

# Textile graphics applied to textile printing

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## INTRODUCTION

### Description of textile graphics

*Textile Graphics* is a computer-aided technique<sup>1</sup> for developing a textile design and textile patterning mechanism information from an artist's drawing. The computer is operated by a textile designer-technician who understands the particular textile machinery for which he is adapting the original drawing. The designer-technician inputs the original drawing by a combination of graphical input devices; tracing on an on-line digitizing tablet, drawing free-hand with light-pen on the screen of the IBM 2250 and manipulating the design with function keys.

After the original design is in core it is developed into the information to control the patterning mechanism of a specific kind of textile machinery. For example, a design to be woven must represent each *interlacing* of warp and weft; a design to be knitted must represent each *stitch* of the knitted mesh; and a design to be printed must represent the areas of each *color* as separate images.

The development of this information is done according to both structural and aesthetic rules. The designer-technician interacts with the computer using the function keys, light-pen, 2250 and photographic plotter.

When the design control information is developed, it may be outputted under function key control. The form of the output is commensurate with a specific patterning mechanism. For example, for a Jacquard loom which is controlled by punched cards, Textile Graphics output is the pattern of the holes in these cards; for a Raschel machine which is controlled by a chain of cam-links, Textile Graphics output is a map of the heights of the successive links; and for textile printing machines which are controlled by etched copper rollers or silk screens, Textile Graphics output is a set of color-separated films.

### Previous applications of textile graphics

The first application of Textile Graphics was to Jacquard weaving.<sup>1</sup> The Jacquard loom is controlled by punched cards and the designs which it produces may be described in computer terms as rectangular (mxn) binary matrices with a "1" in any position. The size of m and n may vary from "one" to several thousand.

This direct analogy between the representation of computer data and textile design information was noted in a description of Charles Babbage's Analytical Engine. It said that his "computer" weaves algebraic equations like a Jacquard loom weaves flowers. It is this analogy which motivated the original work in Textile Graphics.<sup>2</sup>

Textile Graphics was then applied to developing design control information for lace which is manufactured on a Raschel machine. Although the Raschel machine is a warp knitting machine and not a weaving machine like the Jacquard loom, its design control information is currently developed on a grid paper analogous to the point paper described in Ref. 1. This practice permitted the natural extension of Textile Graphics to lace and other knitted fabric design.

### A new application of textile graphics

This paper describes the application of Textile Graphics to textile printing. The application to textile printing differs from applications to other forms of textile design because the printed textile design is applied after the textile is fabricated.

Since the patterning mechanism is independent of the fabric forming mechanism, there is no need to represent the design on a grid paper, (which for other textiles is translated into row by row, design forming information). However, we will show that for a large class of designs, the color-separated images which printed textile designs require can be more efficiently produced using Textile Graphics.

First, the major current methods of producing printed textile designs are presented. Then, the types of designs are analyzed and reclassified to give more insight into new methods of obtaining color separations.

We combine different parts of current methods with Textile Graphics to expedite the production of the design control information (color separations) for approximately half of printed textile designs. In addition, a new category of printed textiles, whose color separations are easily generated using Textile Graphics, is exhibited.

#### *Current method of preparing designs for textile printing*

##### **Description of textile printing**

There are two major methods of printing designs on textiles. One of these, a roller method, uses etched copper rollers to apply the paint directly to the fabric. The area to be printed is etched in intaglio and the remaining portions are left intact. A separate roller is required for each color.

The other method, a screen process, uses fine silk screens through which the paint is "squeegeed" onto the fabric. Here, the area to be printed is left intact; the remaining portions are masked. A separate screen is required for each color.

Since the roller printing method accounts for the bulk of textile printing production, we will illustrate the application of Textile Graphics to this method. There are analogous procedures for the screen method.

Designs to be etched into copper rollers are transferred to the rollers in one of two ways. Either they are traced, with a stylus, into a coating on the roller, or, a film bearing the design is wrapped around the roller and then photographically exposed. The first of these processes is called the "pantographic process"; the second is called the "photographic process." Each of them will now be described in greater detail.

##### **An outline of the pantographic process**

The starting point for producing a copper roller by the pantographic process is an artist's sketch. The first step in this process begins by putting the artist's sketch in a magic-lantern-like device and projecting it, enlarged, on a coated zinc plate. The projection is then traced with a sharp stylus which incises the design into the plate. The people who perform this operation are called sketchers and are the most skilled and use the most ingenuity in the pantographic operation.

