

Abstract Harpers Ferry Regional Textile Group  
10th Preservation Symposium, Nov., 1990.

Fabric Selection and Its Relationship to Dimensional Changes  
in Support Systems for Constrained Fabric Mounting Devices

by Stephen Collins, Marion Mecklenburg, Mary Ballard\*

There has been, and there still remains, a great debate as to how to choose fabric substrates for constrained mounting devices. Selection of mounting fabrics in textile conservation is somewhat random, being dependent upon what is commercially available. Because textile conservators represent a limited market they carry very little weight in determining the types of fabrics being manufactured.

In textile conservation, constrained mounts are considered a treatment rather than simply a method of display. Traditionally, a constrained mounting fabric is stretched tautly around a wooden or cardboard strainer and held in place with staples, glue, or by being laced or sewn to itself. In concept, these mounts attempt to maintain a constant pressure, or yarn stress, which allows little room for dimensional changes. A support system must provide adequate strength and stiffness, and must be dimensionally stable so that its own physical nature will not cause distortion in the textile being supported. This concept of dimensional stability is generally considered debatable when considering the affects of changing conditions due to relative humidity.

The literature reviewed indicates that a support system must be strong enough to carry the weight of the artifact. A support system must provide adequate strength and stiffness, and must be dimensionally stable so that its own physical nature will not cause distortion in the textile being supported. When considering the long term effects of ageing, the inherent ability of certain synthetics to resist the various agents of destruction that cause degradation in natural fiber fabrics is of interest.

There is no body of literature concerning the scientific basis for use of constrained mounting devices within the textile conservation literature. There is, however, a great deal of information that can be taken directly from the textile industry and from paintings conservation. Much of this literature concerns the uniaxial testing of textile fibers and yarns. Although there are some full fabric tests, the majority of testing is done at the fiber or yarn level or with strip tests. There is a great deal of interest in the biaxial study of fabrics as fabrics are rarely stressed in a uniaxial direction. It is generally accepted that the strains generated in a biaxially stressed fabric are considerably different than those generated within an uniaxially stressed fabric. F. C. Brenner and C. S. Chen stated that the forces developed when a fabric is deformed are strongly influenced by fabric geometry and the magnitude of internal stresses. The ability for a fabric to recover from that deformation depends upon how that energy has been stored or dissipated.<sup>1</sup> Klein stated that the biaxial extension is much smaller than that of the uniaxial extension.<sup>2</sup>

---

\*Conservation Analytical Laboratory, Smithsonian Institution, Washington, D.C. 20560.

Between 1937 and 1947, F.T. Peirce<sup>3,4</sup> formalized the subject of fabric geometry through mathematical analysis. In 1967, Freeston, Platt and Schoppee considering the parameters set up by Peirce to be insufficient additional deformation factors occurring in biaxially stressed fabrics.<sup>5</sup>

The studies of Mecklenburg<sup>6</sup> and Hedley<sup>7</sup> on substrates used for canvas paintings provide additional insights. It is Mecklenburg's thesis that assemblies of layered materials, such as paintings, can be researched by mathematically summarizing the behavior of the individual materials found at each layer. If the forces developed by the separate layers of materials are added together at each point of Relative Humidity, a composite results. In other words, one can observe that the stress in the various layers of materials change with Relative Humidity even when there is no change in strain. Mecklenburg tells us that two materials with identical dimensional responses to moisture, upon restraint, can develop very different mechanical properties due to the modulus of one material being greater than the modulus of another.

Recent work at the Conservation Analytical Laboratory by Erhardt and Mecklenburg has shown that relative humidity cycles do result in irreversible changes in some materials. Berger and Russell state that with every change in temperature or humidity, some dimensional changes remain non-recoverable and that repeated variations lead to non-recoverable changes in most materials.<sup>8</sup> Generally slow and moderate changes are recoverable while rapid environmental changes cause disproportionately large stress variations.<sup>9</sup>

At low strain much of the mechanical behavior is simply the result of straightening crimped yarns.<sup>10</sup> After fabric crimp removal has been surpassed by continuous strain, the actual yarn behavior takes over. Upon being stretched beyond the fabric crimp removal zone, a constrained fabric when subjected to high humidity continues to relax by allowing the yarn fibers to slip past one another. Because of this, maintaining fabric tension, even in linen fabrics, with a high strain on a fabric subjected to high humidities appears impossible.

The focus of our current research was to determine the fabric least effected by tension loss due to moisture while under constraint. The severity of these losses aids in determining the most appropriate fabric for use as a constrained mounting device.

The first objective was to compare the dimensional stability of a select group of fabrics, stretched on constrained mounting devices, by observing how tension is effected by the presence of moisture.

The second objective was to compare the dimensional stability of these same constrained substrate fabrics affected by stitching and the presence of moisture. It is not within the scope of this study to examine and compare how stitching techniques effect the dimensional stability of the substrates. However, the subject of how various stitching techniques affect constrained substrate fabrics is an area for further examination.

The third objective was to compare the dimensional stability of these constrained substrates by observing how tension is affected by stitching and the presence of a mounted object, bound together in an assembly, in the presence of moisture.

The fourth objective was to observe how tension was affected by the transfer of the constrained mounting fabric from one strainer to another.

