

THE DEVELOPMENT OF VISUAL AIDS FOR A UNIT
IN SCREEN PRINTING AND HEAT TRANSFER PRINTING

by

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INTRODUCTION AND JUSTIFICATION

Problems in teaching are numerous, while satisfactory and workable solutions are few. With increasing mobility, large numbers, range of abilities and varied backgrounds of students, it becomes more and more difficult to give individual instruction. Teachers have special needs for instructional materials and techniques that would be interesting, communicative, and effective with all students. Visual aids at every level of teaching are needed. When visual aids are integrated into classroom learning situations, behavioral objectives can more successfully be achieved.

"The resources for learning that teacher and his students use can influence the effectiveness of the instructional program" (5, p. 2). Through a creative application of a variety of media, the chance that students will learn more, retain what they learn better, and improve their performance of their skills is raised. The maximum flexibility in education is gained by the application of audio-visual materials (5).

Teachers should possess and be able to apply special knowledge and skills with respect to selecting, using, and producing many different kinds of visual media (9).

In teaching a textile printing course, the historical background as well as the new developments in the area of printing should be covered. Visual materials such as slide presentation and transparencies would be an excellent teaching aid for the students' benefit. Use of such medias along with the lecture will help the students learn the techniques.

The several phases of teaching in which media resources are applied for different purposes and emphasis have been identified as (a) development, (b) organizing, (c) summarizing, and (d) evaluating (5).

The purpose of this study was to develop visual materials for a textile learning unit beginning with a historical printing background and proceeding to contemporary silkscreen printing and heat transfer printing methods.

HISTORICAL BACKGROUND

"From an historical point of view, dyeing is as old as the textile industry itself and this antedates the written documents of human history. Closely connected with the desire of human beings to clothe themselves against the weather is the desire for artistic effects obtained by coloring the material from which this protective clothing is made" (7, p. 12). Surface design is an orderly repetition of lines or spaces managed in a way that a figure is formed (16).

The beginning of the art of ornamentation of textile fabrics by the stamping or printing on of colored designs is not known. They are usually assumed to have originated in the Far East, where the Hindoos (Indians) and Chinese are known to have practiced.

In recent findings in pyramids and other Egyptian tombs pieces of cloth that assuredly have been decorated by some other technique rather than dyeing itself have been discovered. Without any question the ancient Egyptians were aware of the printing art (1, 16).

“Textile printing was also practiced by the Peruvians before the Spanish conquest in 1531-1532, but whether they discovered the process for themselves or derived their knowledge of it from outside sources is not known” (16, p.3).

It is possible that the Chinese learned the art of block printing from the Indians, instead of the reverse case (25). “In this connection, however, nothing can be positively affirmed; and it is well to remember that, judging by the development of other industries, similar materials and methods would not be at all unlikely to suggest themselves as suitable for the decoration of textile fabrics, to dyers, quite independently, in countries and times widely separated” (16, p. 7).

A printed textile fabric can be produced by a wide range of techniques. Printing is faster, more adaptable and economical. Depending on what technique of printing is used, equipment required is different. Some methods need expensive equipment, others only a very modest device. The production of colored motifs and designs on textile fabrics has a long history. “Patterns were being painted on cloth, using pigment and adhesive mixtures, in the Caucasus area probably from about 2000 B.C.” (25, p. 1).

In the beginnings of the Christian era, mordant and resist dyeing were practiced in China and India. Covered wooden blocks with raised surfaces were used for the design application (25). Mordants were used for fixation of natural dyes.

The development of direct printing technique came much later. Throughout the history there has been a uniform progression to the design and structure of fabric (16).

"A glance at the history of textiles even suggests a close correlation between man's accomplishments in these arts and his progress in other phases of his culture" (1, p. 1).

"It is convenient to consider separately the two fundamental operations of textile printing, namely (I) impression and (II) coloration. The first is the essentially mechanical and physical stage of applying the color; the second includes the selection of suitable dyes or pigments, and the chemical conditions of application, fixation and subsequent process" (27, p. 12).

"The development of improved polymer binder systems, which cause little stiffing and give reasonable fastness to rubbing, has given pigment painting a new importance; it is frequently the cheapest method of producing patterns on textiles" (27, p. 9).

"A process or phase of an industry does not live in a vacuum; neither does it emerge suddenly" (19, p. 1). This phenomena is influenced and controlled by socioeconomic factors, by demands, and technology of related techniques in order to improve and develop new techniques (1).

The screen printing process has been affected by other techniques of ornamentation. Among the first items which have been screen printed in the U.S.A. was the felt banner in about 1910. Joseph J. Odajian of Manhattan, New York, was credited for a stencil (similar to the modern textile screen printing table) in 1924 (19).

Automation and mechanization have increased the production and growth of textile screen printing.

Two new changes in this area are the shift toward rotary screen printing and improvement of heat transfer printing method. These can be successfully employed in the home furnishings area where the heat transfer has found only minor use in items such as table cloth, etc. (32, 15).

The discovery that disperse dyes are transferred easily over short time through the vapor phase, as in Thermosol dyeing, has brought in new ideas and created interest in transfer of prints from paper into synthetic fiber fabrics (25).

"The process of printing fabrics and garments by the heat transfer of design from paper has proved to be the kind of breakthrough that appears on the textile scene rarely and at long intervals" (32, p. 13).

The papers for heat transfer process can be printed at high speed using the trichromatic (3 colors and black) technique (25). "Precisely-controlled temperatures in excess of 200^o C, and times of 15-30 seconds are required to effect transfer. Specially-designed hot presses are used for garments and calenders for fabrics" (25, p. 34). Even during a business recession, the simplicity required in the technique of heat transfer printing, the economic gain, and the capacity for new aesthetic creations, have resulted in the expansion of this area of textiles (32).

The accuracy of the printing does not depend upon the thickness of the fabric. For this reason, knitted fabrics may be used advantageously. The sharpness of design on the heat transfer printing paper

has a direct effect on the clarity of the design transmitted onto the fabric.