During this process "improvement" may be made to the original design. For example, lines intended to be made symmetric or with uniform thickness, which were not made precisely so by the artist, will at this stage be made so.

In addition, there may be a special treatment along the boundary of two adjacent colors. Frequently an extra line is placed at a specific distance from the boundary. This line, called a double line, prevents adjacent colors from running together. This double line does not actually appear on the printed fabric but is put on the zinc plate and later traced by stylus onto the copper rollers.

After the zinc plate is prepared, it is given to another person called a tracer. The tracer puts the plate on the flat table-like surface of a machine called a pantograph. The pantograph machine has a stylus with which the tracer will follow lines incised into the zinc plate. As the tracer moves this stylus along the groove in the zinc plate, a row of styli are simultaneously moved. These other styli are tracing the design onto a coated copper roller with the appropriate degree of reduction and number of repetitions across the width of the roller. The areas of the zinc plate have been color coded, and the outlines of each color are traced onto a separate roller.

In addition to the original outline which the artist drew, and the double boundaries mentioned above, other information is imparted and traced onto the copper roller. For example, a sizeable flat area will be incised with parallel, diagonal lines called a *ground*. When to use ground lines is part of the knowledge of the engraver in the shop who knows that the paint must be kept at a certain level in the area to prevent blotching and running during the printing process. Therefore, he will specify to the tracer the density of the lines within each area. A device called an indexing drum is put on the pantograph and aids the tracer in placing these ground lines into the appropriate areas.

Another addition to the original artist's information is called *slashing*: the design is placed on the roller so that lines which are perpendicular to the edge of the roller will be slightly angled. The reason for this is so that the metal doctor blade, which squeegees the paint, will not tend to break down the edges (boundary outline) of the roller. Slashing is anticipated in the initial set-up of the styli which trace on the roller. Each successive stylus is progressively displaced along the circumference of the roller.

After tracing, a roller is sent to a touch up bench where it is reviewed and imperfections are corrected before the etching process. The roller is then dipped in acid to etch lines into it. Lines which are to be

etched deeper go through more than one etching stage. Between these stages, certain areas are painted out. After the rollers are etched, they are chrome-plated.

#### The photographic etching method

Implicit in the discussion of the pantographic method was the assumption that the original artist's design could indeed be conveyed by tracing. This is certainly not true of all original artist's designs. Many of them, which have been created by brush effects, and so forth, cannot be recreated by a stylus alone. Therefore, other techniques are necessary to transfer the original art work to the copper rollers. These other techniques are divided into three major categories: 1. those which are purely photographic; 2. those which are purely manual; 3. those which are a combination of photographic and manual. The object of each of these processes is to produce color separation films—that is, a separate film for each color used in the printing process. This is not a separation into red, yellow, blue, and perhaps black. When the textiles are printed, the color which actually appears on the fabric is the color of the paint used in printing. It is not a mixture at printing time of the primary colors.

After these color-separated films have been made, the process for etching the design onto the drum is the same for each of the three techniques named. Therefore, we will discuss this common etching process after the individual processes for preparing color-separated films.

#### Photographic etching Type I— purely photographic

In cases where it is desirable to reproduce the original artist's drawing exactly in the printed textile, and furthermore, where the number of colors in the design as well as their nature is such that each color can be separated by a series of photographs with appropriate color filters, then the purely photographic Type I process is employed. This is, however, applicable in a minority of the cases. In the purely photographic method, the original design is photographed once for each color in the design. A filter is used to remove all of one color from the design. The resulting film represents the filtered color separated from the other colors. This part of the process produces one film for each color.

#### Photographic etching Type II— purely manual

As in the case with the reproductions of most art work in textiles, and also true in some wall paper and

ceramic designs as well, the original art work is not of an acceptable quality for direct reproduction. The reasons for this are many, but, for example, a simple line which may be of varying degrees of thickness in the original art work must be more carefully drawn to have only a single degree of thickness for the reproduction process. Even the artist would acknowledge this and it is not intent which produces the original unevenness but rather the carrying out, on impulse, of the idea. This kind of inaccuracy seems to be a necessary concomitant of the artistic expression. The restraint and precision necessary for the reproducible design is not and cannot be present in the original creation. There have been many attempts to constrain the artist as he works, constraining him to particular colors or to work with a precision with which he does not now work. These attempts have been unsuccessful, and we believe it is because of something inherent in the original creative process. Therefore, the majority of original designs must be manually recreated.