The final objective was to test for unstable chemical properties within the chemical makeup of the support fabrics. Certain aspects of these mounting fabrics and of their fiber properties negate the affects of particular agents of deterioration. The Oddy test was

used to assess this objective, and as expected the wool outgassed and the remainder of the fabrics tested negatively.

### The Selection of Samples

Fabrics from TestFabrics Incorporated were used to represent the combined categories of medium weight and light weight fabrics. The selection of sample fabrics from TestFabrics was decided upon because of this companies high visibility and history within the textile conservation profession. To reduce the influence of subject variables it was important to select fabrics from each group that are as structurally alike as possible. Only plain weave fabrics were tested. The construction, the number of ends and picks, and the over-all thickness of these test fabrics were chosen to be as similar as possible.

The fabrics used to represent the light weight category include: #435, Combed Cotton Batiste; #609, Habutae, 8mm, silk; #7435, Polyester/Cotton 65/35 Shirting; and #733, 45 inch, Polyester Batiste, Filament Warp/Spun Filling (Draperies).

The mid-weight fabrics include: #266, Spun Viscose Challis; #L-61, Handkerchief Linen; #777, Spun Dacron, T-54, Polyester; and #530, Wool Challis.

The pretreatment of the samples consisted of washing, rinsing, drying, and ironing. Reference test methods for this procedure are AATCC Test Method 124-1984 and Test Method 143-1984.

AATCC Standard Detergent 124 was selected for use as the composition of this detergent is typical. To achieve the critical micelle concentration necessary for cleaning to occur, 90 grams of Detergent 124 was used to wash 1800 grams of sample fabrics other than the wool and silk.

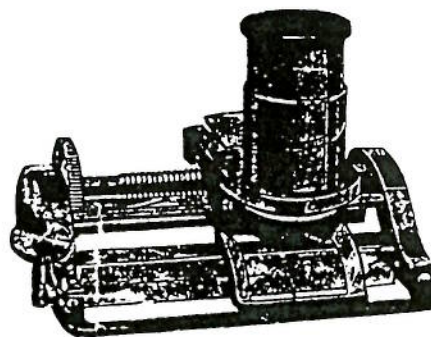
All samples were tested for the presence of starch using AATCC Test Method 103-1984. Both the Cotton Batiste, #435 and the Cotton Print Cloth, #400 (used as a representative, mounted object) were found to contain starch and so were given a treatment with alpha-amylase for the removal of the starch prior to washing.

Wool scouring was done in accordance with AATCC Test Method 99-1988. Scouring of the silk was performed as out lined in a silk degumming procedure compiled by Mary Ballard from the works of Carboni, Howitt and Trotman. In view of the changes of the end and pick counts of the cellulosic fabrics due to washing and drying, it was considered necessary to process all the samples with an aqueous pretreatment.

In this particular study, all supplies and equipment were housed at the Conservation Analytical Laboratory, of the Smithsonian Institution. The fabrics and threads were stored in the textile laboratory in a standard condition of 70°F and 50 percent relative humidity, +/- 2, in order that equilibrium could be maintained in this controlled atmosphere. Hygrothermographs were used to record the temperature and relative humidity fluctuations.

### The Assessment of Dimensional Change

Warp and weft counts were taken at the tension reading sites employing a Lowinson's Thread Counting Micrometer before and after pretreatment, after stretching, after sewing or transfer, at the end of the humidification cycle and after removal from tension. In this manner



LOWINSON'S  
THREAD COUNTING MICROMETER

figure 1.

any changes in the fabric geometry could be monitored and the percentage of stretch at that point determined.

Samples of each of the eight fabrics selected were subjected to fluctuations of relative humidity inside the control chamber over the period of seven days. Tension measurements were taken at specified intervals. The chamber maintained a humidity cycle synchronized to begin with the maintenance of the Belfort Hygro-thermograph each monday.

On the first and second day the frames were outfitted with new substrate samples. These stretched substrates were allowed to relax and be retensioned before being placed into the control chamber. After the reading on the third day, pans of water were placed in the control chamber to raise the relative humidity to approximately 90 percent or greater. The tension was read the following day. The cover of the chamber was lifted off and the pans of water were removed in order to reduce the humidity. The cover was then replaced. Tension readings were taken on the fifth day after the humidity had dropped to around 50 percent. Trays of silica gel were then placed in the chamber. The tension level after desiccation was read the sixth day. At this point the frames were removed from the chamber and left overnight to return to standard condition. A final tension reading was taken and then the frames were prepared for the next cycle of samples.

