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The creating of pattern in woven fabrics by placing design on the warps and/or wefts before they are woven is ancient. Primary examples of these textiles are ikat, which is a resist dyeing technique, and chiné, in which design is painted or in some way printed on the tensioned warp yarns.

This study investigated the use of the screen process method to print the design on tensioned warps in handwoven fabrics. Three experimental warps (cotton, linen, and rayon), were printed and woven. The interaction of the fiber content of the warp, set, weave, and the color of warp, weft, and print were observed. Assessments were made to determine combinations which would achieve a clear and forceful design statement.

Results of experiments suggested the importance of selecting yarn for warp which is inelastic, relatively fine and which will allow

thorough dye penetration. Best dye penetration was achieved in rayon, and best results were achieved when the warp was threaded and woven in a pattern which exposed a high proportion of the warp yarn. In addition, the printed design was strongest after weaving when both warp and weft threads were a neutral color of light value.

Using the screen process method to print design on tensioned warps gave advantages of promoting thorough dye penetration, allowed speed and ease of design replication, and gave the possibility of achieving good precision in edges of design motif.

Screen Printing on Tensioned Warps in Handwoven Fabrics

by

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SCREEN PRINTING ON TENSIONED WARPS IN HANDWOVEN FABRICS

I. INTRODUCTION

An interest in non-structural methods of achieving design in handwoven fabrics, combined with knowledge in the areas of hand-weaving and screen printing prompted this investigation. The effect of the use of the screen process method to print design on tensioned warps in handwoven fabric was studied.

Statement of Problem

An examination of the techniques used and a description of the fabric and characteristic design found in ikat and chiné formed a starting point for this study. A part of the charm and beauty of fabrics woven with tie-dyed (ikat) or painted warps (chiné) is a certain indistinct quality of the edges of the designs. This is caused by, first, the method of dye application used to achieve design on the warps, and second, the distortion and uneven blending caused by lengthwise movement and rotation of warp yarns due to variations in tension.

This blurring of design is a distinguishing characteristic of warp patterned fabrics and doubtless would exist to some degree no matter what technique was used in placing design on the warp. Nevertheless, skilled craftsmen still strive for precision of line and exactitude of design and try to overcome limitations of the technique to obtain the stylistic effect desired (Adams, 1971, p.37). The delicacy of design in many of their products attests to their success. In designing for chiné, it is generally accepted that designs composed entirely or partly of fine lines or delicate areas should be avoided. Any attempt at adding textural quality or shading is likewise discouraged.

Statement of Need

Attempts made by craftsmen to use the screen method to achieve design on tensioned warps seem to be sporadic, and the results of experimentation are not generally available. Hopefully, a study of this type will bring together some of the known aspects of printing on warps and provide some experimental groundwork for the home craftsman who has a background in the use of the screen process method and in weaving, and who wishes to create design in handwoven fabrics by screen printing on the warps.

Purpose of the Investigation

Today, artists and craftsmen are searching for new ways to express themselves in their chosen field by making use of technological advances in materials and techniques. They are combining these materials and techniques with, adapting them to, and making improvements on tried methods and materials.

It was felt by the author that a contribution in the area of designing for handwoven textiles may be made by an investigation of the use of the screen process method to print design on tensioned warps. Designs produced by screen printing have distinctive qualities, and a unique and contemporary direction may be given to the concept of creating design on warps, as it exists historically.

The primary objective, then, of this study was to investigate the effect of the use of screen process printing by the home craftsman on the characteristic design produced in warp printed, handwoven fabric. In this investigation, the interaction of the fiber content of the warp, the set, the treadling, and the color of warp, weft, and print were observed, with the objective of determining combinations which would achieve a clear and forceful design statement. Additional objectives were as follows: to attempt to determine what factors were most critical in achieving a successful warp print, and to identify any unique contributions the use of the screen process method might make in creating handwoven warp printed fabric.

Procedure Followed

A scheme for weaving three experimental warps was devised. Three cellulosic yarns, cotton, rayon and linen were used. In each of the warps, a selected group of factors, including the type and color of dye, the method of printing, and the threading pattern were held constant. Another group, which included the colors of the warp and weft yarns, the set, and the order of treadling, varied in sequence in each of the three warps. The results were dependent on the interaction of the first two groups of factors. These dependent variables were stated as: penetration of dye and strength of design motif.

Prior to the experiments, the following predictions of the results achieved in the three experimental warps were made:

1. The 100% viscose rayon warp will allow greater penetration of dye paste and thus strength of design than either the 100% cotton or the 100% linen warps.
2. The final printed design will be most forceful if the warp is closely threaded so as to achieve a warp-face fabric.
3. There will be differences in forcefulness of printed design in warp printed handwoven fabric when variations in treadling are used, the 3/1 twill treadling giving the greatest strength of design and plain weave the least.
4. There will be differences in strength of printed design in warp printed hand woven fabric dependent on the interactions of colors of dye, warp, and weft.

Three additional projects were woven subsequent to the printing, weaving, and assessment of the experimental warps. The intention was to apply, to a limited extent, the knowledge and skills gained during the experimental work. Three additional stencil designs were produced. A different warp yarn was used in each project. The result was three warp printed pieces differing greatly in concept and execution. A description of these additional projects is found in Appendix D.

Limitations

As stated in the objectives, part of the purpose of this study was to provide some experimentation with variables involved when a home craftsman uses the screen process method to print on tensioned warps. Because these experiments were done in the home, an effort was made to choose equipment, materials, and techniques that were most amenable to use in this setting. The requirements of the situation were manifested in making choices which would take advantage of facilities already available in the home. Equipment, materials and techniques were chosen which did not necessitate any great expense for special equipment or increased or specialized space in which to work. It was felt that there is a wide enough variety of materials and equipment available so that the objectives of the study were not compromised. Keeping these factors in mind, the following equipment, materials and methods were chosen:

1. Stencil method for screen process: Cut lacquer film was chosen because the method is proven, uncomplicated to use, relatively inexpensive, uses materials easily available, and

will produce a design of the type desired (simple, hard-edge, massed).

2. Dye, paint or ink: Inkodye, a product of Screen Process Supplies Mfg. Co., of Oakland, California, was chosen because it is available locally for purchase, is in a form that is ready for use, and is available in a wide range of colors which can be mixed to produce additional colors. The dye is claimed to have good penetration, will withstand strong sunlight for prolonged periods without fading, and does not stiffen fabric. Important to the home craftsman is the ease of clean-up, which is done with water.
3. Printing method: Of the three methods of printing warps suggested in the review of literature, the method chosen for use was that of printing on a board inserted under the tensioned warp between the reed and breast beam. A certain amount of distortion in the printed design can be expected because of tension variations which occur during weaving. This printing method was expected to keep that distortion to a minimum.

II. REVIEW OF LITERATURE

Introduction

The idea of achieving pattern in woven fabrics by placing design on the warps and/or wefts before they are woven is ancient. The idea persisted and with the advent of the machine age, additional methods were developed based on the original concept. Generally, warp dyed, painted or printed fabric can be recognized by a certain hazy and slightly distorted quality in the design. This is caused by the method of placing design on the warps, the natural displacement of the warp yarns when weaving subsequently takes place, and the weaving in of a solid color weft which obscures the warp design to the extent that the weft shows in the woven fabric. Today there seems to be a revival of interest in the method by handcraftsmen. Modern methods and materials may be used to print, paint or dye the design on to the warp, and often the design achieved is combined with certain other weaving techniques, such as the gauze weave, which give a very different character to fabrics woven using that traditional weaving technique.

Textiles Decorated With Design Produced by Dyeing, Painting, or Printing on Warps

Ikat

Ikat is a partial or resist dyeing technique used to produce design on yarns before weaving. A material impermeable to the dye, usually some form of waxed bast, is wound around those areas to be reserved from the dye. The process may involve several applications of color, and each time a different part of the thread is "resisted." The warp may be patterned by this method, or the weft, or sometimes both are combined to form a pattern. These types are called, respectively, warp ikat, weft ikat, and double ikat, and the type used varies in different countries.

The work describing this process is of Malayan origin. It describes the characteristic part of the work discussed in the previous paragraph, "to bind, knot, or wind around" (Leix, 1940, p. 1308; Buhler, 1942, p. 1586). It is not possible to trace the origin of the technique to a single country. It probably developed independently in several places (Buhler, 1942, p. 1606). This tie and dye technique is known by various names depending upon the country of origin, but "ikat" is the term in most common usage. It is carried on today in many areas, but has developed most fully in India, Indonesia, Africa, Japan, and in some parts of South and Central America. In some areas where the craft had all but died out, a revival of interest has taken place, due partly to promotional efforts by certain groups (Arness, 1963, p. 6; Adams, 1971, p. 9).

Ikat dyed fabrics can be recognized by the "soft" effect of the design achieved, caused partly because the dye may penetrate slightly below the edge of the resist, and colors have a tendency to bleed and merge together. Since it is impossible in any kind of fabric in which the design is produced on the warp yarns before weaving, to prevent some shift in position when the yarns are being stretched on a loom, the displacement will cause a blurring of the design. This is in addition to that caused by uneven dye penetration. In ikat, because the yarn is tied in small clusters or sets, the outline of the design is affected. All lines except vertical stripes will have a "stepped" or "jagged" effect. Small design forms and designs having curved outlines would seem to suffer the most disfigurement. It would seem to follow, then, that vertical stripes or large right-angled or stepped designs would be best suited to this technique (Adams, 1971, p. 37).

In ikat, as well as in warp painted and printed fabrics, the finished appearance of the design is dependent to a great extent on the weave chosen, and is clearest when the system of dyed pattern yarns is clearly visible. This would be most evident in a pure rep weave, to a lesser extent in satin or twill, and least of all in a plain weave (Buhler, 1942, p. 1586). The type of weave chosen in ikat is dependent largely on the country in which the weaving is done and also whether the fabric is a warp, weft or double ikat. The fiber content of the yarn, usually cotton or silk, and the type of dye, design motif, and the colors used vary from country to country.

There seems to be a revival of interest in the use of the ikat technique to create design in handwoven fabrics among contemporary craftsmen. For example, innovative methods of tying the warps for resist purposes may be used (Rushfelt, 1968, p. 15). Sometimes a bleach solution may be applied to resisted, dyed yarns and the color is discharged from yarn not resisted. Some artists use the traditional ikat technique primarily to get vague color variation along the length of the warp to be used, as an abstract color background for the incorporation of other weaving techniques, such as open warp effects, or they work tapestry images into the ikated yarns (Place, 1972, p. 45).

Chiné

The term, chiné, is generally used to describe fabric in which the design has been achieved by painting or printing a design on the warp before weaving. The French word, chiné, is from the Italian for this process (Reath, 1927, p. 22), and means "speckled," or variegated. Other names given to the fabrics produced with this technique are warp print, tapestry cretonne, shadow tapestry and shadow prints (Heartz, 1958, p. 8). Though names and techniques have varied around the world, the patterns and designs have remained quite simple, because the technique does not adapt with success to intricate and elaborate detail. The design in the finished fabric is somewhat blurred and indistinct, and colors are subdued.

This technique is very ancient, believed to have come from India. Some of the most elaborate painted designs are found in primitive South American textiles (Heartz, 1958, p. 6). The technique is still used in native fabrics woven in West Africa, Guatemala, the Pacific Islands and Japan (Tidball, 1953, p. 1). This method of warp decoration has not had as wide acceptance as the ikat method with native peoples, possibly because of somewhat uncertain results with color application and achieving permanence in the colors used. A color setting medium would be difficult to apply with the warp set on the loom (Heartz, 1958, p. 4). Some experimentation was done at Lyons in the 18th century and some of the novelty fabrics produced "resemble delicate, faded paintings in water colours!" (Varron, 1938, p. 195).

In some cases, the painting was done on warp yarns to be made into pile fabric. One example of this technique is the small velvet pieces produced by Gaspard Gregoire (1751-1846) at Lyons, and called "velours Gregoire" (Varron, 1938, p. 195). Chiné velvets were also made in the 18th century and possibly earlier in Central Asia (Reath, 1927, p. 26). Designs painted or printed on the warp of chiné velvet would need to be a great deal longer than they appear in the finished piece to allow for take-up in the weaving (Reath, 1927, p. 42).