In this manual method, the art work is placed on a table with light penetrating it from below. A clear acetate film is placed on top of the artist's drawing. Another person, also called an artist in the mill art shop, prepares an acetate mask for each color of the original design. He may prepare an acetate copy of an original color using brushes. He is of course doing his best to reproduce exactly what he sees shining through the light table. However, since this is a copy, it is to some extent an interpretation, no matter how faithful he attempts to be.

#### Type III—A combination of photographic and manual methods

Some of the manually painted acetate masks may be negatives of certain colors, others may be direct copies, hence positives. By photographically combining negative and positive films in different ways, it is possible to create masks of other areas.

In the simple example shown in Figure 1,

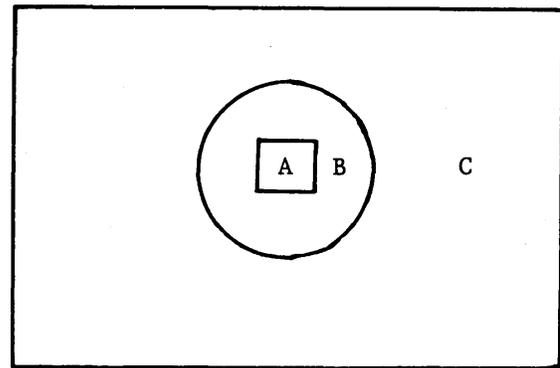


Figure 1—Color "B" is the negative of colors "A" and "C"

if one creates films for A and C, then a film for B can be created by photographing A superimposed on C.

This third category may use some of the original art work to photograph through acetate masks. For example, if there is brushwork in the original which is directly reproducible then it may be photographed and combined with acetate masks of other areas.

#### Choosing method I, II or III

There are cases when it would appear that a purely photographic method is applicable. However, in many cases, there may be an additional consideration; namely, the design will not evenly fit into the basic repeat size of the fabric on the printing machine. Therefore, it must be reduced or expanded by a certain percentage. Although the camera can be adjusted to perform this reduction or expansion, nevertheless, this results in producing a striated effect on the negative rendering it inapplicable for direct photographic reproduction. In cases such as this, a design which seems to be of the purely photographic type may actually be of the purely manual type.

#### Common processes to types I, II, III— photographic etching

After the original color-separated films have been made by one of the three methods above, each film is used to produce what is called a *long film*. The long film bears the original design with as many repeats of it as are necessary to fully cover the roller and is the same size as the copper roller, that is, the same width and as long as the circumference of the roller. This long film is wrapped around a copper roller which is then photographically exposed and etched.

In order to make the long film, the individual color-separated films are put, one at a time, into a machine called a "step and repeat" machine. The data which accompany the original color separation film to this machine consist of the number of times the design will have to be repeated on the drum, and the placement of each repeat. There are step and repeat machines which accommodate these data in some automatic method such as a punch tape control. Other models set the data manually. However, the purpose of the machine is to subject the color-separated film to a number of exposures in different positions. They will be developed on the single "long film." After the long film is developed, it is sent to a room for inspection and correction before it is wrapped around the copper roller and exposed. The roller is then etched in acid.

### Applying textile graphics

#### Categories of printed textile designs

From the previous descriptions of the two basic methods of preparing copper rollers, it seems reasonable to divide textile print designs into two categories: traceable designs and non-traceable designs. Traceable designs are those whose boundaries can be created or recreated (traced) by a stylus. The areas inside the boundaries are characterized by flat painted effects which could be made by a brush although they might as well be made by a device such as a felt-tip pen. Non-traceable designs are those which do not possess these properties. They are characterized by brush and stipple effects.

It should be obvious that traceable designs could be produced on a copper roller by either the pantographic process or the photographic process as these two methods now exist. Indeed what we call traceable designs are sometimes now produced by either process, so that calling such a design by the name "pantographic type" as the industry now does is an artificial distinction.

#### Using textile graphics for traceable designs

Textile Graphics may be used to develop long films for traceable designs which constitute about half of printed textile designs. The input to the computer is an artist's sketch and the output is a series of color-separated long films.