## THE PROCEDURE

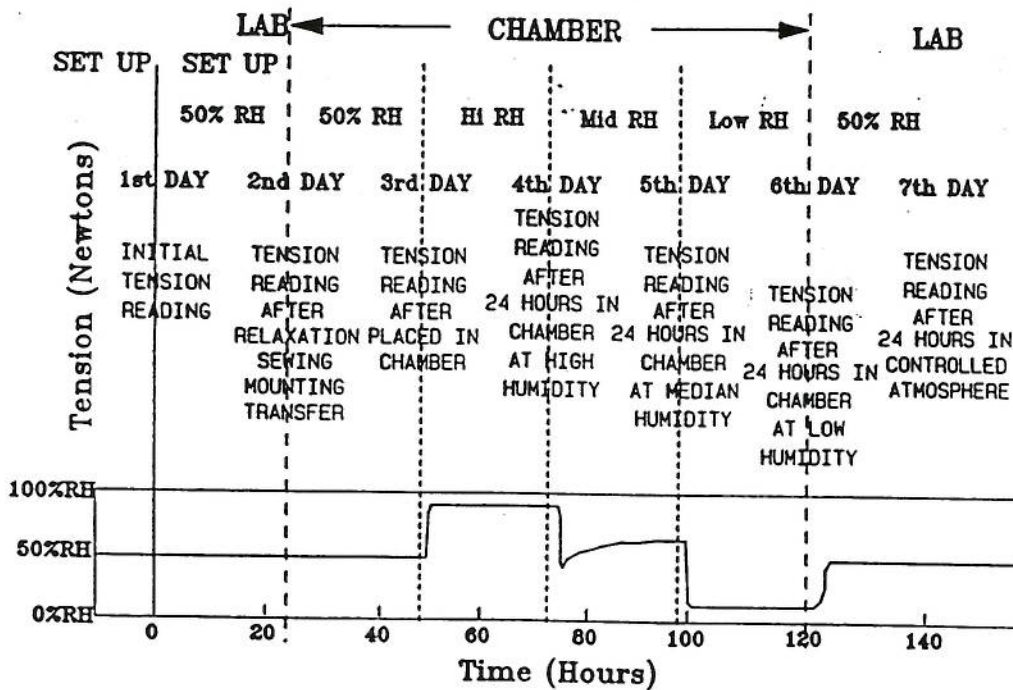
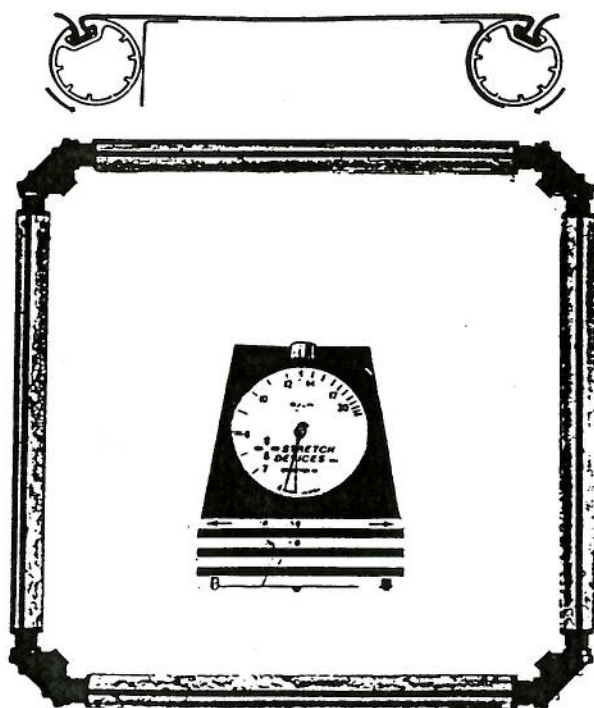


figure 2.

A plexiglass chamber, 48 by 37 by 24 inches, was built to house the five strainers. Metal Newman Roller Frames with variable tensioning devices were chosen as strainers to stretch the sample fabrics so that an even tension could be achieved.

Of these five strainers, one of the M-3 roller frames, one of the M-1X roller frames, and the wooden stretcher were each outfitted with the same fabric sample substrate. The purpose of this section is to observe tension changes due to fluctuations of relative humidity and how those changes vary from strainer to strainer.



M-1X Metal Roller Frame and  
Stretch Devices Tension Meter

figure 3.

The remaining M-3 roller frame and the remaining M-1X roller frame were outfitted with the same fabric sample substrate as the three strainers mentioned above. A sample artifact of Test Fabrics Incorporated Cotton Print Fabric was mounted and stitched around its perimeter to one of the strainers. The remaining strainer was stitched with a combination of zig zag stitching and an all over grid patterning. The purpose of this section was to observe the effects of stitching and the effects of stitched assemblies on the tension of the substrate during fluctuations of relative humidity.

Six crosses marked in soft graphite pencil were drawn to indicate where the biaxial tension readings were taken. To assess the dimensional changes, warp and weft thread counts and micrometer readings were taken at these sites. These micrometer readings were compared to those of the non-pretreated fabric swatches. Two Newman ST Meters were used to measure bi-directional fabric tension in newtons.

A twelve inch square M-1 Roller Frame was out-fitted each week with the substrate fabric being observed in the chambers. This frame was placed in the standard atmosphere of the textile laboratory. Biaxial tension readings of this frame were taken daily concurrently with the reading of the frames inside the chamber. Warp and weft thread counts with the Lowinson's Micrometer and micrometer readings of the fabric thickness were also measured at the same intervals as the samples inside the chamber.

Eight test fabrics were set up on M-1 Roller Frames to observe their relaxation behavior over a longer period of time at a constant temperature and humidity. This test was maintained in the controlled environment of the textile laboratory at the Conservation Analytical Laboratory. Biaxial tension readings were taken weekly for six weeks. Warp and Weft thread counts were taken before and after the six week period.

## The Discussion

It was predicted that the synthetic fabrics would retain tension more evenly than the protein or the cellulosic fabrics. The amount of tension lost among the test samples was determined within each fiber group. Then this loss was compared among fiber groups in order to determine the safer materials for use in conservation constrained mounting assemblies.