The causes of blurring of the design in chiné warps are similar to those previously described for ikat warps. The use of a warp-face fabric woven in plain weave (rep) is often suggested to make the design as strong as possible. Warp yarns are chosen for their fineness, body, softness, non-elasticity, and absorbency. Every warp yarn needs to be at the same tension. If a plain weave is chosen, the use of a metallic yarn for the weft will lessen the "dilution" of the design (Marston, 1970, p. 37).

The design may be painted on to the tensioned warp with a stiff brush, working the paint or dye into and all around each warp yarn, or it can be stencilled or block printed on to the warps. Whatever method is used, getting a good coating of paint on to or deep penetration of dye into the warps is most important (Heartz, 1958, p. 12).

Designs suggested in order to reduce distortion in warp painted fabrics are described as being simple and massed in which fine lines and delicate areas are avoided. The main lines of the design should be in the warpwise direction rather than the weftwise direction. Therefore, in planning a design, consideration needs to be given to the limitations caused by the nature of the technique, as well as the use to which the project will be put.

Three methods of painting or printing on the warp are suggested for the handweaver. The first method consists of positioning a board under the loosened warp, between the reed and the breast beam and resting on the shuttle race and the breast beam. The warp may need to be "extended" in order to be spread over the full length of the board by tying it to a heading stick laced to the apron or by using longer cords on the apron bar (Heartz, 1958, p. 14). The warp is then placed under the same tension as it will be when weaving takes place, and may be combed to arrange the yarns in order and parallel to one another. The printing board could be covered with layers of paper, and the top paper discarded after each time the warp is painted or printed. Also, a sketch may be placed on the board under the warp. The warp is painted and allowed to partially dry. The board is removed and the warp is allowed to dry thoroughly. If heat is required to set the paint or dye, ironing could be done before the printing board is removed from the loom. Care must be taken when inserting and removing the printing board so as not to disturb unduly the arrangement and tension of the warp yarns (Heartz, 1958, p. 16). After the warp is again tensioned, it is woven and rolled forward onto the cloth beam. The whole procedure may then be repeated (Tidball, 1953, p. 2-3). Because of the irregular takeup of the warp in handweaving, only one unit of the pattern should be painted or printed at one time (Heartz, 1958, p. 18).

A second method is to pull a length of warp which has been evenly tensioned onto a strong flat stick, forward through the reed and out in front of the loom over a printing board. It must be tied to a stationary object so the warp is very tight. The design is then painted on to the warp yarns. The painted design is allowed to dry, the warp is wound back on to the loom, and the stick is attached to the cloth beam rod. Then the warp is woven (Black, 1957, p. 84).

A third method especially useful if many design repeats are planned, involves installing a semi-permanent painting board or table in back of the loom. The printing surface would need to be level with the top of the back beam. Provision would have to be made to keep the warp ends in proper order and position. Extra sets of lease sticks or even an extra reed could be used. The advantage of this method would be speed, in that weaving could take place while another design is drying at the back of the loom (Heartz, 1958, p. 20).

In any of these methods, variations may be achieved by using different colors of yarn for the warp or using color stripes in the weft (Tidball, 1953, p. 7).

Machine-Made Warp Printed Fabric

The most common commercially produced warp printed fabric is called "shadow-warp cretonne," one version of cretonne (Marks, 1959, p. 159). Roller presses are used to print a design on tensioned warps. The weft used is a solid color and is of a light hue.

The process involved in creating commercially produced warp prints is as follows: the warp yarns are wound on to the warp beams and before weaving commences, they are run through a roller printing press. Occasionally hand painting or block printing or stencilling may be used to print the design on the warps (Birrell, 1959, p. 424).

Screen Process Method Warp Printed Fabric

Some experimentation in warp printing with the screen process method is being done by English weavers and by art students in Sweden, using smooth cotton and linen warps, and dyes (Willcox, 1970, p. 34). The warp printing is done either off or on the loom, though it was found that design distortion was lessened when the screen print was made on the loom. The method used was that of printing on tensioned warps between the reed and breast beam as described earlier in the section on chiné.

Another method of printing used gives the advantage of printing all the length of the warp consecutively. In this method the warp is threaded on to the loom in the normal manner and tensioned. A few weft yarns are woven in at spaced intervals. The whole warp is then removed from the loom, along with the beams, harnesses and reed, is placed on a long table and then printed (Willcox, 1970, p. 35).

Screen Process Printing

Definition

One of the uses of the screen process method, a form of stencil printing, is to decorate fabric. The stencil is composed of an impervious material usually supported on a piece of fine silk or nylon which has been stretched tightly on to a frame. A squeegee is used to force paint or dye on to the fabric through the open (unblocked) meshes of the silk or nylon, thus printing a design.

Stencil Technique and Materials

The basic materials needed to produce a screen print include a printing frame with its stretched woven screen mesh upon which a stencil has been placed. A squeegee to force the paint or dye through the open area of the mesh, paint or dye, the object or material upon which to print, and a surface on which to place the material to be printed are also needed.

The screen is a simple wooden frame, larger in size than the design to be printed to allow space at both ends of the screen for the paint and squeegee during the printing operation, and space on both sides for the free movement of the squeegee.

Choice of the screen mesh for the frame will be determined by the fineness or coarseness of the design to be produced, the type of surface to be printed and the printing paste to be used. The finer the mesh, the finer the detail it will be possible to produce. Generally, textiles are printed with a relatively coarse mesh, unless photo stencils are used. Textiles printed with pigment colors require a coarser mesh than those printed with dyes (Schwalbach, 1970, p. 99).

The squeegee used to push the paint across the inside of the screen frame consists usually of a wooden frame in which a rubber blade is inserted. The blade giving best results when printing on textiles is rather thin and soft. Also, the blade edge should be basically square, but slightly rounded. These characteristics will help to force more dye paste or pigment into the textile (Schwalbach, 1970, p. 96, 98).

Textile materials are printed most successfully on a very smooth, lightly padded surface covered with a non-absorbent material.

There are numerous methods to create the stencil for the screen, all of which serve to block out some portions of the mesh and leave open those parts which will appear as the design. "Actually, an artist should use no more stencils or different kind of stencils than serve the clarity and strength of his final visual statement" (Schwalbach, 1970, p. 76).

The different kind of stencil methods available fall into four categories: block-out resist methods, wash-out resist methods, cut film stencils, and photographic methods. Factors to consider when choosing a stencil method include the skill of the printer, the amount of equipment he has available to him, the character of the design to be produced, the composition of the paint or dye which will be used, the surface upon which the print will be made and, the number of prints to be made with the stencil.

In the block-out resist stencil, the part of the design not to be printed is blocked out, usually by painting an impervious material, such as clear brushing lacquer, on the screen. This method is used where the design is rather simple or where the negative space in the design will be printed.

The paper stencil is the most simple and fastest example of the block-out resist stencil. A design cut from paper is attached to the screen and it serves to block the passage of the printing medium. This is satisfactory for use in short runs and those having a minimum of detail in the design. The paper stencil is not suitable for use with water-based paints and is generally not used in textile printing.

The washout resist method includes the tusche-glue stencil. It can be used to reproduce hand-brushed or shaded effects. An illustration of the tusche-glue stencil will serve to show the principles of the method. A design is applied to the screen by painting with liquid tusche or drawing with a lithographic crayon. A glue solution is scraped over the whole surface of the screen to plug the mesh. The tusche or crayon is subsequently removed with solvent which will not disturb the glue coating which thus remains as the resist.

The cut film stencil is a material consisting of a thin film of colored lacquer which is laminated to a heavy waxy paper. This paper acts as a base to hold the "islands" of the stencil design in place until the lacquer film is transferred to the screen mesh. The design outlines are cut into the surface of the lacquer, and portions of the design to be reproduced are peeled off the paper backing. The remaining stencil is adhered to the screen with a special adhering liquid, and, when dry, the backing paper is peeled off. The cut film stencil is used for designs having a precise, hard-edge feeling and sharp definition of color boundaries.

There are several varieties of stencil which use the photographic method. The principle behind this method is that a light sensitive substance or film is placed on the screen. Design is achieved by blocking out light on some parts of the film. Light hardens the areas exposed to the light which thus become the resist, and the unhardened (unexposed) areas wash out leaving the mesh open. The duplication of very intricate designs demand the use of this method. The use of rather specialized equipment is a necessity with many types of film using this method.

Dye, Paint or Ink

Types of printing paints, inks, and dyes available for screen process printing are numerous. The one important requirement is that the paint has a certain degree of thickness. Possibilities for the craftsman who wishes to print on fabric are water-based textile inks, pigments in oil emulsion, pigments in water emulsion, and dyes produced in paste form.

Generally, the choice made by the textile printer will depend on the fiber content of the fabric to be printed, the use to which the final product will be put, and the type of screen stencil used. Other factors for consideration include the degree of fastness, clarity, transparency, and the penetration desired. The printer also may want a paint or dye which promotes ease of clean-up.

Water-based textile inks are easy to use and a reasonable degree of washfastness is achieved by simple heat-setting with an iron. Generally, pigments in water and oil emulsion are easy to use, are colorfast and permanent, but do have a tendency to stiffen the fabric (Schwalbach, 1970, p. 101).

The use of dyes is increasing, particularly the use of soluble vat dyes (Roberts, 1958, p. 40) and fiber-reactive dyes (Proud, 1966, p. 74-5). Dyes have the advantage over pigments in emulsion in that the latter simply "coats" the fabric, whereas the molecules of a dye unite with those of the textile fabric on which it is printed. This has implications in regard to the hand of the fabric and the colorfastness and lightfastness achieved. Additional dyes useful to the screen printer are acid dyes, basic dyes, direct dyes, disperse dyes, and household dyes. They need only to be put into paste form (Schwalbach, 1970, p. 101).

Vat dyes are insoluble in water and are thus incapable of dyeing textiles. When treated with a chemical reducing agent, they are put in a form which can be absorbed by textile fibers. This form is known as the "leuco" form, which means colorless. When the fabric has been dyed, the color is developed upon exposure to air and this also changes the vat dye to an insoluble precipitate within the fiber. Vat dyes are effective on cellulosic fibers and their derivatives.

Dye preparations in paste form which can be printed with a water resistant stencil, are becoming more available. The soluble vat dyes are those which are amenable for use by a home craftsman. The leuco form of the soluble vat dye is stable and can be used without provision made for special fixation apparatus. Good results can be achieved by simply using an iron or by exposing the fabric to strong sunlight (Biegeleisen, 1971, p. 122). Furthermore, the dye pastes are sold ready to use out of the container. Their water-soluble properties make clean-up a simple matter.

Method of Printing

Textile screen printing with dye pastes has some special requirements. Dye pastes usually flow more readily than paints, and may indicate the use of a deeper screen frame and a larger well for the color (Roberts, 1958, p. 40). The consistency of the dye may also require experimentation in the amount of pressure exerted on the squeegee and the number of passes made. The nearer to the upright position the squeegee is held, the more rapid the movement or the lighter the pressure used, the less paste that will be applied.

Summary

Design can be achieved non-structurally in woven fabrics by dyeing, painting or printing the warps and/or wefts before they are woven. In ikat fabrics design is produced by tying certain parts of the warp and/or weft to form a resist. In chiné the warps are painted or a design is in some way printed on the warp before it is woven. In both types of decoration, the resulting design is characteristically somewhat blurred and indistinct. Ikat fabrics are produced by individual craftsmen, whereas methods of creating chiné can be adapted to commercial processes.

Screen printing is a form of stencil printing which can be used to print design on fabric. This method can be used to print a design on tensioned warps previous to weaving. Techniques used to produce chiné could be adapted for screen printing design on warps, as well as could techniques and materials used in screen printing on fabrics.