SILK SCREEN PRINTING

HISTORICAL BACKGROUND

Stencils

There is no evidence of the earliest stencils because they were made of leaves and skins which decomposed quickly. Some experts claim that the first stencils used by prehistoric man were made from leaves of bamboo trees. When the leaves fell worms ate holes in them. Primitive islanders used the leaves as stencils to decorate their garments with natural dyes. Later these islanders heated banana leaves to shape stencil patterns, which were printed on a thin bark stripped from the malo tree (29).

"In the Far East the Chinese and Japanese between 500 and 1000 A.D. developed the art of stenciling to a high level. Buddhism was rising in importance, and the faithful were encouraged to seek favor of Buddha by duplicating his picture as frequently as possible. This was best accomplished with a stencil" (29, p. 9).

Borrowed symbols from the various religious faiths were customary in many stenciled silks from China. Other common stenciled motifs were swastika, peacock, royal dragon, and conventionalized clouds and waves and flowers.

Later on in China, another method of producing a stencil was employed. An acid ink was used to fashion a pattern on stencil paper. The acid in the ink reacted with the paper producing the stencil. There is not much known about this method, except that it was used by Chinese (29).

During the eighteenth century Japan developed the original of today's screen process stencil. The Japanese processed a method in which a varnish, Shibu, was painted over a single cut-stencil sheet. Use of fine threads of silk or human hairs served to tie in movable joints to the main body of the cut stencil. In this case, varnish was used to hold the hair in place. The printing of cotton and crepe fabrics with stencils was first practiced in Japan during the second half of the seventeenth century. The invention of this process is credited to a Shinto priest, Yuzen. The movable parts were kept in position for the first time without using the traditional way of earlier stencils (29, 31).

Nigerians use stencils in which they paint parts of material with a starch made out of cassava root. The indigo dye will not be accepted into the unstarched area (29).

Grammar of Ornament, published by Owen Jones in 1868, included many color plates and presented different types of decoration. Nine editions of this book had already been published by 1910, for it was a major influence of the stencil designs in wallpaper that textile designers were producing (29).

The Evolvement from Stencils to Screen Printing

The stencil process essentially is like screen printing. In screen printing, a stencil makes the design to be repeated on a screen of silk or metal cloth. The stencil, while it blocks out the meshes of the silk, in some parts leaves open spaces. Since silk was the original fabric used in this process it is called silk screen printing. Modern screen printing utilizes nylon and organdy screens and the process can be traced back to the use of stencils, an art which gained a high level of perfection by the Japanese (30).

A. The open stencil method. Chinese and Egyptians developed open stencils to decorate their clothing materials, exteriors and interiors of their buildings. Their method was composed of open-cut designs done in an impermeable material, such as papyrus, or lacquer stiffened fabrics. The color then was placed through the cut parts of the stencil by means of brush or stipple (10).

B. The lead-stencil book method. No screen is used in this process. The lead stencil book method was first introduced about 1910. The equipment consisted of two boards joined together to form a "book" which was covered with felt from inside. The color was applied by use of an air brush (10).

DEVELOPMENTS OF SILK SCREEN PROCESS

Samuel Simon of Manchester, England, is the first person credited for silk screen process in 1907 (29, 1). In 1915 John Pilsworth

used this method to produce banners for the U.S. Army. F. O. Brant and J. A. Garner established the Velvetone poster company around 1912, in San Francisco. This company claimed to be the first to use this technique for advertising (1, 29).

In 1914 the Selectasine method, a multicolor screen process, was perfected by John Pilsworth. Brush painting was the method in which the colors were applied by means of a stiff brush to the cardboards. This was done before World War I, but soon was replaced by the spraygun. Still, the same type of stencils were commonly used (29).

In photographic silk screen printing patents were issued in 1915 and 1921. This technique used a photographic compound, potassium bichromate and gelatine for covering the screens (1).

France became the first country to employ the screen process technique for textiles in 1920's. In England the carbon-tissue stencil method was patented in 1920 (29, 1).

The development of the hand screen printing is credited to the need of finding a technique for printing new designs for the 'art silks' and other viscose and acetate rayons. This effort was done in the late 1920's and 1930's (30).

"In 1925, the automatic screen-process printing machine was invented, which made it possible to print faster than the ink would dry" (29, p. 12).

Louis F. D'Sutromont of Dayton, Ohio, developed the knife-cut stencil film tissue in 1929. This technique resulted in a sharp and

clean edge to the print. A. S. Danemon who was an associate of D'Autremont patented his new film and sold it under the commercial name of Profilm (29).

European couture houses advanced screen printed silks and wools during the 1930's and early 1950's. The opening of Rockefeller Center in New York during the early 1930's introduced the Art Deco style, a new art style for its time. This style greatly affected the styles and characteristics of the textile and wall paper designs produced by the screen process (29, 30).

Silk Screen Methods

"A number of different methods are used in silk-screen printing to transfer the design to the screen: the stencil-film method, the tusche method, and the photographic method. These methods differ so markedly that each is generally considered a type of silk screen process printing. Each type has its own specific equipment" (1, p. 441).

A. Stencil-film method (knife-cut film). This process is related to stencil painting. A stencil is made for the screen and the stencil film papers are made in such a manner that a layer of film covers a layer of transparent backing paper (1).

A transparent or translucent film is attached semipermanently to a transparent or translucent plastic or paper in the knife-cut film process (30). "While both types of film are used, the film with the plastic backing sheet is used more, especially where atmospheric conditions or moisture absorption will affect large screens and where very accurate registration of colors is essential" (30, p. 28).

The skill of individual performance notably influences the detail that may be obtained in printing. According to Kosloff (17, p. 28), if a knife-cut film is prepared correctly, it may last for 25,000 impressions and up.

The solvent method is designed generally in order to attach the film to the screen. An adhering liquid is essential to dissolve the film partly or soften it so that it could adhere to the screen fabric (17).

Birrel (1, p. 441) mentioned that lacquer-soluble films are sold under various trade names. Some of the better known are: Nu-film, Blue-film, Pro-film, and Viano speed-cut film. Craftint Cut Film is a water-soluble film which must be adhered to a damp screen; it is satisfactory for small patterns, such as Christmas cards, but is unsatisfactory for large screens such as those used in most textile design work.