This study found that the weft samples generally behaved similarly, or only slightly inferior to their respective warp sample counterparts. In the interest of simplicity for this discussion, only the warp samples have been compared.

The performances of the light-weight control samples are compared in figure #4. After initial tensioning and a retensioning, the tension at the first point on the graph was determined. With the exception of the Cotton Batiste, all the light-weight samples exhibited a further decline in tension over the period of the two following readings. After the third reading, all the samples, in the stable environment, appear to maintain a fairly constant tension.

The reason for the apparent evenness in the tension of the Cotton Batiste, as well as the Spun Viscose and Wool Challis in the medium-weight samples, is due to the necessity of over-tensioning in the weft direction. These samples needed to be over-tensioned in order that an initial tension level could be obtained that would give measurable readings over the course of the humidity cycle within the chamber.

### M-1 CONTROL LIGHT-WEIGHT WARP CONTROL ENVIRONMENT 50%RH

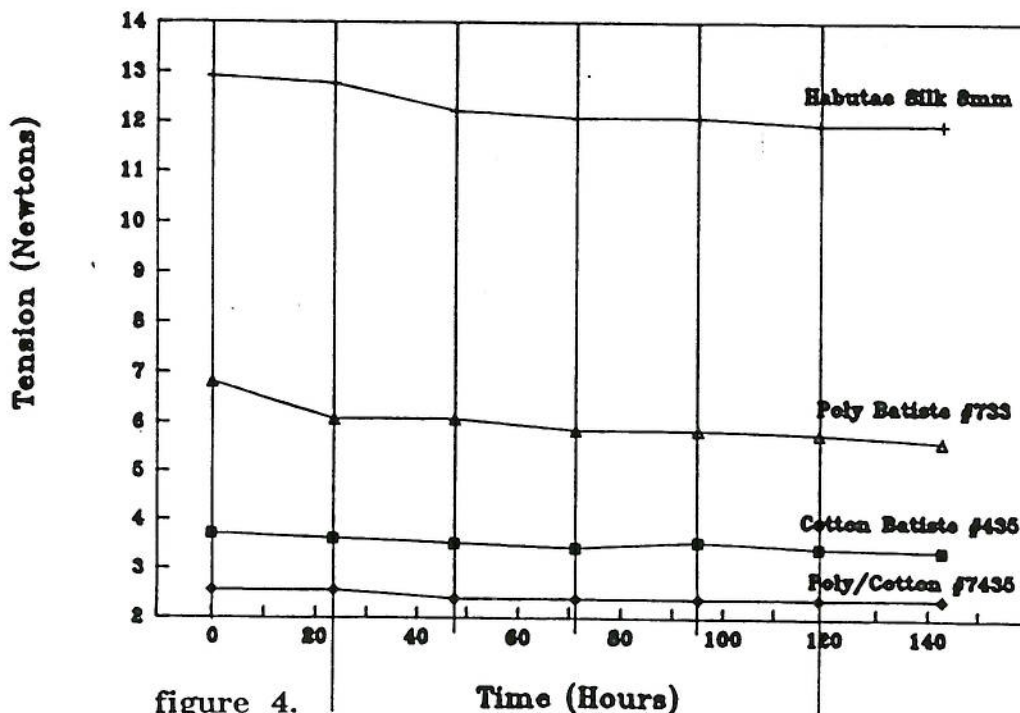


figure 4.

POLYESTER BATISTE #733 WARP

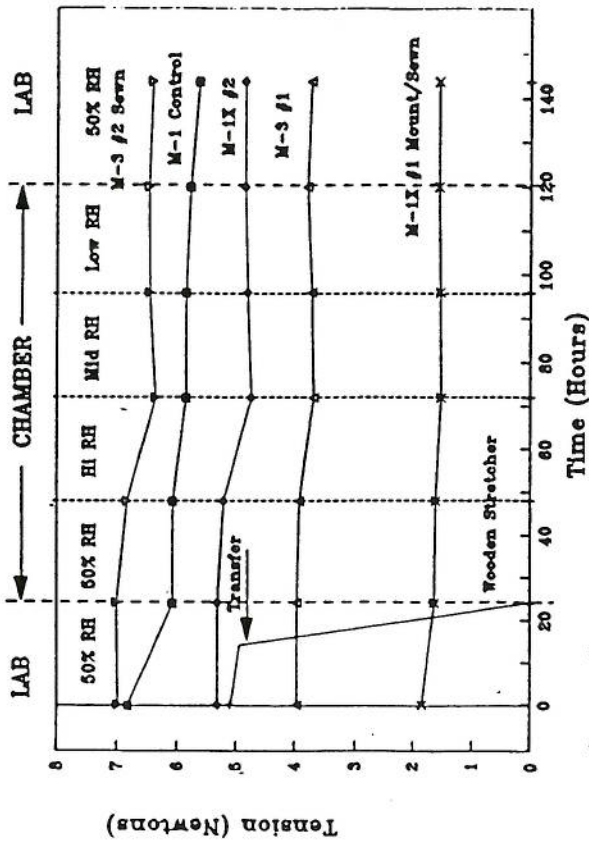


figure 5.