III. PROCEDURE

Equipment and Materials

First, the limits of the study and objectives which could be expected to be reasonably accomplished were determined. In determining the success of using the screen process method in printing on tensioned warps, the interaction of certain factors would be observed. These factors included the fiber content of the warp, the set, the weave and the interaction of the colors used in warp, weft and print. The relative effect of these factors on strength of design would be assessed. After determining the factors to be studied, choices could then be made in selection of equipment and materials and in technique to be used. Shown in Exhibit 1 (Appendix C) are the printing board, the screen with stencil, the squeegee, the dye, and the yarns used in the experimentation.

The choice of equipment, materials and technique in some cases was determined by the limitations imposed by the restrictions of doing the experimental work in the home. Included in this group were the type of stencil technique used on the screen, (cut lacquer film), the type of dye (Inkodye), and the method of printing. Printing on a board inserted under the warp in the front of the loom was the method chosen.

Printing Board

A printing board was designed and built. It was constructed of 1/4" plywood with bracing of fiberboard on its underside to prevent warping of the printing surface. The braces were placed so that the shuttle race and the breast beam would slip securely into position under the board when the printing board was placed on the loom. The presence of these "slots" and the tensioning of the warp yarns across the board prior to printing both acted to hold the printing board in place. Exhibit 2 (Appendix C) shows a side view of the printing board on the loom in position for printing. The printing board measures 51" x 23", thus making it possible to print along the full width of a 40" wide warp, if desired. The 23" width of the board was arbitrarily chosen to correspond to the longest dimension of the largest screen of manageable size for work of this type which the author owns. It is important that all parts of the screen rest securely on the surface of the printing board during printing. Thus the printing board could be used with this large screen or any smaller screen. The upper surface of the printing board was carefully sanded to make it as smooth as possible. It was then covered with a neutral-colored smooth piece of vinyl upholstery fabric which had a backing of a felted synthetic fabric. It was stretched over and stapled into the side edges of the board.

Screen

A 12XX mesh silk was stretched on the screen, a common grade of silk used by screen printers. Twelve refers to the number of mesh holes per linear inch, and the XX signifies its strength as double weight. Generally meshes between 10XX and 12XX are suggested for use in printing with dyes (Schwalbach, 1970, p. 99).

The printing frame measured 12" x 22" in exterior dimensions. Three 5" square design motifs were placed parallel to the longest dimension of the screen, as illustrated in Figure 1.

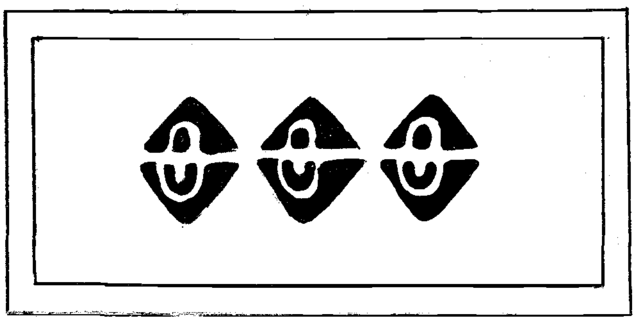


Figure 1. Placement of design motif on screen.

A larger well for dye (more taped area in the inner edges of the screen), as well as a frame which is not too shallow are desirable in printing with Inkodye since the dye mixture is more runny than that of pigment colors. This larger, deeper screen helps prevent dye splashing over the edges of the screen or running back into the stencil area while printing (Roberts, 1958, p. 40).

Yarn

Cellulosic yarns of cotton, viscose rayon and linen were selected as the fibers for each of the three warps. Inkodye, according to instructions of the manufacturer, dyes and develops best on these fibers. This would be expected since Inkodye is a solubilized vat dye.

In addition, a yarn in each of the three fibers was selected that would be readily available and likely to be desired for use as a warp yarn by handweavers. The yarns were also selected on the basis of their relative smoothness, absorptive qualities, and inasmuch as possible, their non-elasticity. Each yarn selected was a 2-ply yarn and was of a medium diameter or weight for that particular yarn fiber. Each of the three yarns could fulfill all the requirements and would not exactly replicate the other yarns in every respect. For example, a medium weight linen yarn would not be of the same diameter as a medium weight cotton or rayon yarn. Lily 3/2 Perle cotton, Craft Yarns Brite 100% rayon, and Craft Yarns 10 lea 2-ply 100% linen were the yarns selected.

Physical tests were made on the yarns to be used as warp. It was felt that the resulting data acquired might be useful in explaining experimental results. In a determination of yarn number, a measure of linear density, the rayon yarn was found to be the largest yarn, and the linen the finest yarn. The yarn number of the cotton was about midway between that of the rayon and linen. A measure of the visual diameter showed that the yarns varied in diameter from largest to smallest in the following order: rayon, cotton and linen. The results of a determination of twist per inch showed the linen and cotton yarns to have almost identical tpi, while the rayon showed only slightly fewer tpi than did the linen and cotton. Specific numerical evaluations can be found in Appendix B, Yarn Description.

The set of each of the three yarns was calculated to give a number of ends per inch which would produce a 50/50 or balanced weave for each particular yarn. Nine threads per inch was calculated to give a balanced weave in the rayon, as well as would 12 threads per inch in the 3/2 cotton and 15 threads per inch in the linen.

The three experimental warps were divided into three sections. The middle section was threaded to give a warp-face fabric. This required double the number of threads per inch needed for a balanced weave. For this warp-faced section, the rayon yarn was threaded at 18 threads per inch, the cotton yarn at 24 threads per inch and the linen at 30 threads per inch. The two outer sections were threaded to weave a 50/50 fabric. This is shown in a diagram of the warp in Figure 2. Sections which would weave a balanced web and a warp-face web were used because most directions for weaving chiné suggest the use of one or the other, and ikat fabrics are nearly always warp-face (Buhler, 1942, p. 1586).

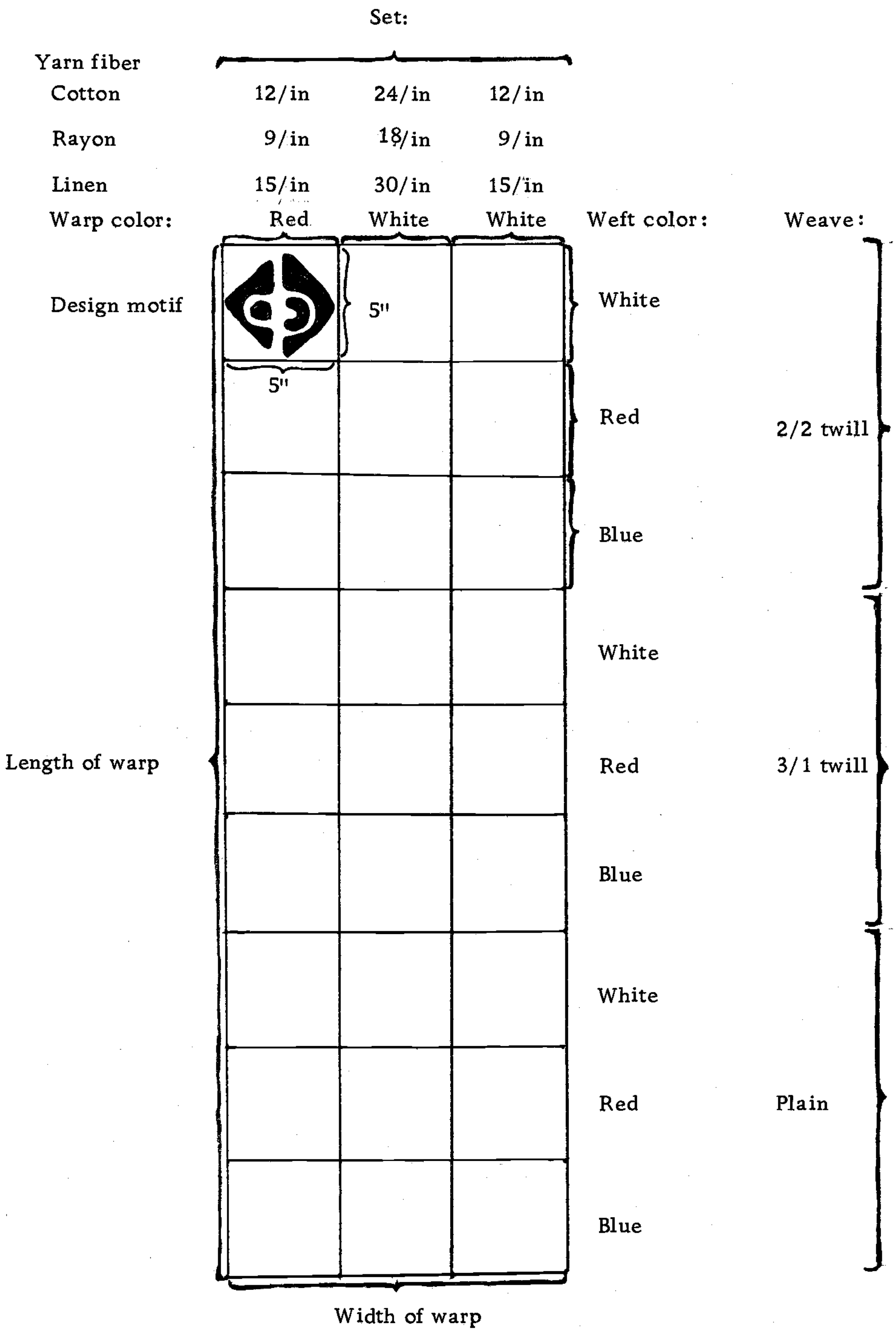


Figure 2. Representation of experimental warp.

Experimental Method

Color

Medium values and intensities of blue, red and white were chosen for yarn colors. Red and white were used in the warp, while red, white and in addition blue were used as weft yarns. As nearly as possible the shades and intensities were matched among the three different yarn fibers. This was necessary in order to be able to make valid comparisons among the three fibers, since the same dye mixture, that of a medium blue color, similar in shade and intensity to the blue yarn, was used on all three of the warps.

Two-thirds of the warp was of the white yarn, the outer part of the white section threaded, as previously described, to weave a 50/50 web and the center one-third section to weave a warp-face fabric. White was chosen as the primary background yarn color because it gave the possibility of obtaining the highest possible contrast to the printed blue design. The remaining outer one-third of the warp was red, threaded to weave a balanced web, and chosen to provide a color contrast between the white and the blue. Also, because dye paste colors are transparent, blue dye printed on red yarn would create a fourth color, dark violet. The color arrangement of warp yarns is shown in Figure 2.

The same red and white yarn used in the warp and an additional blue yarn were used for weft yarns. This color selection provided for yarn to match the background colors (red and white), yarn to match the screen print (blue), and yarn to serve as a contrast to the white warp yarn and the blue screen print (red on the white warp sections and white and blue on the red warp). The order in which the different colored wefts were woven is shown in Figure 2.

The dye, as previously stated, was of a medium blue color, mixed to match as closely as possible the blue yarn. The shade desired was achieved by mixing equal parts of Inkodye blue and Inkodye clear, a colorless extender used to lighten the value of a spectral hue without reducing the consistency of the dye.

Design Motif

A motif was designed to be used in each of the three experimental warps which was a simple massed shape, having no delicate areas. Within the motif, curved, horizontal and diagonal lines were incorporated. These are the design edge line directions which are least likely to remain precise when weaving the printed warps. A vertical line if printed parallel to the warp threads would not distort in weaving even if the tension varied. The design motif was drawn to be 5" x 5" in size. The design motif and its placement on the screen are shown in Figure 1.

Printing

The loom was threaded and beamed with the cotton yarn, the first of the three warps to be woven. A short heading was woven and the tension was released enough to allow the printing board to be inserted under the warp yarns in the front of the loom. The edge of the woven heading or fell was placed at the front edge of the printing board, so that the warp yarns would have the proper order and spacing as they came up over the front edge of the printing board, as illustrated in Exhibit 2 (Appendix C).

The warp was once again placed under tension which helped order and space the yarns as they came out of the reed. The warp was tensioned to approximate the tension to be applied to the yarns when they were woven. It was felt that there would be less design distortion if the tension for printing on the warp yarns was approximately the same as the tension for weaving.

