using heavy weights and upper Gore-Tex layer) was more effective than the unweighted treatments (groups E and F), but could not be differentiated from the groups dried under light plexi weights (treatments A and B).

Observations from Fabric 3, the plain purple lining fabric, yielded the most distinct differences between groups, perhaps because it was much easier for minute differences in creases to be differentiated on a plain fabric than a patterned one. As illustrated in Figure 2, treatment D, the use of heavy weights plus an upper layer of Gore-Tex was more effective in crease reduction than using light or no weights. There was no statistically significant difference between the use of a heavy weight without the upper Gore-Tex layer (treatment C) and treatment D. The unweighted treatments E and F were less effective than treatments B, C, and D, but could not be differentiated from A.

The results described above were somewhat surprising because for half the fabrics tested, the use of weights did not increase the flatness of the specimen any more than simple humidity alone. For the remaining three fabrics, weights did have a positive effect, and heavy weights were better than light weights in two out of the three cases.

Weights apply pressure to the top of the crease, pushing it down, but not out. The addition of tension pulling the fabric out from the crease would appear to also be necessary for more effective flattening. Treatment F, was an attempt at such a tension treatment, but it was never more successful than using weights. This treatment would have been more successful, possibly, if the pins had been moved outward gradually, applying constant tension as the crease flattened out.

It is interesting to note that none of the treatments was completely effective in removing the creases. All methods reduced the crease from around 18.5 to between 2.5 and 7.2 on scale of 1 to 20. A score of 2 or more indicates that some level of creasing was still discernable. Cotton fibres naturally have relatively poor wrinkle recovery, partially due to the fibre's flat cross-section which is easily deformed. Wrinkle recovery is largely determined by the fibre's elastic recovery (Marsh, 1962). After an elongation of only 2%, the elastic recovery of cotton is 75% (Needles, 1986). The calendered finish can further reduce elastic recovery (Knup, 1961). According to Buck and McCord, as referenced by Kaswell (1953), fabrics with a plain weave, such as those used in this study, inhibit movement of fibres more than other weaves, making the fibres more strained and less able to shift to avoid deformation, or recover from deformation. Also, the appearance of a wrinkle is accentuated by how light strikes the surface; deformations tend to show most on shiny surfaces. The combination of these factors make removal of creases from glazed fabric inherently difficult.

Secondary Changes to Glazed Surfaces

This portion of the research project remains incomplete. Any possible changes in

the surface gloss between treated samples and the controls were so visually subtle as to make ranking any differences extremely difficult.⁶ The discussion below is based only on informal observations by one researcher.

A cursory evaluation under raking and then ambient light found no difference in the gloss between the different humidification treatments. There appeared to be no difference among those specimens with nothing resting directly on their surface, compared with those having either blotter paper or Gore-Tex.

There were some gross changes when comparing all the humidified samples as a group to the unhumidified controls. Most obvious was the severe curling of fabric 4, the heavily glazed English print. All of the humidified specimens (including those under heavy weights) curled backward, except one which curled forward. These samples were difficult to evaluate for crease removal as the treated specimens had curled so much. Because the glaze on this fabric was so firm and intact, it is likely the fabric had never been washed, meaning that inherent stresses from the production of the fabric could then still be present. Humidification could have caused relaxation shrinkage of the fabric to release this strain. If the heavy glaze on one side resisted shrinkage (possibly due to a hydrophobic wax component), but the unglazed backside shrank slightly, this would cause the fabric to curl backwards.

The humidified samples for fabrics 1, (Indian printed cotton) and 3, (19th c. lining fabric) showed a slight tendency to curl forward, which is somewhat harder to explain. Either the glazed side of the fabrics shrank slightly, or the unglazed side expanded slightly.

Some very slight overall buckling was also seen in some, but not all of the humidified samples for fabric 1. Fabric 2, also an Indian cotton, may also have displayed some subtle buckling. These distortions may be due to warp and weft yarns reacting differently to humidity, either because they were of slightly different construction, or because the amount of strain they were holding was different. The humidified samples for fabrics 3 and 4 appeared to have lost some gloss when compared to the controls, but the difference was extremely subtle. A change in surface gloss would not be surprising as the presence of moisture by humidification could be enough to cause yarns to swell and lose their flatness. Less light would then be reflected from the surface, making the fabric appear less lustrous. No secondary surfaces changes were noticed for fabrics 5 and 6, both of which appeared to have durable resin finishes. As these finishes work to discourage swelling of the cotton fibres, the yarns remained flattened even after being exposed to water. The finish also makes the fabric more dimensionally stable, perhaps explaining why buckling and curling were not apparent in these samples.