"The development of knife-cut film in 1930 and 1931 did much more for the growth of screen printing than any other product at that time. It offered a printing screen that could be prepared by the processor, that could print on any surface, could be removed from screen fabric, and print sharp lines with varied type inks" (4, p. 63).

B. Tusche glue or washout screen. "Tusche is a thick opaque paintlike liquid available in either water-soluble or benzene-soluble form. Benzene-soluble tusche is usually a black oily substance. Water-soluble tusche is usually a dark brick red, somewhat like poster paint" (1, p. 442).

This method was mostly used by artists for fine artwork--not for the purpose of commercial needs. These silk screen prints were original prints. They were made by the artist and the artist would also make the component color stencils. This method is advised for beginners to create original works of art since the individual can control created lines and patterns in different surfaces (17).

Method I: Benzene-soluble tusche. When benzene-soluble tusche is used, the design is painted directly onto the inside of the screen with it. When the tusche is dry, a thin coating of glue is spread entirely over the screen, on the side with the tusche painting. LaPage's glue is used for this, in a proportion of about 2 parts full-strength glue to 1 part cold water. The screen is tilted and the glue is poured along one end. With a piece of cardboard the glue is quickly pulled lengthwise in several strokes and then crosswise in several strokes--actually it is best if the glue can be put on with one complete stroke. Nothing must be allowed to touch the screen until the glue is dry. When the glue is dry, the tusche is removed with benzene. Any corrections needed can be made with a water soluble tusche (1, p. 443).

Method II: Water-soluble tusche. A thin solution of dextrin or cornstarch which is boiled in water is used. The design is then carefully painted with water soluble tusche on the inside part of the screen. As soon as the tusche is dry, a thin coat of transparent lacquer is placed immediately over the screen with a squeegee, or it

could be painted with a brush, on the same side of the screen as the tusche (1).

"If a caustic dye-paste is used for printing, a caustic-resisting bakelite varnish should be used in place of the lacquer. When the lacquer is dry, remove the tusche with water. In this case water-soluble paint or dye-paste can be used for printing, or any oil paint which does not soften the lacquer coating on the screen" (1, p. 443).

C. Photographic screens. "Photographic screen process printing is based on the principle that certain coating or substances such as gelatin, polyvinyl alcohol, polyvinyl acetate, glue, or albumin when mixed with such salts as potassium bichromate or ammonium bichromate will be changed chemically or hardened when the coating is exposed to light; while those parts of the substances which are protected from the light by an opaque covering will remain soft and may be washed away with a solvent" (18, p. 25). This is the most widely used method for textile printing since any subject, detail, design or effect may be reproduced with clarity and sharpness (19).

Photographic screens are classified in various ways. There are generally two types: (1) direct, and (2) transfer or indirect type (19). The method for the direct screen process is as follows: "The direct screen process printing plate is prepared directly on the screen fabric either by brushing the sensitized or unsensitized emulsion onto the silk or metal fabric, by dipping the screen into the photographic emulsion, or metal fabric. The emulsion is then dried

into fabric either in completely covering and impregnating the fabric. The dried and sensitized screen is then exposed in contact with a photographic or hand-made positive or negative" (18, p. 25). "Those parts not exposed or protected by the opaque areas on the positive are easily washed away with water, leaving areas open in the screen. The open areas represent the printing pattern" (19, p. 75). A very durable method is direct photographic process.

A description of the other method, i.e. indirect screen, is: "The indirect or transfer type, screen process photographic film, or carbon tissue type screens are prepared first on a temporary support (a transparent thin plastic sheet), then the processed film containing the design to be printed is transferred and adhered to the underside of the prepared and cleaned screen fabric" (19, p. 75).

NEW DEVELOPMENTS

"The development of commercial methods of printing has been rapid. At first, only small screens were used, no wider than the reach of the individual who did the printing" (1, p. 439).

Among the first progress made in commercial printing technique was the use of racks or rails to move the screens above the fabric stretched over a long base table. This arrangement needed two people to operate the squeegee--one pushed it toward the center of the screen and the other then pulled it toward the opposite side. Later on, a wider squeegee was developed which could be held by two persons, one

on either side of the screen, and pulled lengthwise down the screen frame (1).

"While research into, and development of, coloring matter proceeded apace, the means of obtaining the print remained practically unaltered, apart from relatively minor modifications to the printing machine, e.g., improvements to the printing blanket, chrome plating of copper printing rollers, remote control of the registration box-well, and hydraulic loading of the printing rollers" (12, p. 53).

Fritz Buser Engineering Company has invented new electronic devices used in silk screen process machinery, now being installed by many textile plants. The fabric itself is drawn along a table; as it moves it will be printed from screens with squeegees operated mechanically. Eight colors can be printed in this manner. Then the fabric moves on from the printing table to the drying device. This is such a perfect process that the designs on the fabric have the characteristics of the hand painted prints (1).

Mather and Platt in 1956 from the Manchester Engineering Firm, introduced two devices: helical pitching device and hydraulic loading (30).

The Helical Pitching Device

The operation of this equipment is as follows: "Box-wheels" were used in the past for adjusting the roller. This use was eliminated by helical pitching device. This new mechanical device makes a very short raised surface indented area in the drive being transferred to

the mandrel. One single turn of the hand-wheel makes approximately a 1 mm. pattern movement. This system also has an economic advantage which is that the performance of a safe operation is accomplished in less time compared to the older box wheel (30).

Hydraulic Loading

The operation of the device is as follows: "This is more sensitive method of loading which allows the pressure applied on each side of each printing roller to be separately adjusted, measured and recorded so that operating conditions can be repeated accurately day after day. As a result of controlled loading, the expensive lapping on the central bowl retains its active life much longer and the time saved in bringing the engraved rollers evenly to the printing bowl is greatly reduced" (30, p. 98).

The short runs in printing were made possible by the improvement of the fully automatic flat-bed machine. It reduced the cost of printing and this was very important especially with patterns consisting of many colors such as in home furnishings. The printers of home furnishing fabrics were the first to support the device (12).