Three prints were made each time the board was positioned for printing. The printing board was used three times during the weaving of each of the three warps. Thus, nine prints were made on each warp.

The screen was placed on the warp in position for the first of the three prints. Refer to Exhibit 3 (Appendix C). The edge of the printing screen furthest from the printer rested tightly against the reed, which helped hold it stationary. The red outer section of the warp was printed first. Eight single warpwise swipes of the squeegee were used in each of the printings. This was the number felt to give maximum dye penetration without excessive dye application which might cause the dye to spread under the stencil. The white outer section of the cotton warp, threaded at 12 threads per inch, was printed next, and finally the middle section threaded at 24 threads per inch. The printing of the center section is shown in Exhibit 4 (Appendix C).

The tension on the warp was released slightly from the back of the loom, and the printed warp yarns were allowed to become nearly dry. Then, a board covered with a terrycloth towel, large enough to be placed under the whole of the printed area was carefully slid under the printed warps and rested on the printing board. Next, according to manufacturer's directions, the design was ironed with a steam iron to obtain maximum development of dye color and concurrently, dye fixation in the yarns. The process of dye development is shown in Exhibit 5 (Appendix C), where only a portion of the design motifs has been developed. Limited color development may have taken place prior to ironing if the printed warps were in direct sunlight.

After dye development, the ironing board and printing board were carefully removed, taking care not to catch and pull and thus possibly change the tension on any of the printed warps.

Weaving

The warp was again tensioned, placing the fell in position to once again resume weaving. This necessitated pulling a part of the printed warp back through the reed and partially through the heddles. Exhibit 6 (Appendix C) shows the warp in readiness for weaving after printing and dye development. Exhibit 7 (Appendix C) shows the weaving of the printed warps. The warp was woven to a point where the placement of the second and subsequent set of three prints could be printed directly in sequence relative to the previous, and at that point partially woven, first print. This meant weaving only about two-thirds of the length of the first print, so the location of the fell was positioned immediately outside the edge of the screen nearest the printer.

The warp was threaded on a simple twill threading. This made it possible to treadle a plain weave, a 3/1 twill and a 2/2 twill with simple changes in treadle tie-up. These treadled patterns gave variety in the relative amounts of warp and weft showing in the woven piece, and include the treadlings usually suggested for weaving chiné (Buhler, 1942, p. 1586).

Each experimental warp was woven using the same sequence of weaves treadled, first the plain weave, then the 3/1 twill, and last the 2/2 twill. Within each of these patterns 5" or one design motif each was woven in first blue, then red, and then white weft yarn. This scheme for weaving is shown in Figure 2. The three experimental warps when completed then appear as a sort of patchwork design. Each of the 27, 5" squares is different from all the others. The completed linen warp is shown in Exhibit 8 (Appendix C).

Method of Assessment

At the beginning of the study, certain predictions of experimental results were made. These predictions were concerned with the effect of dye penetration, set, weave and the interaction of warp, weft and print color on strength of design motif. In order to be able to make precise discriminations and hopefully obtain definitive and meaningful rankings, the number of samples to be compared within each area assessed was limited. The rationale behind the selection of samples ranked within each area is given under the discussion of each of the assessments made.

The first assessments (dye penetration) were made on the printed unwoven warps. The remaining assessments were made after weaving had taken place. A system of numerical ranking was devised to be used in presenting the results of the comparisons made. In all cases the samples judged were ranked in order of descending numerical order. For example, a sample receiving a ranking of one received the highest rating of the group, and nine, for example, received the lowest. In addition to the numerical rankings, any unanticipated results were recorded during the time the rankings were being made.

Dye Penetration

The first evaluations were made on the unwoven warps after printing and before weaving had taken place. This was judged to be the time at which the most valid assessment of dye penetration could be made. This set of results was independent of the end woven product. The depth of dye penetration could best be judged after dye development by observing the relative evenness of color distribution in the printed yarns.

Since the same amount of dye was printed on all sections of the experimental warps, it was reasoned that the evaluation could be made at any place along the length of a warp. Results could be expected to be influenced by the fiber content of the yarn, the color of the warp yarn, and the set, both within each warp and between warps. As a result, assessment of comparative depth of dye penetration was made on the nine sections of the experimental warps shown in Figure 3.

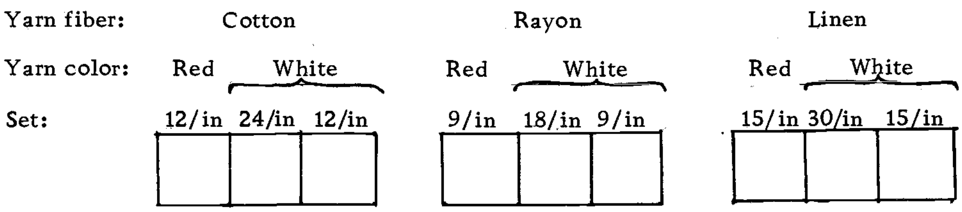


Figure 3. Sections of experimental warps used in assessing dye penetration.

Effect of Set

In assessing the effect of set on the strength of design motif, sections of each of the three warps which were woven in 3/1 twill were used. This treadling was chosen because it was felt that in these sections the weft would interfere less with an evaluation of the effect of set than it would in either plain weave or 2/2 twill. In addition, sections within the 3/1 twill were chosen for evaluation in which the weft color would interfere the least with a determination of the effect of set. As a result, those sections in which the weft color was the same as the warp color were used. The nine sections evaluated are shown marked by X in Figure 4.

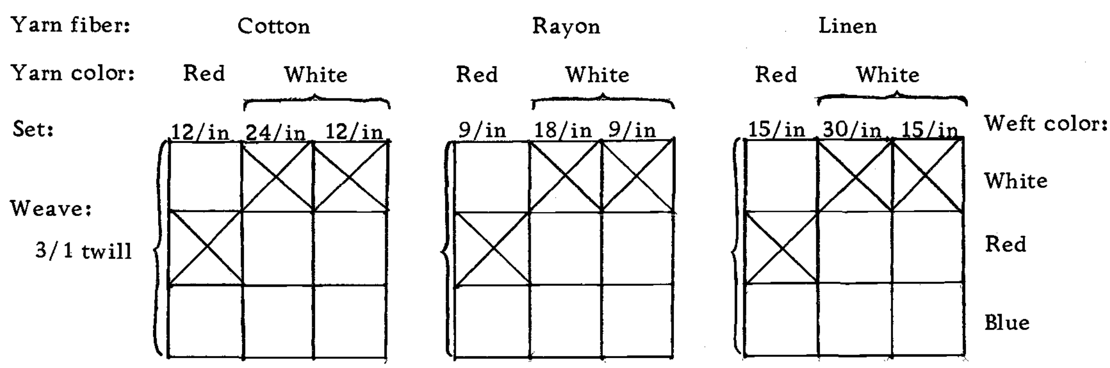


Figure 4. Sections of experimental warps used in assessing effect of set on strength of design motif.

In observing the effect of set on strength of design, a distortion of the edges of the printed designs was observed to have taken place. The clarity of the design outline was affected by what appeared to be a lengthwise movement of warp yarns. It was assumed that this was due to variation in elongation of warp yarns in tensioning. The sample shown in Exhibit 9 (Appendix C) illustrates this effect. Even though no predictions had been made here, it was felt that since the effectiveness of the printed design was greatly influenced by the clarity of the design outline, some evaluation should be made.

Several factors were considered in selecting those portions of the warps to be assessed. First, since some difference in elasticity of yarns would be expected, the three experimental warps were compared each to the others. In addition, a portion of the 3/1 twill weave in each warp was chosen because more warp surface is exposed in this weave than in either plain weave or 2/2 twill. It appeared that set also had an effect on apparent clarity of the design outline. Since evaluations made of dye penetration had shown a difference between red and white warp yarns, it was felt that sections containing both warp colors should be compared. Consequently, the sections of warp illustrated in Figure 5 were chosen to assess the clarity of design outline.

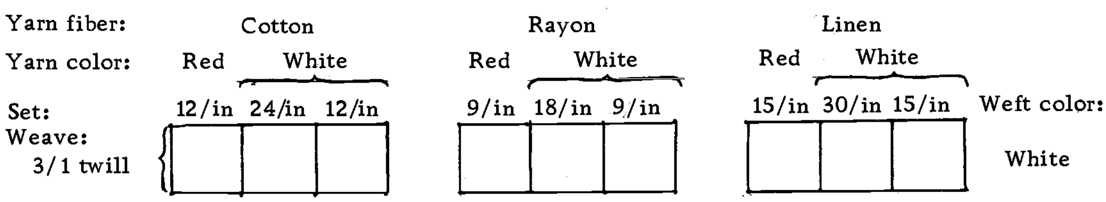


Figure 5. Sections of experimental warps used in assessing clarity of design outline.

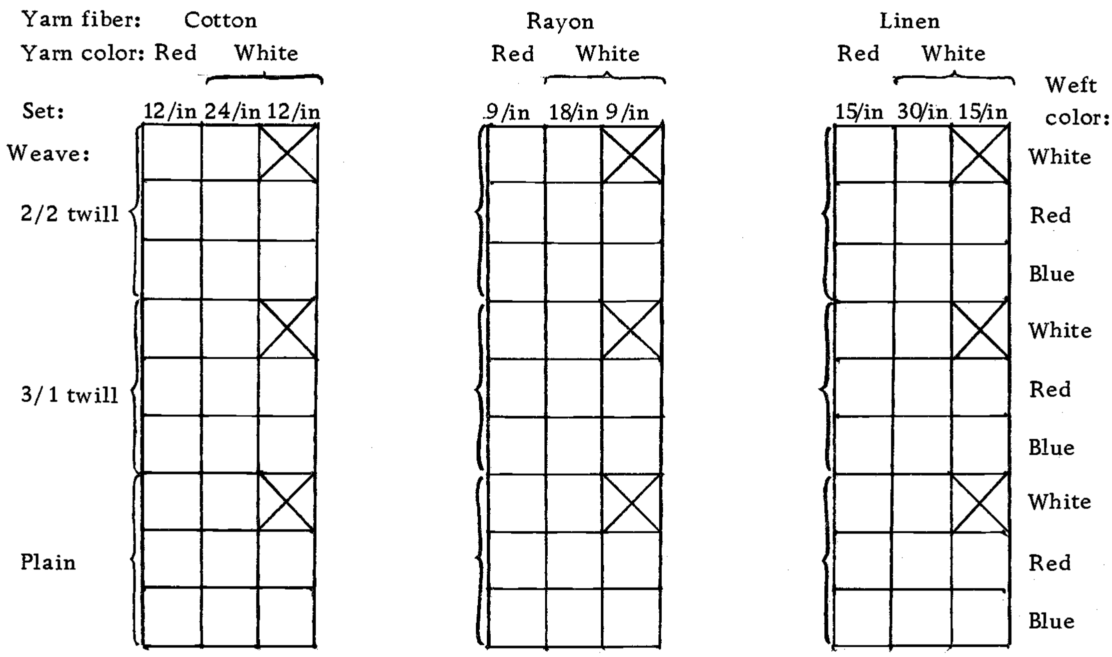
Effect of Weave

In assessing the effect of the weave on strength of the printed design, each of the three weaves was evaluated, and comparisons were made among the three experimental warps. Within each warp, only the sections of white warp, balanced weave, woven with white weft were used for evaluation. The warp-face areas were eliminated from consideration because the effect of a change in treadling in these areas results mainly in a slight change in texture. The warp and weft color selection resulting in a woven solid white background was chosen because it was felt it would produce the most contrast in value between the background and the printed design making comparison easier. The balanced weave sections and the warp-face sections were evaluated independently because it was deemed impossible to make a valid discrimination if 18 samples were involved. The nine individual sections assessed in each of these independent evaluations are marked with X and shown in Figure 6.