CONCLUSIONS

All of the humidification treatments employed in this study were effective in diminishing creases in the 6 selected glazed cotton fabrics, but none were successful in removing them entirely. It would seem that complete removal of such creases from these textiles may not be possible due to their generally firm weave structures, and the

⁶In order to do a trial run of the experimental procedure, and to train the observers in evaluating the creased samples a 7th glazed fabric not included in the formal study was purchased at a local fabric store. It was a solid colour with a very glossy, crisp handle. The trial fabric was exposed to the same experimental conditions as those formally in the study after which all the humidified samples showed a large change in their surface; the glazed effect had almost disappeared. None of the variations in Gore-Tex humidification was effective in retaining the glaze.

unforgiving nature of their lustrous surfaces on which any imperfection shows.

Results from this study indicate that simply piling more weight onto the crease may not necessarily produce more beneficial results. Only 2 fabrics out of 6 studied showed heavy weights to produce statistically significant improvements from the other treatment variations. In fact, for half the fabrics, all the humidification treatments were seen to be equally successful by the trained observers; those under weights or pinned around the edges were not statistically different from those with no weights or restraint.

The use of Gore-Tex film or blotter directly against the glazed surface appeared to have no effect on the gloss of the six fabrics evaluated in this experiment. The humidification treatments appeared to have no effect on the glaze on 4 of the 6 fabrics, with possible subtle changes in 2 fabrics. Two other fabrics in the study, both Indian printed cottons, exhibited some overall buckling of the surface of humidified samples, which could translate into an unacceptable surface change if the treatment were carried out locally on a larger textile. The severe curling of the heavily glazed English print is an indication that localized humidification of similar textiles could be problematic. It is possible, then, that all four of the fabrics with starched finishes underwent some minor surface changes when exposed to humidity, either in the form of buckling, curling, or loss of lustre; however, further testing in this area is required before any firm conclusions can be drawn. The two fabrics which appeared to have durable resin glazes both responded reasonably well to the humidification treatments. As these finishes are insoluble in water, full wetting would also have been an option.

The resistance to damage by moisture of non-permanent calendered finishes varies from fabric to fabric. Hall (1957) states that wash-fastness of finishes is much higher for fabrics which were passed through very hot calender bowls in a wet state; calendered finishes of a moderately moist fabric are easily removed. As the exact production methods used for the finishes on textiles in museum collections very likely is not known, it would be safest to treat all starched glazed finishes with due caution, especially if they appear to have not been wet previously.

FURTHER RESEARCH

An accurate assessment of the composition of the glazed surface would be very helpful in determining whether to expose a glazed cotton textile to moisture. Knowledge of date, origin, and corresponding production techniques would be helpful, and there is room for more historical research in this area. The identification of durable resin finishes on twentieth century fabrics might be most easily carried out by employing the spot test described in by Van Loo et al (1956) "A Rapid Spot Test for the Identification of Aminoplasts on Textiles". An investigation into the spot test's applicability for use on historic textiles would be beneficial.

Further evaluation of secondary changes to the glazed surfaces caused by humidification of creased areas is necessary in order to obtain quantifiable results. It was hoped that a variation of the observation technique used to evaluate crease reduction could be adapted to evaluate the change in surface gloss in this study; however, the production of a scale of fabric standards proved problematic. Also, the changes, if any, were too subtle to be visually ranked. A glossmeter might be a useful instrument to employ in evaluating these fabrics, and is an option which could be explored.

Alternatively, an entirely different experimental set-up might make any changes more easily seen; for example, changes might be more obvious in a larger panel of fabric. Selected areas could be humidified using a range of treatment variations and compared to the adjoining unhumidified area. This procedure would be closer to what would be done in an actual localized humidification treatment of a flat textile, and might yield more meaningful results.

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NOTES