There are three phases of this computer-aided application: input, development and output. During the input phase, part or all of the original artist's drawing is traced on a digitizing tablet; any untraced portions are built up with "symmetry" and other function keys. The regularizing of the design (described above), which is currently done by the sketcher, is done in this phase.

In the development phase, the designer-technician interacts with the computer to develop the additional information needed for printing the design. This information, (described above) which consists of *color separations*, *double boundary lines*, *ground lines*, and *slashing* is currently divided between the sketching and tracing phases of the pantographic operation, or between the painting and photographing phases of the photographic operation. The purpose of this development phase is to develop one complete repeat of the design for each color.

During the output phase, the designer specifies the "step and repeat" information to the computer and a series of long films is outputted on the photographic plotter.

### Input—phase I

Because a great deal of regularizing of the original artist's sketch takes place during the tracing phase or, what is called in the printing mill, the sketching phase, it is necessary to retain this tracing in any computer assisted process.

The artist's sketch is entered into the computer by tracing it on a digitizing device. The tracing styli of commercially available digitizers are electrostatically or capacitively coupled to a flat surface upon which the art work is positioned. As the tracer moves the pencil-like stylus along the boundaries of the design, this outline coordinate data are transmitted into the computer. The data are collected in the computer's main storage and simultaneously displayed on the IBM 2250 display screen. The 2250 also has a keyboard of "function keys." When the operator depresses one of the keys, the computer program determines which key was depressed and branches to the appropriate section of the program to perform the requested "function." Using these function keys and the light-pen, the designer-operator can translate, enlarge, reduce, erase, or repeat part or all of the displayed design. If the design has symmetry, the operator may elect to trace only a portion of it and request the computer to generate and display the remainder reflected about any chosen lines of symmetry.

The advantages of this input technique over both the tracing that is performed in the pantographic method and the painting that is carried out in the photographic method are significant. Less care and precision is required of the operator (sketcher) because the program "smooths" the free hand tracing. Even assuming no data smoothing, the tracing is physically easier. It requires no more pressure on the stylus than that normally used for pen or pencil on paper, while in the pantographic process, the sketcher must *inscribe* the design into a zinc plate, and in the photographic process he must *paint* the outline on film with brush and ink.

The on-line graphic devices speed up the tracing phase of the process for a number of other reasons:

(1) The pantographic sketcher is working on a design at a fixed enlargement. The simpler areas of a design are unnecessarily traced at this enlargement. Conversely, the photographic sketcher is working with a design at actual size, so that the complex areas of the design must be painted at actual size. The computer-aided approach permits the sketcher to trace various sections of the design at different degrees of enlargement. Under function key and light pen control, the completed sections are then overlapped and given a common enlargement factor.

(2) When there is symmetry present in the artist's sketch, the sketcher may need to trace only a portion of the design. The computer program may calculate and display the remaining symmetrical portions.

(3) Any regular shapes, e.g., squares, rectangles, and circles, present in the design would not have to be traced at all. The desired shape is retrieved from an expandable library of frequently used shapes stored in the computer, and displayed on the CRT. It is given the required degree of enlargement and then rotated and translated into position within the design.

(4) Sketching errors are easily corrected with the light pen.

(5) It may be clearly the artist's intent that lines of varying thickness in his sketch should actually be of constant thickness. The sketcher, using brush and ink, would find this operation tedious, at best. Using light-pen and function keys, the sketcher maintains uniform line thickness of any desired amount.

(6) Both the tracer operating the pantograph machine and the sketcher painting acetate film will circumscribe the entire outline twice. In the pantographic process, the boundary line separating two colors will be traced on each of their respective rollers, while in the photographic process, the boundary line separating two colors, will delimit each area painted on their respective films. Tracing on a tablet will eliminate all of the former tracing operation and half of the latter.

(7) In pantographic tracing, if the length of the basic design is a submultiple of the roller circumference (and it frequently is), additional complete tracings are required. A digitizing tablet eliminates this requirement.

### Development—phase II

When the outline of the design has been completely transmitted to the computer, a function key will initiate an algorithm which assigns a unique label to each disjoint area of the design (Figure 2), and displays the labeled areas on the 2250. This algorithm is described in detail in Ref. 1. It performs a raster scan of the design and assigns a zone number to each row segment between "strikes." Every zone is checked against the preceding row to determine if there is any vertical overlapping. If there is, the current zone is given the same label as the zone with which it has common columns. By successive applications of this process, and reassigning labels when it becomes apparent that two zones are equal to each other, it is possible to separate all disjoint areas.