Effect of Interaction of Color of Warp, Weft and Print

This assessment was the most complex and perhaps the most subjective of all the evaluations made. The number of sections to be compared had to be narrowed to a workable number; otherwise making a definitive assessment would be impossible. First, the warp-face

A. Evaluation of Balanced Weave Sections:



B. Evaluation of Warp-Face Sections:

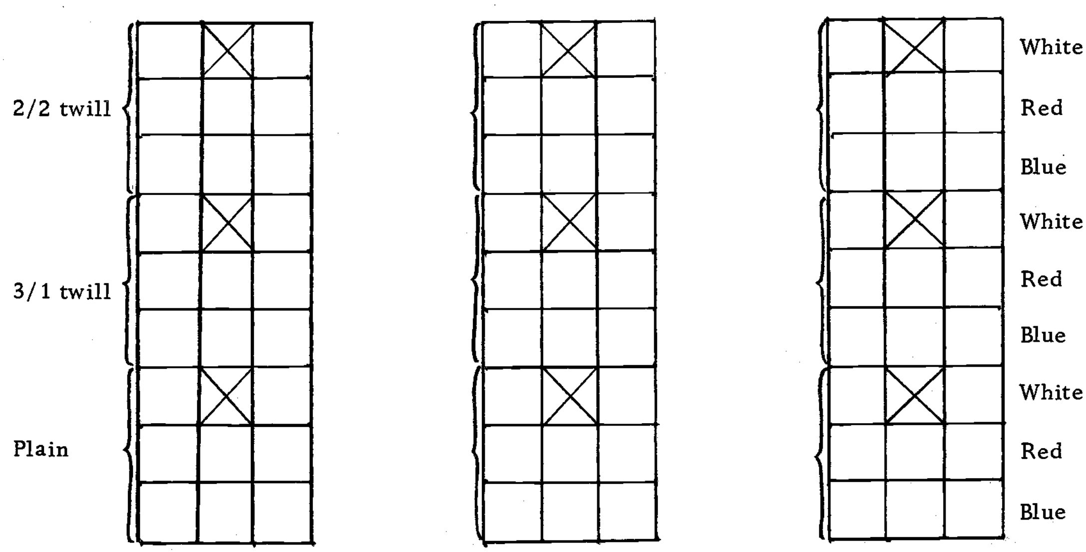


Figure 6. Sections of experimental warps used in assessing effect of weave on strength of design motif.

sections of all warps were eliminated from consideration since in these the contribution of the weft color in promoting strength of design is negligible. Consequently, balanced plain weave sections were those chosen for evaluation because in them equal amounts of warp and weft yarn appear. The rayon warp was chosen for evaluation because dye penetration was previously judged to be the deepest of the three experimental warps in the balanced weave section. Finally, comparisons were made among those sections in which the weft yarn was the same color as the warp yarn, where the weft yarn color was the same as the printed design, and where the weft yarn color was a contrast to both the warp and the printed design. Those sections evaluated are marked by X and shown in Figure 7.

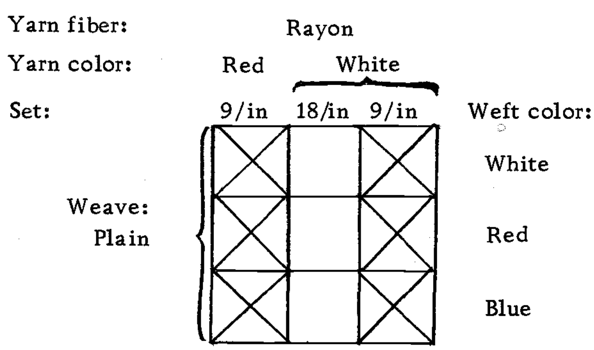


Figure 7. Sections of experimental warp used in assessing the effect of interaction of color of warp, color of weft, and print on strength of design motif.

IV. FINDINGS

Dye Penetration

Results of Assessments

Results of assessments of dye penetration are shown in Table 1. A ranking of one indicates deepest dye penetration, and nine the least amount of penetration as judged by observation of the apparent evenness of color distribution after dye development in the unwoven printed yarns.

Table 1. Dye penetration in unwoven printed yarns.

Yarn fiber:	Cotton			Rayon			Linen		
Yarn color:	Red	White		Red	White		Red	White	
Set:	12/in	24/in	12/in	9/in	18/in	9/in	15/in	30/in	15/in
	5	9	8	1	6	2	3	7	4

Dye color appeared to be most evenly distributed in the printed yarns in sections of the rayon warp threaded to weave a balanced web, the red section receiving a higher rating than the white. The poorest color distribution and thus least apparent dye penetration in printed yarn was judged to be found in the two white cotton warp sections. Of these two sections, the portion threaded to weave a warp-face fabric received the lowest rating. On the average, the rayon warp yarns received the highest ratings in apparent dye penetration and the cotton yarns the lowest ratings. Dye penetration was judged to be deeper in the sections of all the warps threaded to weave balanced webs than in the sections threaded to weave warp-face fabric. In addition, the red sections in each of the individual warps received higher ratings than did their corresponding white sections. The greatest variation in penetration as judged by color of warp yarn was found in the cotton warp.

Additional Findings

Dye appeared to be pulled under the portion of the stencil closest the printer in printing the sections of warp threaded to weave a warp-face fabric in both the cotton and linen warps. This had the effect of elongating and consequently distorting the shape of the design motif. This phenomenon is shown in Exhibit 10 (Appendix C).

There appeared to be a general all-over spreading of the dye along the warps and under the stencil boundaries in the prints made on all sections of the rayon warp. The effect of this was to enlarge slightly the size of each motif and also render the finer design areas in the center of the motif less precise.

There appeared to be some difference in the value and intensity of dye color after development among the cotton, rayon and linen experimental warps. Generally darker values and brighter intensities of print color appeared on the portions of the warps in which dye penetration was judged to be deepest. The only exception to this was found in the section of white linen threaded to weave a warp-face fabric. Even though dye penetration was judged to be more thorough in that section of linen than in both white sections of cotton warp, the color of the print in the linen appeared lighter in value.

Effect of Set

Results of Assessments

Rankings of the assessment of the effect of set on strength of design motif are shown in Table 2. This evaluation was made on the woven warps. A rating of one indicates the strongest contrast between the design motif and its background, a nine the least amount of contrast.

Table 2. Effect of set on strength of design motif in woven fabrics.

Yarn fiber:	Cotton			Rayon			Linen			
Yarn color:	Red	White		Red	White		Red	White		
Set:	12/in	24/in	12/in	9/in	18/in	9/in	15/in	30/in	15/in	Weft color:
Weave: 3/1 twill		2	9		1	5		4	6	White
	8			7			3			Red
										Blue

The design motif appeared strongest in the warp-face section of the rayon warp, and next strongest in the warp-face section of the cotton warp. Balanced weave sections received ratings to indicate that the design motif stood out least from the background in these sections, the white balanced weave section of the cotton warp receiving the lowest rating. An exception to this is found in the linen warp. The red linen balanced weave section received a higher rating than did its warp-face section. The light value of the dye color described under "Additional Findings" in the previous section would account for this.

Additional Findings

As discussed under "Effect of Set" in "Procedures," a decision was made to evaluate the clarity of design outline. The results of that assessment are shown in Table 3. A rating of one indicates the most precise design outline and a rating of nine the most distorted outline.

Table 3. Clarity of design outline in woven fabrics.

Yarn fiber:	Cotton			Rayon			Linen			
Yarn color:	Red	White		Red	White		Red	White		
Set:	12/in	24/in	12/in	9/in	18/in	9/in	15/in	30/in	15/in	Weft color:
Weave: 3/1 twill	8	5	9	6	3	7	1	2	4	White

The most precise design outline was found in the red balanced weave section of the linen warp. The most distortion of design outline was found in the section of white balanced weave in the cotton warp. On the average among the three yarn fibers, the linen warp received the highest ratings and cotton the lowest. In both the cotton and rayon warps, the design outline in the warp-face sections appeared less distorted than it did in the corresponding sections of balanced weave. However, the red balanced weave section in the linen was judged to show less distortion than did its corresponding white warp-face section. Within each of the three warps the design outline appeared less distorted in the red balanced weave sections than in the corresponding sections of white balanced weave.

The printed portions of the rayon yarn were observed to become quite stiff after drying and development. When the warps were pulled back part way through the reed and heddles prior to weaving, there occurred a certain amount of selective pulling on the yarns. It is possible that this could have contributed to any distortion in design outline caused in tensioning. This would occur in addition to that distortion caused by variation in elasticity among the three warp yarns used in the experiments.

Effect of Weave

The results of the assessment of the effect of the weave on the strength of design motif are shown in Table 4. Part A shows the results of the comparisons made on sections of balanced weave, and Part B shows results of comparisons made in sections of warp-face fabric. In both cases, one indicates the weave which exhibits the design most strongly, and a nine indicates the weave in which the design is weakest.

In the evaluations made on the balanced weave sections of the three warps, the 3/1 twill treadling was judged to exhibit the strongest design. The rayon warp received the highest rating of the three experimental warps. The 2/2 twill weave sections as a group received the lowest ratings within each of the three warps, the 2/2 twill section of the cotton warp receiving the lowest rating. However, the linen 2/2 twill treadling was judged to show more strength of design than did the plain weave section of the cotton warp.

Evaluations made on the warp-face sections of the three warps showed the rayon 3/1 twill treadling as giving the strongest contrast between design and background. The lowest rating was given the 2/2 twill section of the cotton warp. For each fiber the 3/1 twill sections received the highest ratings within each warp and the 2/2 twill sections the lowest ratings. The rayon plain weave section was judged to

Table 4. Effect of weave on strength of design motif in woven fabrics.

A. Evaluation of balanced weave sections:

Yarn fiber:		Cotton			Rayon			Linen		
Yarn color:		Red	White		Red	White		Red	White	
Set:	Weft color:	12/in	24/in	12/in	9/in	18/in	9/in	15/in	30/in	15/in
Weave: 2/2 twill	White			9			8			6
	Red									
	Blue									
3/1 twill	White			3			1			2
	Red									
	Blue									
Plain	White			7			5			4
	Red									
	Blue									

B. Evaluation of warp-face sections:

2/2 twill	White		9			5			8	
	Red									
	Blue									
3/1 twill	White		3			1			4	
	Red									
	Blue									
Plain	White		6			2			7	
	Red									
	Blue									

exhibit more strength of design than did the 3/1 twill section of the cotton. The rayon 2/2 twill section was rated higher than the plain weave sections in both the cotton and linen.

Assessments of the effect of weave on the strength of the design motif are fairly consistent between the balanced weave evaluation and the warp-face evaluation. Differences that do exist may be caused by variations in dye penetration between the three experimental warps. Another factor may be the proportionately larger amount of warp yarn which shows in the warp-face section than in comparably treadled sections in balanced weave.

Effect of Interaction of Color of Warp, Weft, and Print

Ratings of the effect of the interaction of the color of the warp, weft, and print on the strength of the design are shown in Table 5. A ranking of one indicates the strongest contrast between design motif and its background. A ranking of six indicates the least contrast.

The section in which a white weft yarn was woven into a white warp yarn was judged to produce the strongest design motif. Thus, the highest ranking was given to a section in which a solid background color of high value contrast to the printed design is produced when woven. The lowest ranking was given to a section in which the weft yarn (white) was a contrast to both the warp color (red) and the print color (violet, from blue dye on red yarn).

Table 5. Effect of interaction of color of warp, color of weft, and print on strength of design motif in woven fabrics.

Yarn fiber:	Rayon			
Yarn color:	Red	White		
Set:	9/in	18/in	9/in	Weft color:
Weave: Plain	6		1	White
	5		3	Red
	4		2	Blue

The sections in which the weft yarn was the same hue as the warp yarn received rankings of one and five. The section in which the weft yarn was of the same hue as the printed design was ranked two. The sections in which the weft, warp, and print colors were all of different hues received rankings of three, four and six.

Summary

An assessment of dye penetration as a function of the evenness of color distribution in printed yarns was made on the three experimental warps after printing and dye development and before weaving. Dye penetration was judged to be most thorough on portions of the rayon warp. Sections of the cotton warp exhibited the least amount of dye penetration. There were differences in penetration between portions of the warps threaded to weave a balanced web and those threaded to weave a warp-face fabric, with less dye penetration in yarns placed closely together. A difference in dye penetration was also noted between the red and the white warp yarns with greater dye penetration in the red yarns than in the white yarns. A spreading of dye under the stencil boundaries was observed in certain portions of the warp. In addition, variations in value and intensity of developed dye color were observed.