On all flat-bed screen machines the fabric is held to the printing blanket by an adhesive, so that it does not move between screens to cause misfitting. A water-soluble component is used for the adhesive. It is spread and decorated on the blanket at the entrance to the machine and is washed off at the end, when the blanket is dried to start the cycle (12).

Rotary-Screen Printing Machines

The introduction of the Aljaba machine was the first effort in rotary screen printing machines. This device is formed of a central cylinder with cylindrical screens around the external part of its circular shape. Feeding devices are arranged for printing paste by pressure to the inside of the screen and through the open spaces of the cloth. The Aljaba machine is very light in weight compared with the traditional roller printing machine. On heavier fabrics such as home furnishings and towelling very good prints are obtained by the roller printing machine (12).

"Another advantage of the Aljaba machine is its running speeds of 75 yd/min, now a common practice, compared with an absolute maximum of 20 yd/min for flat screens" (24, p. 45).

Very good accuracy in fitting patterns and in design changes can be obtained in three minutes per color (24).

The rotary screen machine is similar to the flat bed machine, except that the printing stations are closer together, it has a smaller printing section, and a much shorter printing blanket. The rotary screen machine requires less mechanical maintenance than the flat bed machine, as there is no stop-start sequence, and the design register is obtained much more easily (24).

An external supply feeds the rotary screen by pump. The level of paste is controlled by a probe or some other level control, operating the pump. Paste is transferred to the cloth by the pressure of a

squeegee inside the screen. The paste can be different according to the fabric and the type of design (12, 24).

Surface Printing Machine

There are only a few surface complex devices that are used for printing furnishing fabrics. The printing rollers in the Stalwart machine are vertically arranged with the horizontal pairs parallel. A Stuart machine is a modification of the Stalwart machine but it has only one single side unit. This machine is used in the U.S.A. for printing tufted carpets (24).

"The combined rotary-screen and flat-bed machines now supplied by most manufacturers enable warp-stripe designs, with long repeats, to be produced" (24, p. 55).

Roller Printing

For about 200 years, the copper roller method of printing has been used. During this time, there have been very few basic changes in the printing method. The only major development in the field seems to be the Saueressing Machine which still used the same engraved copper roller method (called intaglio). In this machine, central individual back rollers are used in place of a drum (20). Most prints--possibly as much as 80 percent--are still produced by roller printing (24). In the new Saueressing machine the quality of production is controlled by scientific instruments, not by human judgement (30).

DYE INKS FOR TEXTILE SCREEN PRINTING

In choosing the paint for silk-screen printing, the most important aspect is to select a type of paint that will not dissolve the coating used on the screen. The fabric used for the screen must also be considered. Many printers use nylon in place of *silk fabric* for the coverage of their frame. Water soluble paints or pastes available on the market cause nylon to stretch, therefore it makes the screen pliable during printing process (1).

Finishing treatments given to fabrics are interrelated with the chemical composition of the fibers used. New finishes for fabrics and new fibers are introduced periodically by the textile industry. Certain treatments are given to the fabrics at the textile mills or in screen printing plants to remove impurities which may cause problems when the dyeing process takes place. The fabric to be printed should be clean whether it is fastened to a hand printing table or to an endless blanket on a screen printing textile machine. Difficulties may arise when raw silk is screen printed, since raw silk contains a gum known as sericin. This type of silk must be degummed before the dyeing process is started.

"Generally there is no difference between dye paste consisting of the same chemical ingredients manufactured in one part of the world and in another. While these may be the same chemical compounds, they do have different trade names, depending on the manufacturer" (19, p. 45). Synthetic dye products are so complicated chemically that it

would be impossible to market all of them under their chemical name (19). Pigment type ink or paste is the most common type of ink used in textile screen printing. These pigments are very finely divided particles which give color and other properties to the fabrics. These pigments are insoluble in the vehicle, courier or the coating material in which they are mixed. Pigments contain colored, transparent white particles of synthetic and mineral origin. These particles are very finely ground and dispersed in the carrier. Extender is another name for the transparent pigment. A suitable binder or carrier is fixed onto the fiber for pigment fixation (19).

The pigment type inks can be used for all types of screen printing process. The pigment inks can reduce "crocking" or rubbing off of color through abrasion. In order to get the best result for printing, the fabric should be free from sizing and finishing agents. The pigment dyes requiring two operations after printing--drying or driving off the vaporizable materials, and fixing the binder in order to set the color. One of the advantages of the pigment ink is that it may be used directly from the container or the color may be mixed simply by the processer. These colors have excellent fastness to light, to washing, and to dry cleaning.

In order to get variety of different shades and tints, the pigment dyes can be combined together. The pigment dyes can be printed on the same cloth with other types of dyes. They are easy to clean off the printing screen. Any print detail can be printed on all natural, synthetic or blends of fibers by the use of pigment dyes (19).

PAPERS AND CARDBOARDS USED IN SCREEN PRINTING

Cardboards

The types of boards which are suitable and available for the screen printing process are showcard boards, lined boards, paste boards, etc. These are supplied in white and a variety of colors and in different thicknesses. The most suitable and satisfactory board is a straw board especially when it is covered or wrapped with paper. The lined paper could be either white or colored, and it should be lined before the screening process. This is done because there is a certain amount of grease in the pulp which will show through the screen paint if it is applied directly on the brown surface of the board, especially in the less expensive grades (10).

Paper

The most commonly used paper for screenwork is the M. G. (machine glazed) paper. The paper is supplied in terms of 500 sheets, and the thickness is denoted by the weight per ream (10).

CONCLUSION

The textile industry has found that screen prints have an advantage over the faster roller printing of textiles, because screen colors penetrate the cloth much more deeply. This makes it possible to obtain brighter colors which were popular during the 1960's (29). "The extreme versatility of this medium has opened completely new

possibilities for design and expression to the textile designer" (29, p. 14).