In Figure 3, when the scan reaches row  $(n + m)$  it detects that the entire row is one zone. This row-zone

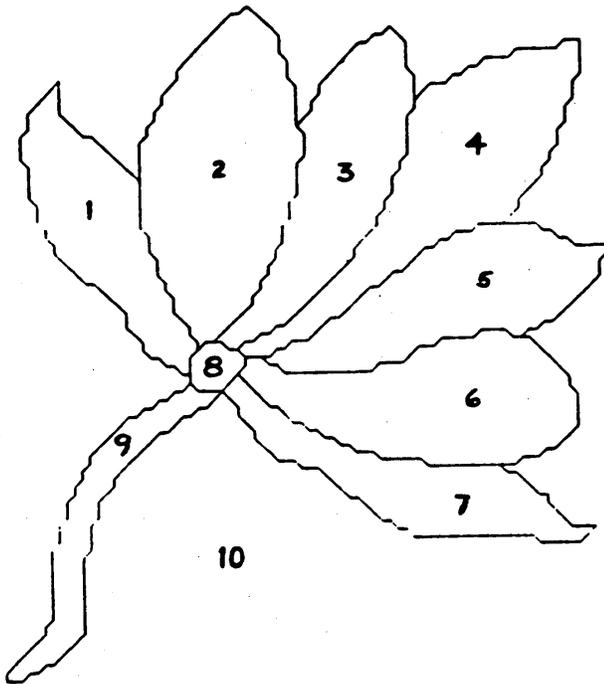


Figure 2—Design with each disjoint area assigned a unique label

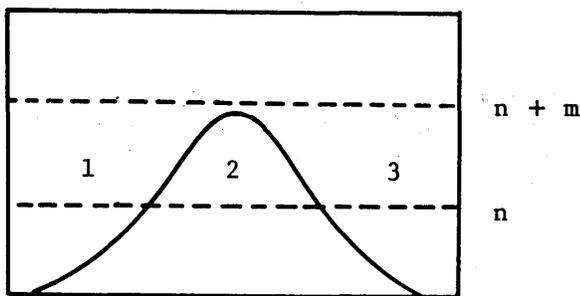


Figure 3—Example of zone merging

is the same as zone 1 because no curve has intervened. On the other hand, the zone of this row is the same as zone 3 for the same reason. Therefore, the algorithm concludes that zone 1 and zone 3 are in the same connected area. A table of zone equivalences is kept, and after the entire design is scanned, each row-zone is assigned its unique area label.

Figure 4 is the inverse of Figure 3.

It should be noted that this algorithm does not make demands on the user to label his own areas as he creates them, a common procedure in some graphics applications. The purpose of our approach is to permit the designer to operate as naturally as possible.

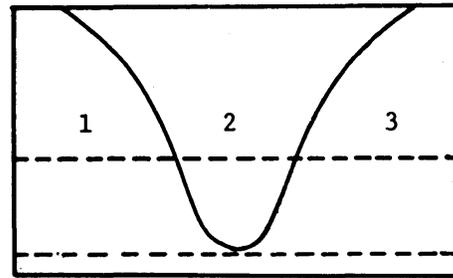


Figure 4—Example of zone diverging

Colors are separated in the following way: the designer uses a function key to enter the "EQUATE" mode. Then he detects, with the light-pen, the labels of all areas which he wants to be the same color. These labels all become the same as the first label detected. A separate file is created containing the set of boundaries for this color. This process is repeated for each color.

Some areas of different color, which have a common printed boundary may actually have such boundaries etched into the respective color rollers at a slight displacement. This displacement prevents "bleeding" of the paint during printing. Such a displacement can be specified on the total design by specifying a double line at such places. The designer specifies, with function keys and light-pen, the areas and the amount of displacement between their common boundary. Then a double line is created along this boundary which will give rise to the proper displacement on the rollers.

The ground lines, which are parallel, diagonal lines within the boundaries of sizeable areas, are used to prevent the paint from running out of the intaglio area on the roller. The areas which need such lines are determined by an engraver and specified by him on the original drawing. The designer-technician transmits this information: name of area, angle of lines and distance between lines—with function keys and light-pen. He may display the design on the 2250 either with or without these lines depending on whether he is looking to make a technical or an aesthetic judgment.