An assessment of the effect of set on strength of design motif was made after weaving. The design motif was rated strongest in the warp-face sections of two of the warps. The lowest ratings were received by sections of warp threaded to weave a balanced web.

An evaluation was also made which compared clarity of design outline. Results were somewhat inconclusive, since it was difficult to separate out any one factor which was primarily responsible for the results.

Two individual assessments were made on the effect of weave on the strength of design motif. Selected samples of balanced weave and samples of warp-face fabric were evaluated separately. Comparative results showed that the 3/1 twill weave exhibited the design most strongly in both evaluations, while the 2/2 twill sections were rated the lowest.

Assessments were made on the effect of interaction of color of warp, weft and print on strength of design motif. The sample judged to exhibit the design motif most strongly was that in which a solid white background was woven (white warp and weft, blue print). The sample receiving the lowest rating was that in which the warp, weft, and print colors were all different (red warp, white weft, violet print, from blue dye on red yarn).

V. CONCLUSIONS AND DISCUSSION

Dye Penetration

As suggested in directions for weaving chiné, thoroughness of dye penetration in the painted or printed area of the warp is very important in achieving a strong design statement. In incomplete penetration, the only portion of the yarn receiving dye would be the very top surface which came in actual direct contact with the dye. Because of yarn rotation during weaving, it might happen that portions of the printed design might not be visible at all on the "right" side of the woven piece. Since this rotation of yarn would likely occur in a fair proportion of all the warps printed, the forcefulness of the design would be greatly diminished. This would also cause a distortion of the outline of the design, which would be in addition to that which might be caused by the expected variations in elongation of warp yarns when the yarns are woven under tension. In Exhibit 11 (Appendix C), a section of the experimental cotton warp woven in plain weave is shown, which illustrates the effects of incomplete dye penetration.

Fiber Content of Warp Yarns

It was hypothesized that of the three cellulosic yarns used in the experimentation, the 100% viscose rayon yarn would allow greatest penetration of dye paste. The results of the experimentation bore out this prediction in the two sections of the rayon warp threaded to weave a balanced web. The fact that the section of rayon warp threaded to weave a warp-face fabric had relatively low dye penetration when compared to the sections threaded to weave a balanced web is discussed later in this section under "Effect of Set."

Printing Technique

The number of strokes of the squeegee and thus the amount of dye needed to penetrate the yarn in screen printing is affected by the permeability of the printing surface. Eight strokes of the squeegee were used for each print made on the experimental warps. As described earlier, sections of the rayon warp threaded to weave a balanced weave absorbed the dye more readily than did corresponding sections of the cotton or linen experimental warps. After the dye had thoroughly penetrated the printed areas of the rayon warps it spread along the yarn under the stencil boundaries. This produced a consequent enlargement of design motif and blurring of detail within the design motif. This result would suggest that less dye applied on the rayon warp would have achieved a more precise print. A good print is achieved in printing on tensioned warps by applying just enough dye to completely penetrate the yarns. As shown in Appendix B, Yarn Description, in a determination of twist per inch, the rayon yarn had the lowest twist of the three yarns tested. This might account in part for its superior degree of dye penetration.

Effect of Set

It was observed that dye penetration was less thorough in sections of the experimental warps threaded to weave a warp-face fabric than in those threaded to weave a balanced web. It appeared that less dye was absorbed in these more closely threaded sections because in these portions the yarns were placed very tightly together. The dye could not penetrate through the yarns possibly because it could not be forced between them.

The same amount of dye was applied to all portions of all warps. If dye applied in the sections threaded to weave warp-face fabric did not penetrate, it had to go elsewhere. It spread under the perimeter of the stencil in these areas. This occurred most often in the warp-face sections of the linen and cotton warps and in the design motifs closest the printer. This spreading of dye, occurring probably in a sort of capillary fashion, caused the elongation and thus distortion of certain of the design motifs. The fact that this elongation and distortion occurred in the prints closest to the printer could be accounted for by the more intense amount of pressure which could be applied to the squeegee as it was moved on the part of the screen closest to him.

Yarn Color

The only warp in which the red section of warp threaded to weave a balanced weave was rated much higher in dye penetration than in its corresponding section of white yarn was in the cotton warp. One explanation for this might be that the white cotton yarn used for the experimental warp was not a pure white, i.e., bleached white. It was a slightly off-white or natural color of cotton yarn. Thus, it had not gone through a bleaching process as had the white linen yarn and was not a man-made yarn as is rayon yarn. Because it was the only white yarn of the three to be in its "natural state," and because it was cotton, the presence of an unremoved plant substance, possibly pectin, may account for its lower degree of permeability.

Effect of Set

A prediction was made that the design would be strongest in those portions of the warps threaded to weave a warp-face fabric. The experimental warps proved this to be correct.

Fineness is a desirable characteristic of yarn to be used, in a chiné warp, according to readings on the subject (Marston, 1970, p. 37). Physical testing showed the experimental linen yarn to be the finest yarn. It had the smallest visual diameter. As a result, more threads per inch in the warp would be needed to achieve a warp-face fabric than in the rayon or cotton. As a consequence, the printed design in the linen warp had very good strength and definition. High ratings were achieved even though the linen warp had relatively low dye penetration in the section threaded to weave a warp-face fabric.

Clarity of Design Outline

An analysis of the assessment of the effect of clarity of design outline on strength of design motif was difficult to make since results were influenced by many factors. Differences in elasticity of yarn, relative dye penetration, and set appeared to be very crucial. A print made on yarns threaded very close together will given the illusion of less design distortion, even though the warp yarns are pulled out of position the same amount in this area as in a section threaded to weave a balanced web. Thus, the advantage which might be obtained by threading the yarns more closely may be lost because it was found that the closer the yarns, the less the dye which will penetrate the yarns.

In addition, the spreading of the dye along the warps, especially in the rayon warps, produced a blurring of the design outline which made comparisons even more difficult.

A yarn may allow deep dye penetration, but if the yarn is relatively elastic, the advantage of the deep dye penetration may be lost. This was true in the rayon yarn in which distortion caused by lengthwise movement of yarn seemed to be most pronounced. The linen yarns would be expected to be the most inelastic of the three warp yarns used. The high ratings in clarity of design outline assigned the linen seemed to indicate the correctness of this assumption.

Effect of Weave

Predictions were made that the 3/1 twill treadling would exhibit the strongest design and plain weave the least strength of design. As suggested in directions for weaving chiné (Buhler, 1942, p. 1586), the printed design would be clearest when the dyed pattern threads (warp) are most visible on the surface of the fabric. The 3/1 twill threading did prove to give the strongest design. However, on the whole, designs in the 2/2 twill sections were less strong than were designs in the plain weave sections.

The few exceptions in the ratings can be explained by the influence of variations among the warps in dye penetration. For example, the rayon warp-face plain weave section was rated higher in strength of design motif than the warp-face 3/1 twill section in the linen warp. The warp-face sections of the linen were rated relatively low in dye penetration, and the print in addition, was of a very light value, as described in "Additional Findings" under "Dye Penetration."

Effect of Interaction of Color of Warp, Weft, and Print

The number of colors used in the experimental warps was necessarily somewhat limited. However, results of the assessments made in comparing different combinations to determine which produced the strongest design do suggest some guidelines.

Most directions for chiné suggest the use of a neutral-colored weft yarn (Marston, 1970, p. 37); i.e., one that does not interfere with or "dilute" the design. Other possibilities open to the handweaver include choosing a weft yarn which exactly matches the warp color, one which is the same as the printed design, or a weft which contrasts with both the warp color and the printed design.

Results showed that the white weft yarn woven in a section of white warp exhibited the strongest design. The design printed on red warp and woven with a red weft yarn (thus also producing a solid color background for the design) received a relatively low rating. The white yarn is certainly more "neutral" in color than is the red. In addition, a blue design on a solid white background provides more contrast than would a violet design on a solid red background.

A statement cannot be made as to which exact combination of warp, weft, and print colors (weft same as warp, weft same as print color, weft contrast to both) produces the strongest design. The results achieved in the experiments may hold only for the particular group of colors used and thus it is felt that a general guideline cannot be given. A large part of success would seem to depend on which specific hues are selected for the warp and for the printed design.

An experienced weaver who understands color theory should be able to make color selections which will result in a forceful design statement. Interesting and effective results could be possibly achieved by choosing a weft hue which, when woven, blends visually with the print color to form a strong and vibrant third hue. Another possibility might be using a weft hue which is of a lighter than normal value for that hue. The print color could be of a darker than normal value for that particular hue. The vibrance which would result from the dissonance produced might serve to call attention to the print, which, of course, is the objective sought.

Summary

In weaving a chiné warp, certain choices in selection of materials and technique can be made which will most likely give a strong design statement. A suitable warp should be selected which is inelastic, relatively fine, and which will promote thorough dye penetration. The yarns could be threaded to achieve a warp-face fabric. The web could be woven in a pattern in which proportionally more warp than weft shows. The weft yarn could be of a hue which closely matches the warp color. Exhibit 12 (Appendix C) shows a section of experimental warp which most closely meets the above criteria. The X marks a section of the rayon experimental warp. It is warp-face, is treadled in a 3/1 twill and was woven with a white weft.

VI. SUMMARY AND RECOMMENDATIONS

Summary

The creating of pattern in woven fabrics by placing design on the warps and/or wefts before they are woven is ancient. Primary examples of these textiles are ikat, which is a resist dyeing technique, and chiné, in which design is painted or in some way printed on the tensioned warp yarns.

The primary objective of the study was to investigate the effect of screen process printing by the home craftsman on the characteristic design produced in warp printed, handwoven fabric. Directions for producing ikat and chiné were used in selection of yarn, and determination of set and weaves most amenable to achieving a forceful design statement. They were also helpful in designing printing equipment and in determining a printing method, since the techniques of painting and printing on warps are similar.

Three experimental warps were printed and woven. After the experimental warps were woven and assessed, three additional projects were designed and woven.

Two-ply, medium weight cellulosic yarns of cotton, linen and rayon were selected for the experimental warps. A medium value red and a white were chosen for the warp yarns, colors which were threaded to weave sections of both balanced weave and warp-face fabric in each of the experimental warps. Calculations were made to determine the number of ends per inch which would produce this variation for each of the three warp yarns. The same red and white yarns used in the warp, and an additional blue yarn, were used as weft yarns. This color selection provided for yarn to match the woven background colors (red and white), yarn to match the screen print (blue), and yarn to serve as a contrast to the white warp yarn and the blue screen print (red on the white warp sections and blue on the red warps).

A simple design motif, incorporating curved, horizontal and diagonal lines was used for the screen print. Inkodye, a solubilized vat dye, in a medium blue color which closely matched the blue weft yarns was selected for the print. A printing board to fit on a loom was designed and built. Printing was done on the tensioned warps in the front of the loom, between the reed and the breast beam.

Nine prints were made on each warp. Along the length of each warp, plain weave, 3/1 twill and 2/2 twill were treadled in sequence. In addition, the three colors of weft yarn were alternated. This procedure produced three woven pieces which have a sort of patchwork design.

The interaction of the fiber content of the warp, the set, treadling, and the color of warp, weft, and print were observed, with the objective of determining combinations which would achieve a clear and forceful design statement. Specifically, the dependent variables were stated as depth of dye penetration and strength of design motif.

Assessments of dye penetration were made on the printed, unwoven warps. The remaining assessments were made after weaving had taken place.

Results of the assessments made were as follows: Dye penetration was judged to be most thorough on portions of the rayon warp and least thorough on sections of the cotton warp, thus supporting the hypothesis made at the beginning of the research. There were differences in penetration between portions of the warp threaded to weave a balanced web and those threaded to weave a warp-face fabric, with less dye penetration in yarns threaded closely together. A difference in dye penetration was noted between the red and the white warp yarns, with dye penetration greater in the red than in the white yarns.