Historically, each new development in the textile technology has brought about new ideas for printing. A good example is the roller printing designs which could not have been done by block printing. Screen printing makes designs which cannot be achieved by roller printing, and now transfer printing is the most adaptable and expanding technique in the field of textile printing (4).

HISTORICAL BACKGROUND IN HEAT TRANSFER PRINTING

"The concepts of transfer printing and vapor phase dyeing are not new--more than 100 years ago, embroidery transfer prints were obtained by women who ironed on a design made up from shellac and ultramarine" (23, p. 59). Kartaschoff was the first one who observed the vapor phase dyeing of secondary acetate with different anthraquinon (a yellow crystalline ketone $C_{14}H_8O_2$) dyes in 1925. Since then others have investigated vapor phase dyeing of polyester and polyamid fibers (23).

This method of printing fabric has resulted from the decalcomania (the art or process of transferring pictures and designs from specially prepared paper as to glass) process. It is based on the principle of transferring a previously printed design on a paper or similar vehicle to a textile material which is knitted, woven or of any other construction (33).

Dry Method

The main important element in dry transfer printing is sublimation, in which a solid is changed into a vapor by heat and back again into a solid on cooling. For this reason, the process is sometimes referred to as sublimation, gaseous or vapor phase transfer printing. In simple language, the transfer printing method operates as this: A special variety of prepared paper is printed in a design form containing one or more colors with specially formulated transfer printing "inks," actually dyes (33). This method was developed to produce a satisfactory way of printing on 100 percent polyester double knit fabrics because other techniques were not suitable for this type of fabric (4).

The process we know today as vapor phase dyeing or transfer printing was first introduced by the firm of Sublistatic about 1968. This process involves the transfer of a colored pattern from a specially prepared paper to a synthetic textile material by the application of dry heat. There is no further treatment required, because the dyes will be dried immediately (6). Knitted fabric can be transfer printed in 3 ways: (1) in yard goods form, (2) in fully constructed garments, or (3) partially constructed garments.

There are two processes involved in heat transfer printing. First, designs are printed on a paper with ink containing sublimable disperse dyes. Second, the printed paper is placed in contact with fabric. Heat and pressure are applied to the back of the paper. The

dyes transfer by subliming from the paper onto the fiber surface penetrating into the interior of the fiber (22).

METHODS OF HEAT TRANSFER PRINTING

Dry Method

The principles involved in this technique date back to the 1920's. Two patents were issued to British Celanese for a technique by which acetate rayon could be dyed under dry conditions by exposing the fabric to vapors from heated disperse dyes. Radio-frequency (electro-magnetic wave) heating is recommended for this type of transfer printing (22).

This process has been established by the Swiss-based firm Sublistatic S. A. and became very important after an exhibition in Atlantic City in 1969 (3). According to N. dePlasse (3, p. 240), sublimation transfer printing is 'dry dyeing'.

The best results in transfer printing are obtained on "Terylene" and other polyester fabrics when sublimable disperse dyes are used to print the paper (33).

Wet Method

In Japan two related techniques have been developed since the early 1970's. They are the 'Max-Spielio' and 'Plus-Max' methods. The term 'wet'-transfer is often applied to all of these processes, but there are differences between them in terms of fixation and pressure in order to make the dye to transfer to the fabric. In all processes

a washing off treatment (aqueous or solvent) is needed to remove the excess dye from the fabric (3).

Joseph Dawson (Holdings) Ltd., developed the wet transfer printing method. This printing process is based on the fact that transfer papers are used for fibers that have no attraction for sublimable dyes. The paper which is printed with the appropriate dyes, e.g., acid dyes for wool, basic dyes for acrylic fibers, is brought into contact with the textile which has previously been impregnated with an acidic aqueous paste and heat is applied. By the use of radio-frequency heating, thick masses of garments or fabrics can be quickly and uniformly printed (11). "The printing of woven or knitted fabrics of wool or acrylic fiber in lengths of up to six feet and widths of up to three feet is also possible" (11, p. 18).

DYES AND INKS USED IN HEAT TRANSFER PRINTING

"The dyes used for sublimation printing must be capable of being vaporized very fast at temperatures below those at which the cloths to be printed would be damaged within the range of 150° to 220° C" (11, p. 14).

If the dispersion of the dye is insufficient, the result will be unsatisfactory. Dye which has not been reduced in particle size will be present in the ink in crystalline forms. When the ink is printed and then transferred, the crystal particles will transfer, and result in a spotted print which is totally unsatisfactory to the textile industry (33). Fastness properties are the most important

characteristic of a dye. Disperse dyes are grouped into three energy levels, depending upon the degree of exhaustion from the paper at a given temperature: (a) Low energy, 80-90% exhaustion, (b) Medium energy, 65-80% exhaustion, and (c) High energy, less than 65% exhaustion. In order to get the proper color, it is important to choose the dyes in the same energy level range (33).

"Energy levels become specially critical when (1) the conditions of time and temperature vary as they may very well do to some slight degree from one day to the next, or (2) two or more colors are blended together to achieve a desired shade" (8, p. 27).

The degree of sublimation always depends on the pressure of the dyes which increases by temperature. The temperature at which a dye sublimates is determined by its molecular weight. Dyes which have been found suitable for transfer printing under practical conditions have molecular weights between 250 and 400. But the number, type and location of color groups have direct influence in sublimation (26). "A dye with a lower molecular weight, but with a more strongly polar structure, may sublime less than a higher molecular weight dye with lower polarity" (26, p. 84). According to Borden Chemical in its development of the heat transfer inks, solvent and water based inks have been used for printing transfer papers. The drying properties of the solvent based inks are better than the water based inks. Water based inks will penetrate through the paper. It is very important to determine the solubility properties of the solvent based dyes. Disperse dyes have a wide range of solubility levels--some will dissolve much faster than

others depending upon their molecular weight, polarity and other physical and chemical properties (8).

DEVELOPMENTS IN HEAT TRANSFER PRINTING

In England, the development of the transfer printing operation was expedited by the adoption of transfer printed fabrics by Marks and Spenser, a large English merchandising chain. One of the major improvements in the art of decorating textile fabrics has been with the development of heat transfer printing (26).