The engraver also specifies the *slashing* angle of the design. The designer, who transmits this, may also view the design with or without this "angling."

### Output—phase III

The output phase of the process is the generation of "long films." These are efficiently produced by an on-line high speed photographic plotter. The film is wrapped around a cylinder and the cylinder is rotated

under a CRT. The scanning electron beam of the CRT is digitally modulated, resulting in a plotting time that is independent of the density of the information plotted.

The computer program was initially supplied with the exact width and circumference of the copper rollers to be used. The basic design has been exactly scaled and adjusted to provide the specified number of repeats, both vertically and horizontally, that will completely cover the roller.

A separate film is now plotted for each roller in the design. For example, the design shown in Figure 5 will

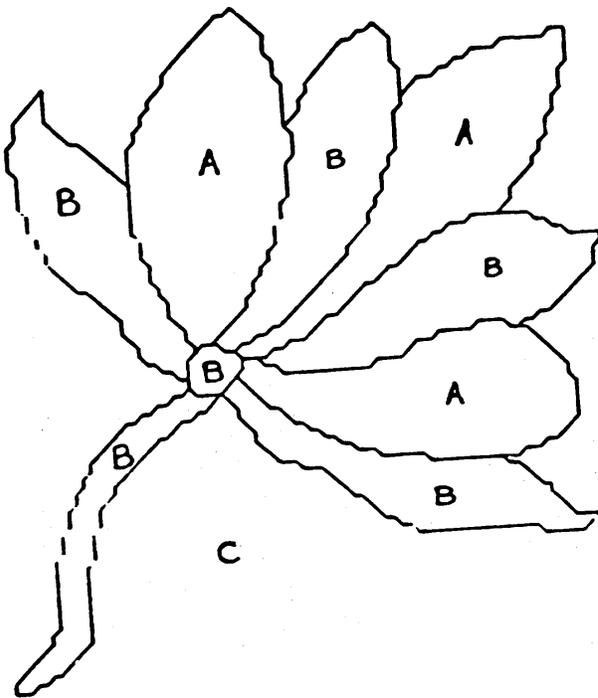


Figure 5—Three color design

result in the color separated films shown in Figure 6. The double line, ground lines, and slashing (which are not shown in the figure) would, of course, be present. Using the on-line plotter to automatically produce the “stepped and repeated” long films has eliminated the set-up time and possible errors that result when using either the engraving machine in the pantographic process or the “step and repeat” machine in the photographic process.

Looking ahead to a “second generation” textile graphics system, it appears feasible to replace the film and cylinder of an on-line plotter with the copper rollers and to directly photo-expose the design.

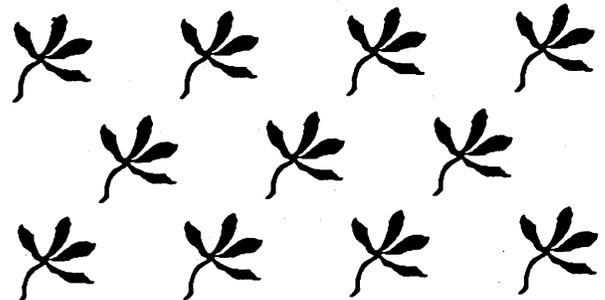
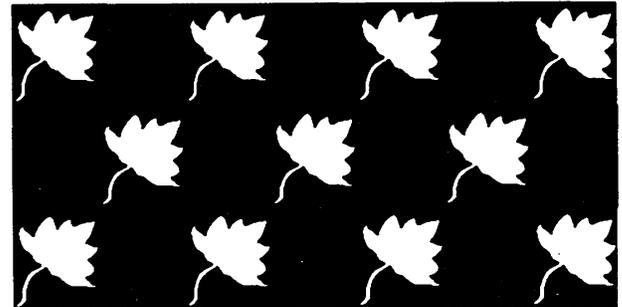
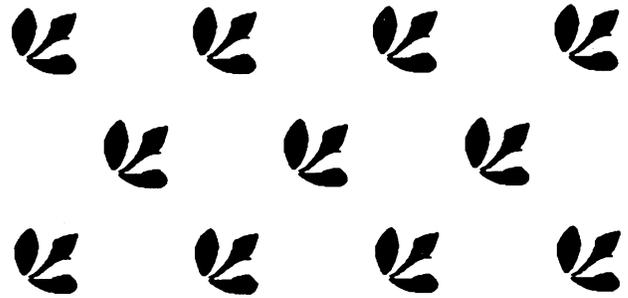


Figure 6a,b,c—The three color separated films of design shown in Figure 5

#### A new designing tool

With Textile Graphics it is possible for the designer to do something which he has not been able to do before.