The design motif was generally rated strongest in the warp-face sections of the experimental warps and weakest in those sections threaded to weave a balanced web. These results supported the prediction made at the start of the study.

In sections of both balanced weave and warp-face fabric, the 3/1 twill weave was judged to exhibit the strongest design and the 2/2 twill sections received the lowest rating. It had been hypothesized earlier that the plain weave sections would show the least strength of design motif.

In assessing the effect of interaction of color of warp, weft, and print on strength of design motif, the portion judged to exhibit the motif most strongly was that in which a solid white background was woven. The sample receiving the lowest rating was that in which the warp, weft, and print colors are different.

Conclusions formed upon analysis of the findings indicated that of primary importance was a careful selection of the warp yarn when choosing material for a chiné project. Most important, yarn chosen for warp should allow thorough dye penetration. The yarn needs to be completely without a finish, which would inhibit dye penetration. In yarns in which dye penetration was poor, rotation of yarns during weaving caused a distortion of the outline of the printed design and its effectiveness was diminished.

Yarn selected for warp should be relatively fine; inelasticity is also an important characteristic, since design distortion is an effect of retensioning the warp each time a print is made. Reducing the number of printings also could reduce design distortion. This could be accomplished by the use of repeats of the design motif on the screen or printing several repeats at once by using a large printing board. Of course, other factors which must be considered in determining the size of the printing board include: the width of the loom on which it will be used, the width of the warp on which one wishes to print, and the size of the design motif one wishes to use. The use of a small and lightweight board would have advantages in ease of use if only a narrow warp were to be printed.

Yarns should be threaded and woven in a pattern which exposes a high proportion of warp yarn. When yarns were packed too closely together, dye did not thoroughly penetrate below the very top surface of the yarn. However, decisions as to selection of set and weave would depend on the effect one wished to achieve. If more subtle effects were desired, a plain weave or 2/2 twill would give satisfactory results.

The warp and weft threads should be of a neutral color of light value. However, interesting and effective results could be achieved by choosing colors of varying values and intensities for warp, weft, and print, which combined would result in a forceful design statement.

Dye applied to the yarns in printing should be of an amount which will just completely penetrate the warp yarns. This would indicate experimentation to determine a proper number of squeegee strokes, angle of squeegee while printing, as well as attempting to vary speed of stroke and pressure.

Screen printing may offer advantages in promoting thorough dye penetration, speed and ease of design replication and the ability to achieve great precision of design edges.

It was concluded that the use of the screen process method to achieve design on tensioned warps in handwoven fabrics has a potential for success. If one can screen print and weave, has necessary materials and equipment available, and is interested in non-structural methods of achieving design in handwoven fabrics, the use of this method can give very gratifying results.

Recommendations

Perhaps the findings of this study will recommend the use of the screen process method for printing design on tensioned warps by handweavers.

In general, the results of the experimentation were somewhat predictable based on descriptions of successfully woven ikat and chiné fabrics. However, certain differences emerged because screen printing was the technique used to get the design in the warps. Some experimental groundwork was provided and factors were identified which appear to be critical in achieving a successful warp print.

However, the real value of the experiments would seem to be in the identification of the unique contributions the use of the screen process method can make in creating handwoven warp printed fabric.

First, the importance of thorough dye penetration in achieving a clear and forceful design in warp printed fabric cannot be overstated. The technique of screen printing would seem to have a real advantage over other methods of printing, such as block printing or simple stencilling; with the use of the latter two methods the design likely would be printed only on the very top surface of the yarn. The use of a squeegee combined with repetitive pressure to force the dye into the yarns could promote greater dye penetration.

The second value might be in the speed and ease of design replication inherent in screen printing. Painting on warps is slow work. Each yarn is actually individually painted. It often must be rotated by hand so dye covers all sides of the yarn. In screen printing, once the stencil is made, the design can be printed in a matter of minutes and replicated as many times as desired.

The third value may be in the ability to achieve more precision of design edges with screen printing than would be possible with either painted warps or tie-dyed warps. If the optimum amount of dye were applied to the warps so that sufficient dye penetration could take place without dye seepage outside the stencil area causing blurring, a relatively hard-edge design could result. This would occur if care were exercised to take the usual precautions against distortion caused by tensioning. Because of the design precision possible in screen printing on warps, more complex designs than are usually suggested for tie-dyed or painted warps might be attempted.

In consideration of the findings of the experimentation and the conclusions drawn, the following recommendations are made for further research:

1. Additional experimentation should be done with the factors which influence optimum dye penetration in printed yarns (fiber content, finish, diameter and twist, set, dye viscosity and printing technique).
2. Other types of dye and paint could be used for screen printing so different warps of a wide variation in fiber content could be used.
3. Experimentation with the use of a printing board positioned at the back of the loom (Heartz, 1958, p. 20), may prove this method a reasonable possibility when screen printing on tensioned warps.
4. Further work in color and design could be done, exploring possibilities in choice of color of warp and weft yarns and in dye for printing. In particular, the transparency of dye and the effects produced by overprinting may provide some interesting effects. Additional prints could be made on the woven fabric to produce a possible shadow effect.
5. The unique advantage of ease of design replication in screen printing could be further explored. Relatively complex designs could be attempted. In addition, a screen printed design could be used to enhance a loom-controlled (repeated) woven design.

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APPENDICES

APPENDIX A

Definitions

1. balanced weave--weave produced when the same size threads are used for warp and weft and beating is correctly done. A 50/50 web is woven in which there are the same number of warp and weft threads to the square inch (Black, 1957, p. 51).

2. breast beam--stationary beam at front of loom, over which woven cloth passes to the cloth beam

3. chiné--(pronounced shē nā́) general term for fabric in which the design has been printed, dyed, or painted on tensioned warps before weaving takes place. The design in the finished fabric is blurred and indistinct, and colors are subdued (Marks, 1959, p. 125).

4. chiné velvet--a type of velvet produced when the pile warp yarns before weaving are printed or painted so that, when woven, the patterns appear in different colors all on the same threads (Reath, 1927, p. 16)

5. clarity of design outline--degree of precision which the edges or perimeters of a design printed on tensioned warps remain after weaving

6. cloth beam--the front roller on which the cloth is wound and tensioned after it is woven

7. dye paste--viscous mixture of dyestuff, chemicals and thickener used to color fabric in printing techniques

8. fell--the edge of the weaving where the warp yarns cross after the shed is changed, after the insertion of the last weft yarn

9. fiber-reactive dye--class of dyes discovered and developed by ICI Dyestuffs Division, introduced by trade name Procion, which react chemically with the fiber being dyed

10. ikat--(pronounced ē kät) method of achieving pattern in fabric where the warp and/or weft yarns are resist-dyed before weaving

11. motif--dominant feature or theme in a design, often repeated to form a pattern

12. plain weave--warp yarns and weft yarns pass over and under each other alternately

13. reed--comblike piece in the beater which separates warp yarns and helps to beat the weft yarns into place

14. resist--process or material used to prevent dye from reaching certain areas on the yarn or fabric

15. screen process method printing--process whereby thickened paint or dye is forced by means of a squeegee onto a fabric through the open meshes of a fabric stretched tightly on a frame. Parts not to be printed are blocked out by means of a stencil adhered or applied to the stretched fabric on the frame.

16. set--number of warp yarns threaded per inch through the dents in the reed (Black, 1957, p. 556)

17. shuttle race--horizontal crosspiece below reed on beater on which shuttle runs back and forth

18. solubilized vat dye--stable leuco form of a vat dye which is soluble in water or weak alkaline solutions. The dye can be applied from an ordinary hot dye bath or used for printing (Russ, 1965, p. 12).

19. stencil--a material from which certain areas have been removed. Color passes through the holes and prints on the surface below

20. strength of design--degree to which a design printed on tensioned warps stands out clearly and forcefully from its immediate background after weaving

21. threading--order in which yarns are pulled through the heddles on various harnesses

22. tie-dye or tie-dyeing--a resist dyeing process in which certain portions of the warps and/or weft yarns are bound in such a way that when dyed, the dye cannot penetrate those areas

23. treadling--order in which the foot pedals attached to harnesses are raised or lowered

24. twill weave--weave in which weft yarns pass over warp yarns in a regular recurrent pattern, producing a diagonal pattern. In 2/2 twill, the weft yarns pass over two, then under two warp yarns. In 3/1 twill, the weft yarns pass under three, and over one warp yarn.

25. warp--all the yarns running parallel lengthwise in a fabric

26. warp beam--beam at back of loom around which unwoven warp is wound

27. warp-face weave--a firm, close weave in which the warp yarns almost entirely cover the weft yarns

28. warp printing--placing a design on tensioned warp yarns before weaving takes place. The printing may be done by a roller printing machine, a stencil or by the screen process method.

29. web--piece of woven cloth

30. weft--all yarns intersecting the warp yarns at right angles

APPENDIX B

Yarn Description

1. Fiber Content

   Lily 100% 3/2 cotton Perle
   - white # 862
   - red # 439
   - blue # 635

   Craft Yarns Brite 100% rayon
   - white
   - scarlet
   - blue

   Craft Yarns 10 lea 2-ply 100% linen
   - white
   - rouge (red)
   - blue

2. Weight

   cotton 79 yds/oz
   rayon 63 yds/oz
   linen 94 yds/oz

3. Direction of Twist

   a. reference: ASTM Standards D-123-72
   b. results: 2-ply cotton yarn S-twist
   2-ply rayon yarn S-twist
   2-ply linen yarn S-twist

4. Yarn Number (a measure of linear density)

   a. method; Direct system: Tex
   b. reference: ASTM Standards D-1059-72
   c. instruments: Suter's Precision Twist Tester
   Alfred Suter Co.
   Torsion balance

   d. conditions:
   1. distance between clamps 9.875"-0.25 m
   2. deflection load 3 g.
   3. temperature 68°F
   4. relative humidity 67%

e. results:	white cotton	442 gms. per 1000 meters
	red cotton	408 gms. per 1000 meters
	white rayon	526 gms. per 1000 meters
	red rayon	526 gms. per 1000 meters
	white linen	364 gms. per 1000 meters
	red linen	320 gms. per 1000 meters

5. Visual Diameter

a. method: mechanical stage method

b. reference: Heyn, A. N. J. Fiber Microscopy. New York: Interscience Publishers, Inc., 1954, pp. 97-99.

c. instrument: Spencer microscope

d. results:

white cotton	1.18 mm.
red cotton	1.28 mm.
white rayon	1.44 mm.
red rayon	1.34 mm.
white linen	0.92 mm.
red linen	0.96 mm.

6. Twist Per Inch of Plied Yarns

a. reference: ASTM Standard D-1423-71

b. instrument: Suter's Precision Twist Tester
Alfred Suter Co.

c. conditions:
1. initial length of specimen 10"
2. deflection load 3 g.
3. temperature 68° F
4. relative humidity 67%

d. results: (average of 8 specimens)

white cotton	5.5 tpi
white rayon	4.9 tpi
white linen	5.6 tpi

APPENDIX C

Exhibits

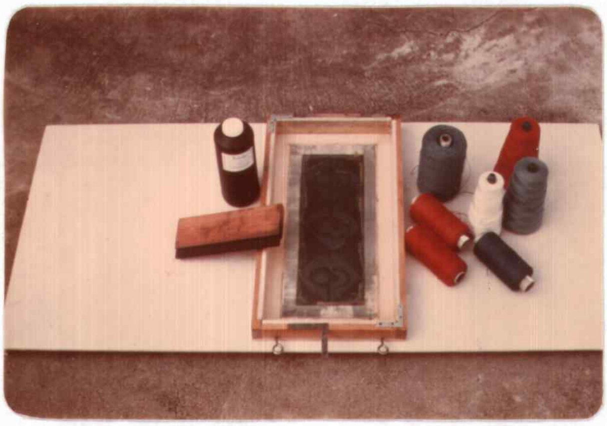

Exhibit 1. Equipment and materials used in experimental warps.

Exhibit 2. Printing board in position on loom.

Exhibit 3. Screen positioned for first print.