Developments in Wet Transfer Printing

There are new possibilities for those fibers which cannot be dyed with dry heat method of transfer printing. The Fastran process was developed by CIBA-GEIGY Limited and by Joseph Dawson (Holdings) Limited. The wet fabric and paper are heated on a conventional flat-bed press. High frequency heating provides quick and uniform energy transfer. The dye transfers from the paper and becomes affixed by the steam generated from the heated water (26). After the process of wet-transfer printing, the fabric must be washed, the thickner must be removed and the fabric must be frame dried (26).

Developments in Dry Heat Transfer Printing

The dry heat transfer printing of polyester/cellulose is a new development in this area. With this method, the transfer occurs for 100% polyester with dry heat. By choosing the correct dyes, both

polyester and cotton can be dyed the same shade and depth, and good color and fastness are obtained. This method is known as the Hecowa Print Process of Heberlein Holding, A. G. (26).

Vacuum Transfer Printing

This is another recent technique. "In 1966 F. Jones of Leeds University described the vapor phase dyeing of polyester under vacuum conditions" (6, p. 59). The vacuum improves sublimation of the dye-stuff. This makes it possible for high energy dyes to be transferred on polyester. It also reduces the time on the transfer machine, or decreases the transfer temperature for delicate polymers such as acrylics (26).

By using the vacuum system, the gaseous dyestuff will penetrate in to the interstice of the fabric. A noncontinuous version of this has been successfully employed on carpet tiles to penetrate the full length of the tufts. This concept will increase production and is less harmful for delicate fabrics and also preserves the texture of certain materials (33).

A West German company, Kannegiesser, is building transfer printing equipment using the vacuum principle in its vacumat machine. When the sublimation process is taking place, vacuum is used to hold the fabric being printed onto the main drum.

With the use of the vacuum it will be possible to transfer high energy dyes to give better sublimation properties (33). "Other advantages claimed for this machine are elimination of glazing and

flattening of the fabric in addition to improved penetration of the dyes" (33, p. 22).

PAPERS FOUND IN USE IN HEAT TRANSFER PRINTING

80 gm² cartridge

70 gm² wood free

60 gm² mechanical

55 gm² M. G.

70 gm² coated wood free

70 gm² M. G., loaded (6, p. 9)

Mechanical is the name given to papers made by using pulp prepared from trees by a mechanical, e.g. grinding process. These papers in general have poor color, low strength and poor light stability (6).

Wood free papers are made from chemical pulps, using fibers derived from hard-woods and soft-woods, and containing not more than 5% of mechanical wood (6).

"Loaded papers are made by incorporating in the finish an amount-- sometimes over 20% on weight of fiber--of an inorganic pigment such as china clay, titanium dioxide, etc. The function of this loading is to improve the opacity, appearance and stability of the sheet and reduce cost" (6, p. 9).

The terms mechanical, loaded, and wood free deal with the material used to make the paper (6).

"M. G. (machine glazed) papers are made by pressing the sheet at a part-dried stage, and containing 40-50% moisture, on to a revolving

glazed cylinder. The moist sheet adheres to the polished surface, and dries in contact with it. The dried sheet is peeled from the cylinder, with a glazed finish on the side which dried in contact with the cylinder. The reverse side of the paper is relatively rough" (6, p. 10).

A suitable paper must have these characteristics:

- 1) It should be technically acceptable at the paper printing stage.
- 2) It should be technically acceptable at the transfer stage.
- 3) It should be commercially acceptable (6).

A sufficient thickness and substantiveness is required for the paper in order to be handled mechanically during the printing time. Also the paper must withstand both human and mechanical handling when in heat transfer process (26).

The paper should also have these properties:

- a) good ink holdout--the ink should remain on or as near as possible to the surface of the paper, thus assisting dye release;
- b) should have freedom from pin holes;
- c) should be free from surface-born foreign matter. Foreign particles on surface of the paper may be printed very successfully (26).

Paper for this process has only been produced in the United States since 1970; before that, all the paper came from Europe, and there was only one source (Sublistatic). Now paper is printed in at least 12 countries: i.e., United States, United Kingdom, Belgium, France, Switzerland, Germany, Spain, Italy, Japan, Republic of China, Mexico and Australia (7).

DEVELOPMENTS IN HEAT TRANSFER PAPERS

Twin Tran paper made by "Trantex" holds designs on both sides and can print two webs of fabric in one press (33).

"Brian Lyttle has a paper from Flo-Tech Corporation which is printed by the floatation method where the dyestuffs are dropped onto a moving web, which is then agitated resulting in a swirl-like pattern. Unlimited patterns are produced by the use of a computer" (33, p. 22).

According to Irving Lackritz who is the general manager of Ortherm Division of the Orchard Corporation of America, "Paper is being produced with an overall application of dyestuff and then heat transferred onto a blend with polyester and cotton. The polyester accepts the color while the other component rejects it, resulting in a heather or denim look" (33, p. 23).

"Orchard Corporation claims that its Ortherm transfer paper can run 25% faster than previously because of special dyestuffs developed by DuPont which sublimes 25% faster maintaining high integrity of color" (33, p. 22).

CONCLUSION

The changing textile market will affect transfer printing in a most beneficial way because this method of printing lends itself to any last minute change (4).

In conclusion transfer printing is still in its beginning stages. It is a permanent method of printing in textile industry.

This method can achieve a very high level of perfection with the interchange of ideas from all divisions of the industry (30).

It can be claimed that heat transfer printing is becoming accepted as a technique. This is due to the technical and commercial work of the paper printers. Heat transfer printing is highly suited to the current development of the fashion articles. There are rapid changes in the demand for this process of printing fabrics and it is expected that transfer printing will meet these successfully.

SUMMARY

The past 10-15 years many changes have occurred in the complexion of textile printing. The industry has gone from a predominantly intaglio engraved roller printing industry (90%) in 1964 to an estimated 60% roller 40% screen ratio in 1974, with rotary screen capturing virtually all of the growth. (21)

"A fast-growing section of the printing industry in recent years is that dealing with carpets and floor covering. In addition to the stalwart machine, flat-bed and rotary-screen machines are used." (33, p. 55) Good penetration of the pile is essential, so, in the flat-bed screen-printing machine invented by the Bradford Dyer's Association, powerful suction is applied below the carpet at the point of application of the printing paste. The Zimmer flat-bed machine using two magnetic rollers is considered to produce good results on low to medium-high piles.