COTTON BATISTE #435 WARP

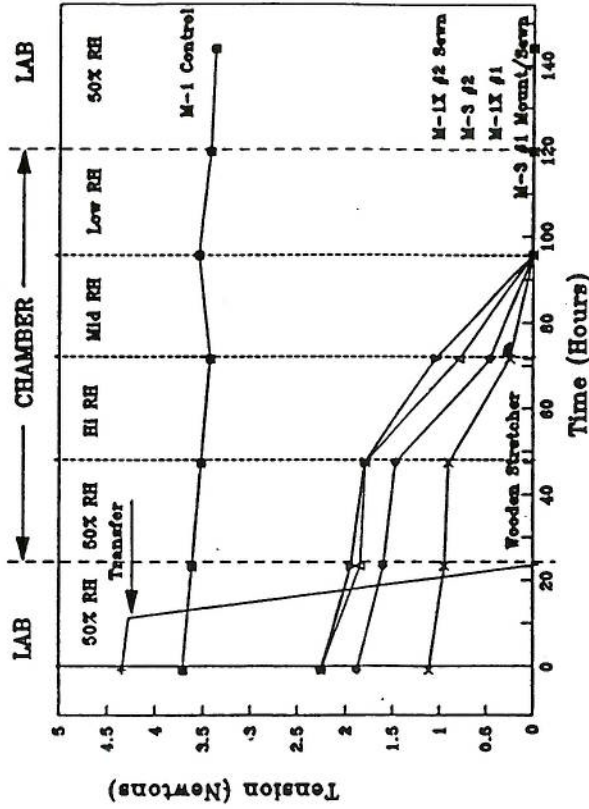


figure 6.

POLYESTER/COTTON #7435 WARP

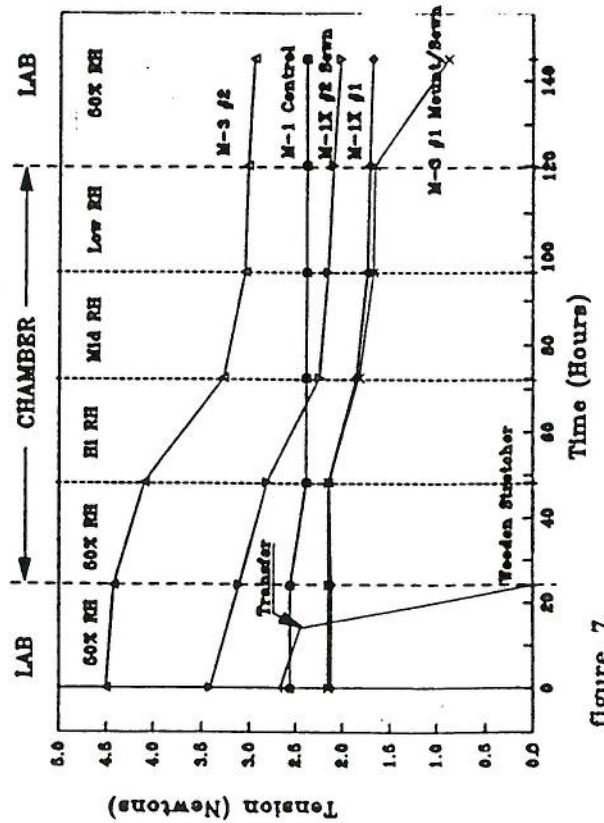


figure 7.

HABUTAE SILK 8MM #609 WARP

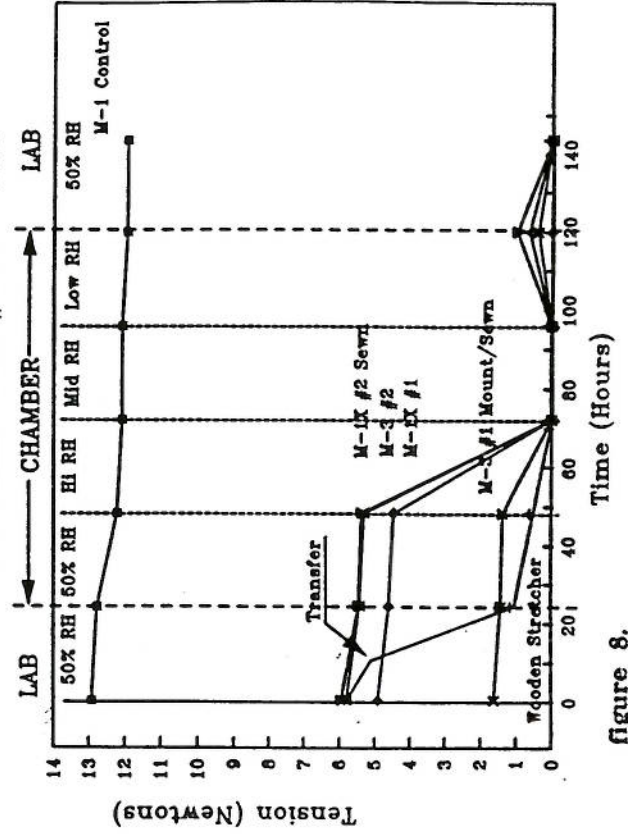


figure 8.

The tension of the Polyester Batiste in figure #5 appears to stabilize after the first three readings. This sample is virtually unaffected by the fluctuations of the humidity cycle, the changes in tension, most likely, due to cold flow.