Both the photographic etching process and the pantographic etching process have a library of “effects.” For the pantographic process this is a set of small round mills which are pressed onto the roller over its entire surface; and for the photographic process this is a library of negatives with repetitive patterns. Both methods use these libraries to generate an entire copper roller with this effect repeated over it.

We store such a “library” within the computer. While sitting at the 2250 console, the designer can specify any of these “effects” to occur within any disjoint area which he points to on the screen. This

greatly enhances his ability to generate patterns since he can use these effects like a Jacquard designer uses "weaves."<sup>1</sup>

An illustration of this technique is shown in the following figures.<sup>7</sup>

The outline of the design is the same as Figure 5. The design is to be printed in four colors. Areas 1, 4, 7 are color #A, areas 2, 6, 8, 9 are color #B, area 3, 5, color #C. The background, area 10, is color D. Note that in areas 1, 4, 7 there is an "effect" which is also color D. This is represented in figure 7.

SUMMARY

We have demonstrated a computer-aided method for generating color-separated "long films" for traceable textile designs; starting with an artist's drawing. These films are the direct input to the roller etching process.

This method merges parts of two processes which are almost distinct at the present time. Namely, the tracing of the pantographic process is maintained, but the etching is continued by the photographic process.

This method is a new application and extension of the Textile Graphics techniques described in Ref. 1. Previously, Textile Graphics had been applied only to Jacquard weaving and to warp-knitting.

We have shown that Textile Graphics can significantly shorten the lead time between the creation of the original art work and the etching of copper rollers. The next logical step is to tie the technique into a fully integrated system monitoring the other operations in the mill. For example, the colors specified for the design, and the anticipated yardage to be produced using this design, would be inputs to inventory control and production scheduling programs. Raw material requirements, finished goods inventory, costing, and printing machine down-time analyses are other areas of importance that can be made available to the textile manufacturer on demand.

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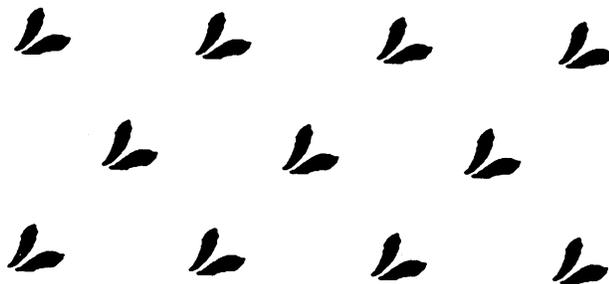
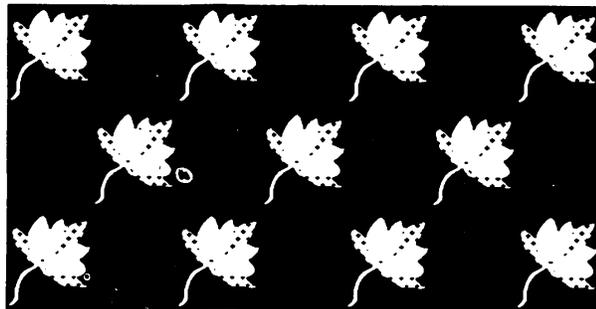
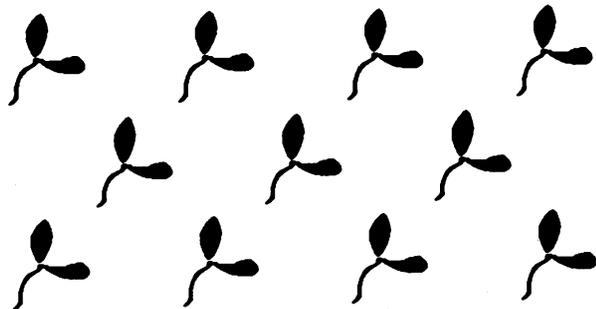


Figure 7a,b,c,d— Color separated films for four color design showing "effects"