According to Howarth, A. (33, p. 55) recently, printed bed-sheets have been introduced, and so far the flat-bed screen-printing machine has been used for printing them. Although it is expensive to make screens for printing the full width of the fabric, and a long repeat length is necessary, these disadvantages are accepted, for, in general, long printing runs are available. The automatic rotary screen printing machine is the machine of the moment for textile

printing. It offers a simplicity of operation and versatility. (22, 33)

Transfer printing has attracted considerable attention and capital investment. Although the heat transfer technique was proposed as early as 1938, successful commercial development occurred only from 1966 after pioneer work by the French company Filatures, Prouvost, Masurel La Lainiere de Roubaix. Polyester and cellulose tricetate fabrics are ideally suitable because of the good color range and fastness to washing of the prints obtained and the stability of these fibers at the temperatures employed. Production of printing transfer paper was originally available in limited widths (30-36 in.), but new gravure plant has made widths up to 84 in. possible. In addition to gravure printing, Flexographic and lithographic techniques have been used. It has been suggested that rotary-screen printing could increase flexibility in volume of dye applied and length of economic run. Rotary-screen machines suitable for printing wallpaper and transfer paper have been constructed with drying units between printing positions. The long-term possibility that textile printers will print their own paper and offer a complete service, choosing transfer or direct printing according to circumstance, has therefore emerged. It is not yet clear whether the same screens could be used to print paper or fabric, or how costs would compare. (24, 33)

There is every reason to believe that similarly many changes will occur within the next 10 years which will have considerable impact on the print operations of many mills. However, the transfer printing

operations are not always of the highest quality. Sometimes transfer papers which have already been printed before are used in low quality fabrics. Moreover, it is possible to make money quickly in these first stages. The transfer printing machines are relatively cheap and few are needed in contrast to the tremendous amount of money unavoidable for large scale factory operations. If the competition stiffens, later by the time they quit, they will not have suffered a loss because of the small investment and the early profits.

"Transfer Printing, this dynamic industry, which has been enjoying a fantastic growth rate recently, discovers that it is not immune to fashion swings and a general decline in prints, causing widespread concern." (32, p. 37)

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APPENDIX

**SILK SCREEN PRINTING
SLIDES**

Visual

Narration

A-1. Basic wooden screen frame and four methods of joining the corners	<ul style="list-style-type: none"> a. A simple butt joint glued and pinned with oval nails b. The same joint this time fixed with corrugated dogs c. A simple halving joint glued and pinned d. A shoulder joint glued and pinned
A-2. Covering the screen frame	<ul style="list-style-type: none"> a. Pin, tack or staple one side in the order of the numbers, making sure that there is some tension between 2 and 3. b. Now pin or tack the opposite side in the same order, but this time stretching the material tightly, using the thumb and forefinger. Pin the other two sides in the same way, checking that the warp and weft of the organdie (the fabric used on the frame) remain as true as possible. c. Finally tuck in the corners neatly and trim off any surplus material.
A-3. Masking the frame	Gumstrip (masking tape) is stuck to the outside of the screen to form a mask to contain the pigment and at the same time control the size and the shape of the print.
A-4. An example of how the process works	<ul style="list-style-type: none"> a. Marking the perimeter of the shape to be printed through the organdie with a soft pencil or charcoal. b. Cut out newsprint shapes placed on the marked sheet ready to be picked up by the screen. c. Squeegee in the pigment across the screen to pick up the newsprint shapes. d. The printed design remaining when the screen has been lifted away.
A-5. Methods of supporting screen frame	Usual method of supporting the screen frame with pin hinges on a movable printing base, which is placed on a stationary table. With these means, the screen frame is readily removable.

A-6. Hand model screen	Hand model fitted with adjustable hinges.
A-7. Griffon screen printing table	The Griffon screen printing table with Formica base and counterbalanced screen frame.
A-8. Screen printing unit	The simplicity screen printing unit incorporating a vacuum base and one-arm squeegee attachment.
A-9. The K.P.X. Automatic screen printing machine	This unit is powered by compressed air.
A-10. Argon vacuummatic screen printing machine	This unit has automatic take-off unit.
A-11. Argon Ultramatic screen printing machine	The Argon ultramatic screen printing machine with the "Ink-o-flux" attachment which is an automatic ink feeder which feeds the exact quantity of ink needed for one print directly on to the screen at the beginning of each printing stroke.
A-12. Table for exposure unsensitized (Ulano polyx) films	See attached sheet.
A-13. Table for exposure presensitized (Ulano super prep.) film	See attached sheet.
A-14. Comparison table of wet and dry exposure methods	See attached sheet.
A-15. Line drawing of hand screen printing	Hand screen printing with a simple registration and stop system.

A-16. Rotary screen printing machine RD-IV by STORK	The RD-IV can print repeats of up to 2 yards. For bigger repeats it can be equipped with an Intermit System and with Rema Color system. A simple modification enables the machine to be used for printing transfer paper.
A-17. Rotary screen printing by STORK	Adjustable support rollers. This is a close up of the idler.

A-12. Table for Exposures

Light source	Carbons	Distance		Seconds
		inches	cm.	
20 amp carbon arc lamp	3	32	80	45
30 amp carbon arc lamp	2	40	100	60
40 amp carbon arc lamp	2	30	75	35
60 amp carbon arc lamp	3	56	140	50
1 HPR 125 W	-	20	50	90

A-13. Table for Exposures

Light source	Carbons	Distance		Seconds
		inches	cm.	
20 amp carbon arc lamp	3	32	80	270
30 amp carbon arc lamp	2	40	100	360
40 amp carbon arc lamp	2	30	75	200
60 amp carbon arc lamp	3	40	100	120
1 HPR 125 W	-	16	40	300

A-14. Wet Method Procedure

1. Sensitizing tissue.
2. Squeegeeing sensitized tissue onto temporary support.
3. Exposing WET tissue.
4. Washing out in hot water and removing backing sheet.
5. Attaching developed tissue to screen fabric.