Comparing the control samples of figures #5-#8, the degree of tension loss is roughly similar. Both the Cotton Batiste and the Habutae Silk, figures #6 and #8 are drastically affected by the fluctuating humidity cycle. The Polyester/Cotton blend in figure #7 displays a loss of tension but not nearly so severely as the unblended natural fiber fabrics. It is interesting to note the slight regain of tension upon desiccation of figure #8, the natural protein fiber. This is also in evident in the medium-weight protein fiber, figure #13, Wool Challis.

In the constant environment the control samples of the medium-weight category, the category from which support mounting fabrics are generally chosen, did not vary greatly from the behavior of the light-weight samples. With the unexpected exception of the Spun Viscose sample, the decline in tension does not appear to even-out. In comparison within the medium-weight samples, the linen displays a loss of tension greater than any of the other three samples. The polyester behaves little better than the wool under constraint within the controlled environment. One expects the loss of tension due to the elasticity of the wool. The loss of tension in the polyester is most likely due to slippage of fibers within the staple yarns.

## M-1 CONTROL MEDIUM-WEIGHT WARP

CONTROL ENVIRONMENT 50%RH

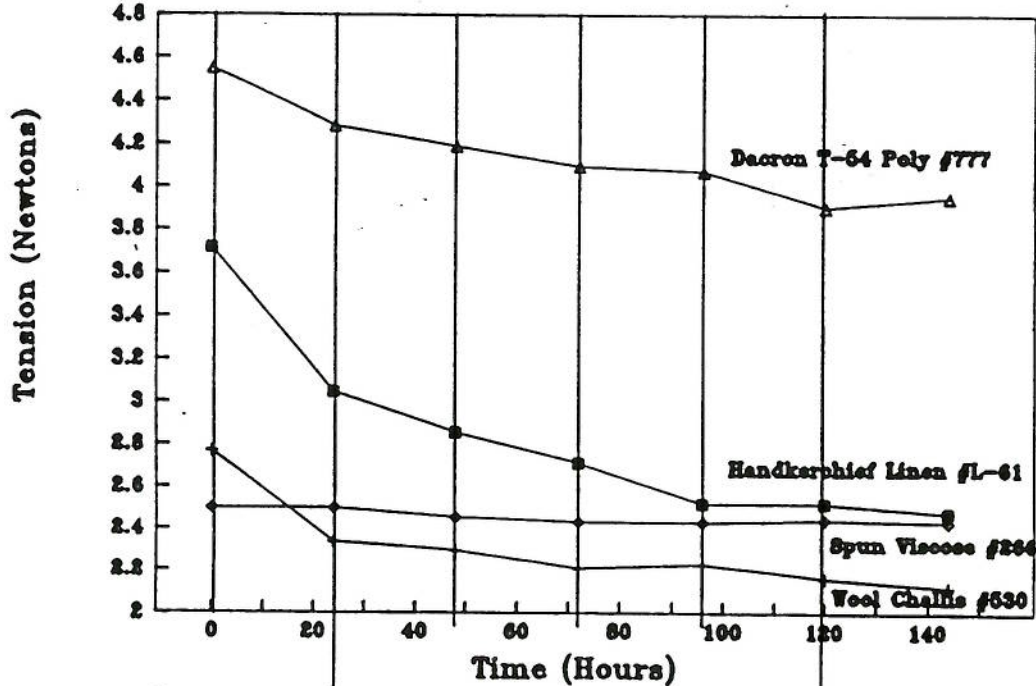


figure 9.



### HANDKERCHIEF LINEN #L-61 WARP

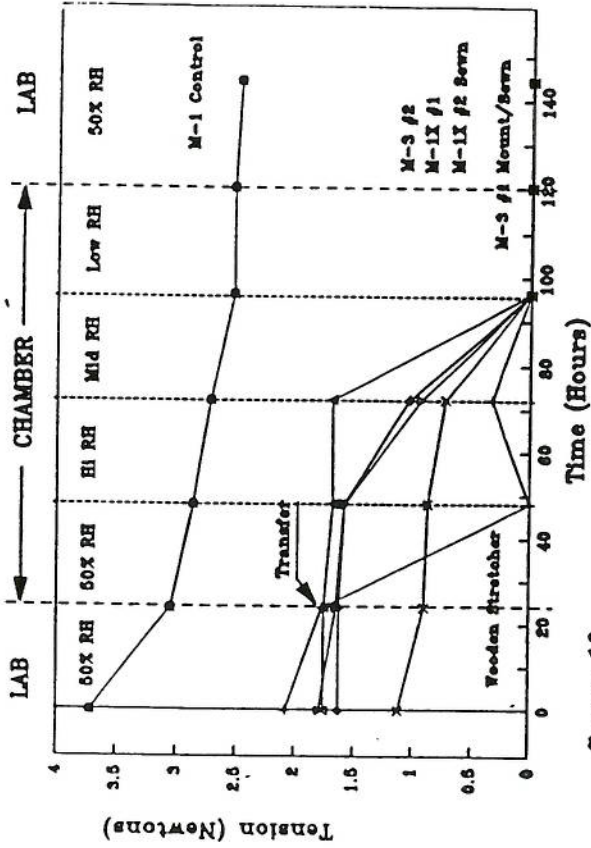


figure 10.