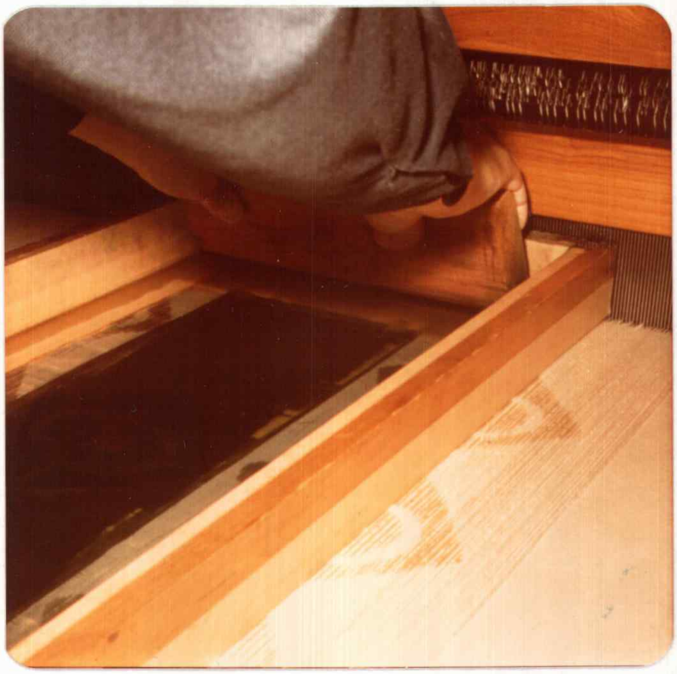

Exhibit 4. Printing center section of the experimental warp.

Exhibit 5. Developing the dye.

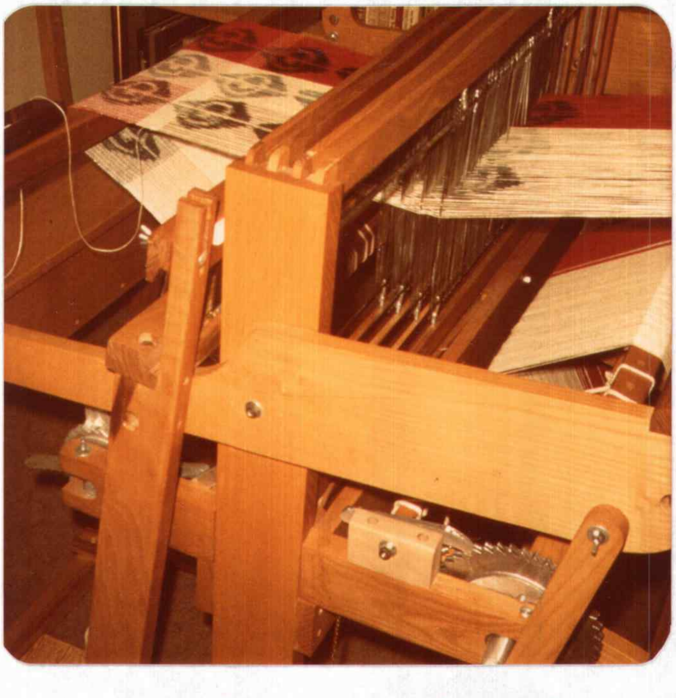

Exhibit 6. Printed warp in readiness for weaving.

Exhibit 7. Weaving the printed warp.

Exhibit 8. Completed experimental linen warp.

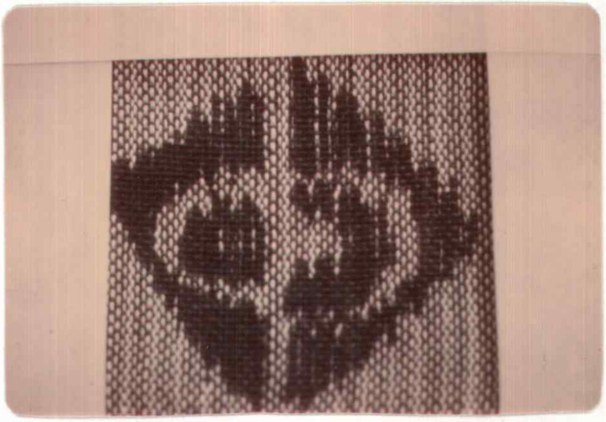

Exhibit 9. Effect of variations in elongation of warp yarns producing distortion of edges of design motif.

Exhibit 10. Distortion of shape of design motif caused by dye pulled under stencil.

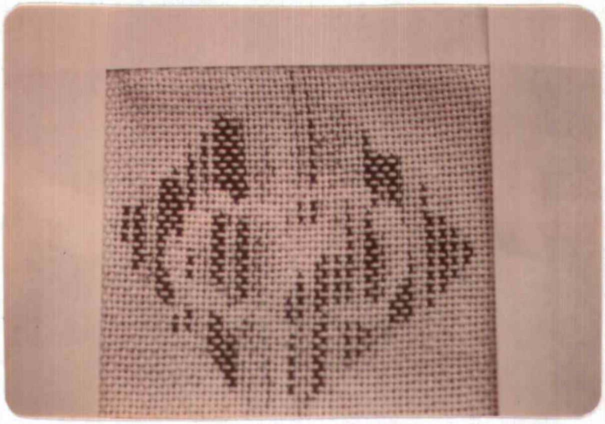

Exhibit 11. Effect of poor dye penetration on clarity of design outline and strength of design motif.

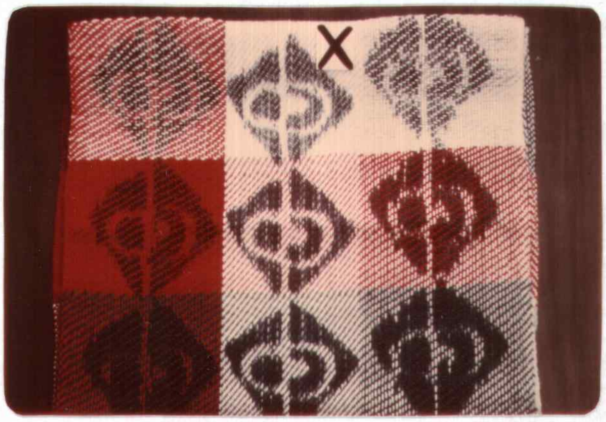

Exhibit 12. Warp-face, 3/1 twill section of experimental rayon warp.

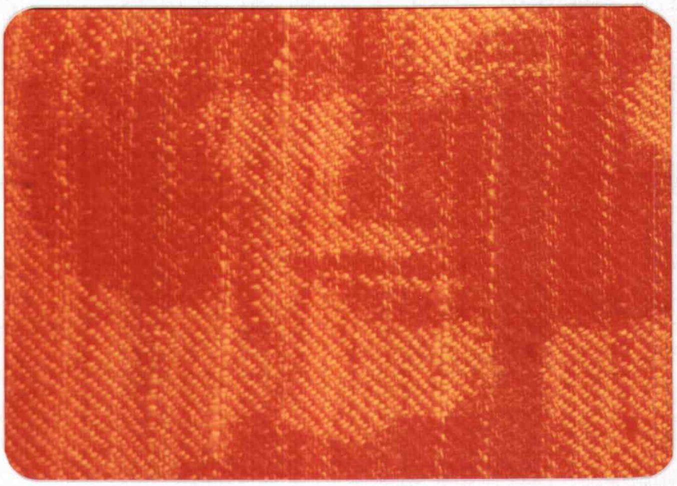

Exhibit 13. Additional project: Self-Portrait.

Exhibit 14. Additional project: Linen Table Runner.

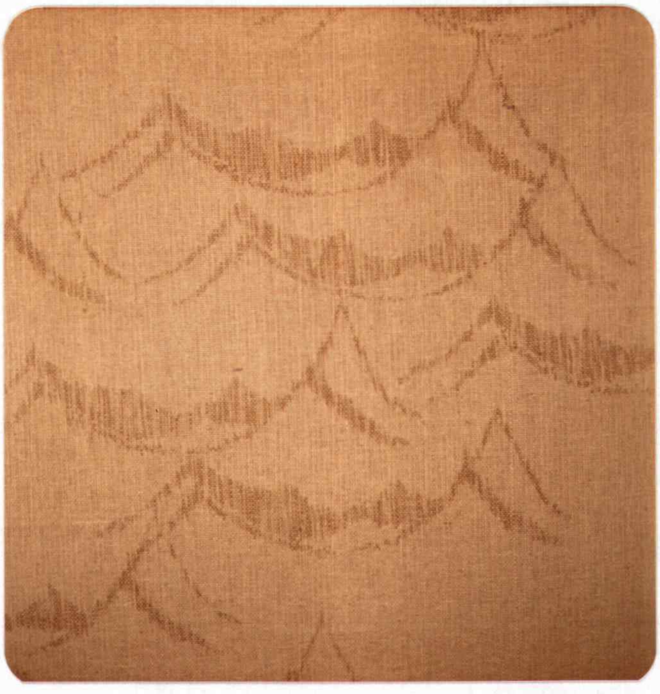

Exhibit 15. Additional project: Large Wall Hanging, "Coast and Cascades."

APPENDIX D

Additional Projects

1. Self-Portrait. Shown in Exhibit 13 (Appendix C).

   A. Purpose of Project: to use a variegated weft yarn (having color of both warp and print) of a smaller diameter than the warp yarn in a weft-face treadling.

   B. Materials:
   Screen Printing: Resist stencil (Inko Direct Fillin-Lacquer-Proof Maskout) used on a silk mesh
   Dye: Inkodye red
   Weaving: Warp--2-ply rayon in color of yellow-orange
   Weft --single ply slub novelty yarn in colors or variegated red and yellow-orange

   C. Procedures: Set--12 threads per inch
   Treadling--1/3 twill
   Screen was printed on its side, so the project when upright would exhibit the weft threads in a vertical position.

   D. Evaluation of Results: In addition to excellent dye penetration, vibrant color and interesting textures were achieved. The screen printed portrait appeared somewhat vague, but was obviously still a portrait.

2. Linen Table Runner. Shown in Exhibit 14 (Appendix C).

   A. Purpose of Project: to attempt a very precise repeated geometric design printed on warp stripes. The negative parts of the design composed of circles were printed. Changes of color in the warp and weft were used to emphasize the positive parts of the design.

B. Materials:

Screen Printing: cut lacquer film screen stencil used on a nylon mesh

Dye: Inkodye--1 part blue, 1 part yellow, 1 part clear

Weaving: Warp--10/2 dry spun Scottish linen in colors of straw gold and spring green

Weft --same as warp

C. Procedures: Set--15 threads per inch

Treadling--3/1 twill

Screen was centered over a 2" green stripe in the center of the warp. Weft colors alternated to weave weft stripes.

D. Evaluation of Results: Dye did not always satisfactorily penetrate, so the clarity of design edges was poor in some areas. Variations in diameter of yarn may have affected penetration as well as use of insufficient squeegee strokes for type of screen mesh. Yarn was inelastic, so there was little design distortion caused by tensioning.

3. <u>Large Wall Hanging</u>--"Coast and Cascades." Shown in Exhibit 15 (Appendix C).

A. Purpose of project: to print on a very fine yarn threaded to weave a plain weave, with the object of achieving an "abstract" design composed of randomly printed motifs. The absorbency of a spun cotton and linen yarn was tested.

B. Materials:

Screen Printing: cut lacquer film screen stencil used on a silk mesh

Dye: Inkodye--various proportions of yellow, clear, and brown

Weaving: Warp--2/22 Danish cottolin in color of natural

Weft --2/22 Danish cottolin in color of white

C. Procedures: Set--18 threads per inch

Treadling--plain weave

Motifs were randomly printed along length of warp. Progressively more yellow dye was added to brown/clear dye mixture as printing proceeded.

D. Evaluation of Results: Found difficulty in designing on a long hanging when only a small section of the hanging was printed at one time and the rest was hidden from view. The natural cottolin was found to allow only moderate dye penetration, possibly because of the presence of a finish on the yarns. With the type of motif used this was not considered disadvantageous.