Dry Method Procedure

1. Sensitizing tissue.
2. Squeegeeing sensitized tissue onto temporary support.
3. Drying and removing sensitized tissue from temporary support.
4. Exposing DRY tissue.
5. Immersing exposed tissue in cold water and squeegeeing it onto temporary support.
6. Washing out in hot water and removing backing sheet.
7. Attaching developed tissue to screen fabric.

HEAT TRANSFER PRINTING
TRANSPARANCIES

Visual	Narration
B-1. Diagram--Gravure Printing Unit	The diagram shows basic gravure printing unit. Lower image-carrying engraved cylinder rotates in fountain of fluid ink. Ink dries rapidly after printing.
B-2. Diagram--Flexography Printing Unit	The diagram shows typical arrangement of rollers (cylinders) in a flexographic press. Sizes vary widely for different purposes.

HEAT TRANSFER PRINTING
SLIDES

Visual	Narration
C-1. Press operation condition. Recommended time and temperature conditions for various fibers	<p>Polyester--200-230°C (392-446°F) 20-45 s</p> <p>Nylon 66 --190-210°C (374-410°F) 20-40 s</p> <p>Nylon 6 --190-200°C (374-392°F) 20-30 s</p> <p>Secondary acetate--190-200°C (374-392°F), 15-30 s</p> <p>Cellulose triacetate--190-210°C (374-410°F), 20-40 s</p> <p><u>Acrylics</u></p> <p>Courtelle--190°C (374°F) 20-40 s</p> <p>Acrilan, Orlon--200-210°C (392-410°F), 15-30 s</p> <p>It is recommended that the first experiments are conducted at the lower temperature and the shortest time. If this is not completely satisfactory then the time should be extended before raising the temperature.</p>
C-2. The Hunt & Moscrop	The first British machine for continuous processing (1969). Also called Transfaprint. 6 ft. model by: Hunt & Moscrop Limited.
C-3. Heat transfer machine single and double tray feed	Used for sublimated heat transfer printing. By: Union Special.
C-4. Heat Transfer Dew Print Machine	Dew Print machine is by Dinting Engineering Works, a division of Tootal Ltd. Dew Print machine utilizes the wet process because fabric is "wet-out" in a solution containing a thickener of the normal textile type dissolved in water. There is also a PH buffer system to maintain the correct PH during the fixation stage.
C-5. Examples of lithographic heat transfer printing	Holt Manufacturing Company developed engineered lithographic heat transfer printing in 1970, and was the first in the U.S.A.

<p>C-6. Morrison Heat Transfer Printing Machine Model 960</p>	<p><u>Features of the machine</u></p> <ul style="list-style-type: none"> --8" diameter specially designed oil cylinder --short heat-up time --temperature controlled within $\pm 10^{\circ}\text{F}$ --choice of oil heating systems, gas, propane, oil or electric --more yards per minute, per hour, per shift. Continuous operation. --reversing gearmotor drive --accurate cloth guiding system
<p>C-7. Photo-lith heat transfer press</p>	<p>A new transfer press--it can meet every heat transfer requirement a manufacturer might have for ready to wear, cut piece goods, or full panels. It handles all heat transfer processes--photo-lith (lithographic) and photo-static (sublimated) on all types of cloth. And it's manufactured for high-speed application.</p>
<p>C-8. STORK TC 101 Model</p>	<p>Transfer calender with excellent result. It is a compact calender that occupies little room. Its length is 125 cm and its width is 260 cm. The calender is equipped with a 24 hour timer switch that can be adjusted in such a way that the machine has the correct temperature when working hours start. Dependent on the desired printing result the transfer speed may vary between 3 and 5 metres per minute at a maximum cloth width of 180 cm.</p>
<p>C-9. STORK TR 101 Rewinding and inspection unit for transfer paper</p>	<p>In order to be able to inspect printed paper and moreover to rewind onto smaller reels, the rewinding and inspection unit TR 101 was developed. This unit can process a maximum of 200 cm wide transfer paper with a maximal clean web width of 190 cm.</p>

C-10. STORK VACUUM Transfer Calender TC-451	With the TC-451 the transfer process takes place continuously under vacuum. Due to the vacuum the sublimation point of the dyestuff is 30°C lower than under normal atmospheric pressure. This means that transferring can already be carried out at temperatures of 180°C. The polyester fiber is less deformed and the cloth maintains its flexible touch.
C-11. As above	As above.
C-12. Rotary screen printing	Printing transfer paper with the STORK rotary screen printing machine. This is a very recent development of the short history of this printing method. In 1970 STORK began an investigation into the possibilities, starting from the principle that it is possible to obtain great variations in dyestuff.
C-13. Printing paper for heat transfer printing with rotary screen printing machine	A rotary screen-printing machine is easy to operate and a team of three operators is sufficient. The advantages are: --low screen cost --simple engraving method for screens --short changing times --simple operation, which can quickly and easily be learned, even if the operating personnel have little or no printing experience, as printing is always done on one material only (paper).
C-14. STORK TC-1 Calender	These transfer papers are ready to be transferred on a continuous heat transfer calender. The slide shows STORK TC-1 Calender.

THE DEVELOPMENT OF VISUAL AIDS FOR A UNIT
IN SCREEN PRINTING AND HEAT TRANSFER PRINTING

by

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The slide and transparency presentation accompanying script of silk screen printing and heat transfer printing for use in textile laboratory was produced. The planning and shooting of a slide series and transparencies gave an opportunity to develop a teaching aid that is both interesting and useful.

The production of these visual aids involved planning and preparing the slide story, writing the shooting script, shooting the pictures, arranging the finished slides and preparing the instruction script. These series of slides and transparencies were designed for use in the textile laboratory class to help students to have a better understanding of the equipment and methods involved in the process and technique of silk screen printing and heat transfer printing.