### DACRON T-54 POLYESTER #777 WARP

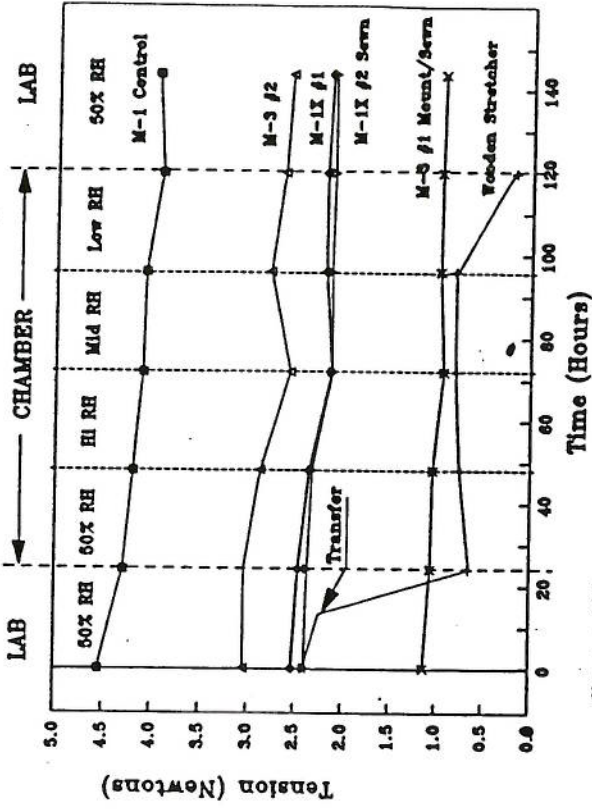


figure 11.

### SPUN VISCOSE CHALLIS #266 WARP

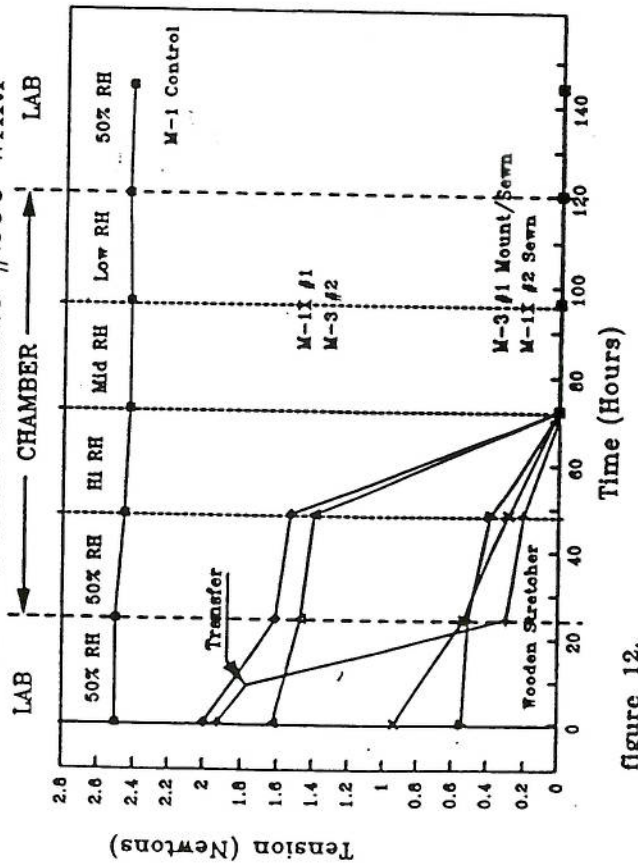


figure 12.

### WOOL CHALLIS #530 WARP

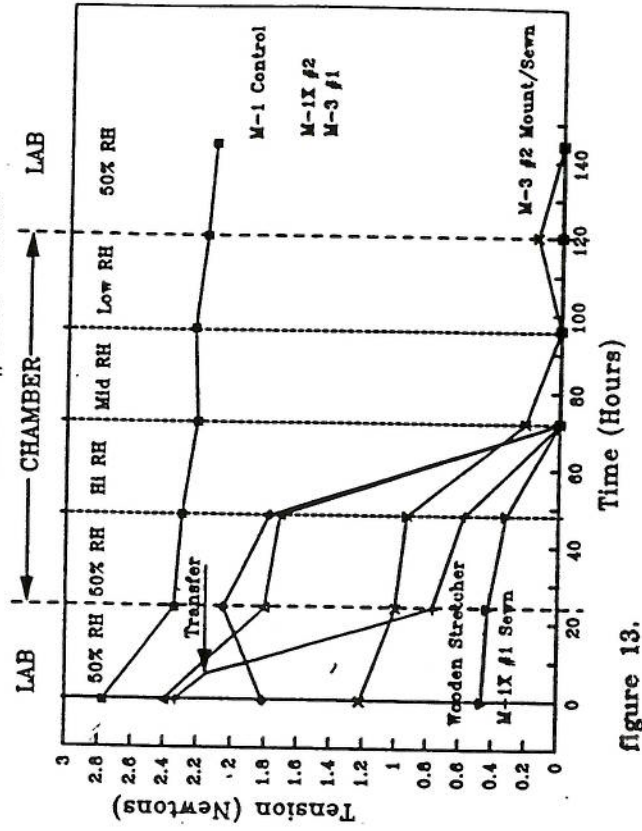


figure 13.

When subjected to the humidity cycle, the behavior of the samples of the medium-weight category quite similar to the behavior of the light-weight samples. Again, after an initial loss of tension over the course of the first three readings, the Dacron Polyester, T-54 (figure #11), began to even-out. Both the Spun Viscose, figure #12 and the Wool Challis, figure #13, display a drastic loss of tension due to high humidity. As noted previously, the protein fiber shows a slight regain in tension upon drying. This appears to also be the case in the Dacron sample. The Handkerchief Linen, figure #10, maintained its initial tension setting in a manner similar to the Dacron Polyester, figure #11, during the first three tension readings. With the introduction of high humidity, the Linen evidenced a slight rise in tension. This regain of tension in the linen was lost and surpassed upon a return to a mid-range humidity.

The presence of stitching, and of a stitched artifact in assembly with a constrained mounting fabric did not drastically alter the way the substrate behaved while under tension. Depending upon the nature of the substrate, the stitching thread, and the "sample artifact" there were very different reactions of the three components after removal from tension.

In figures #5-#8 and figures #10-#13 the affect of transferring a substrate under tension on one frame to a wooden stretcher was examined. This transfer was carried out by attaching the fabric under tension to the wooden stretcher with push pins. The tension on the first frame was carefully removed and the loose fabric turned to the back of the wooden stretcher and attached with Monel staples. The push pins were then removed. In every instance there was a marked loss of tension immediately after transfer.

### Conclusion

My main conclusions are that at constant relative humidity, the tension of the substrates remain fairly constant under constraint regardless of the type of fabric.

Natural and man-made fabrics loose their tension drastically compared to the synthetics fabrics when effected by high relative humidities.

Even with a loss of tension due to humidity, the construction of the substrates is only slightly effected while under constraint. The problem occurs when the substrate is untensioned.

Lastly, the concept of transferring mounted artifacts from strainer to strainer, while maintaining a constant tension is questionable.

The observable and measurable properties of such small test sampling can only be an indication of the results of a larger sampling. The measuring devices used for this test can only make gross evaluations. A suggestion for further study would be to redo the study with more precise measurement equipment. A more precise observation of the exact Relative Humidity where tension begins to evidence decline would be of great interest.

A second suggestion for future study would be to test a greater number of samples and a wider range of fabrics over longer periods of time. The affects of multiple cycling on the fabric substrates should also be examined. It was not within the time constraints of this study to observe the effects of temperature. Future studies should examine both the effects temperature changes at a constant relative humidity and the effects of varying both temperature and the relative humidity simultaneously.

The Mecklenburg method of sample observation allows for the study of relatively small uniaxial samples. Small textile samples of artifacts could be studied with this

method, although, in most cases, random sampling would not be possible. Because random sampling is impossible, an accurate measurement of an artifacts behavior can only be intimated. To overcome this limitation, artificially aged samples might be used instead.

A correlation between the results of these tests would be of great interest to the textile conservation field. In this way, textile conservators may have additional fabric model data by which to select the most suitable fabric type for constrained fabric mounting devices.

### Notes

1. F. C. Brenner and C. S. Chen, "Mechanical Behavior of Fabrics. Part III: Effect of Density of Construction on Recovery from Deformation," in the Textile Research Journal 35, No. 7 (July 1965): 587-591.
2. W. G. Klein, "Stress-Strain Response of Fabrics Under Two-Dimensional Loading. Part I: The FRL Biaxial Tester," in the Textile Research Journal 29, No. 10 (October 1959): 816-821.
3. F. T. Peirce, "The Geometry of Cloth Structure," in the Journal of the Textile Institute 28 (1937): T45-96.
4. \_\_\_\_\_, "Geometrical Principles Applicable to Design of Functional Fabrics," in the Textile Research Journal 17 (1947): 123-147.
5. W. D. Freeston, Jr., M. M. Platt, and M. M. Schoppee, "Mechanics of Elastic Performance of Textile Materials. Part XVIII: Stress-Strain Response of Fabrics Under Two-Dimensional Loading," in the Textile Research Journal 37, No. 11 (November 1967): 948-974.
6. M. Mecklenburg, Some Aspects of the Mechanical Behavior of Fabric Supported Paintings, Report to the Smithsonian Institution (1982).
7. G. A. Hedley, "Relative Humidity and the Stress-Strain Response of Canvas Paintings: Uniaxial Measurements of Naturally Aged Samples," in "Studies in Conservation," The Journal of the International Institute for Conservation of Historic and Artistic Works (IIC), 33 (1988): 133-148.
8. Gustav A. Berger and William H. Russell, "Practical Applications of Stress Tests," in Preprints of Papers Presented at the sixteenth Annual Meeting, New Orleans to The American Institute for the Conservation of Historic and Artistic Works(AIC), (June 1988).
9. Gustav A. Berger, William H. Russell, "Investigations into reactions of Plastic Materials to Environmental Changes. Par I: The Mechanics of the Decay of Paint Films," in "Studies in Conservation," The Journal of the International Institute for Conservation of Historic and Artistic Works (IIC) 31, No. 2 (May 1986): 49-64.
10. Ibid.



# HARPERS FERRY REGIONAL TEXTILE GROUP

Textiles and Costumes on Parade: Exhibition Successes and Disasters

November 8-9, 1990

National Museum of American History