As textile fibers have been discussed for their varied qualities and as the spinning and weaving processes have been explained, the qualities of durability and serviceability have been constantly stressed. When the yarn is made into fabric, the interesting and intricate constructions begin to add beauty of appearance as well as serviceability. The various finishing processes suggest additional means of enhancing the appearance of the newly formed fabric. It remains for the dyeing and printing processes to provide lasting beauty and delight to the beholder by adding color to fabrics. Dyeing and printing differ in the method by which color is applied to fabric. In the dyeing process, fiber, yarn, or fabric is impregnated with a dyestuff. In printing (described in Chapter 12), a pattern or a design is generally imprinted on the fabric in one or more colors by using dyes in paste form or some related means.

SELECTION OF DYE

To select the proper dye for a fiber, it is necessary to know which dyes have an affinity for the vegetable, animal, or man-made fibers. In general, the dyes used for cotton and linen may be used for rayons, but other fibers require different dyes. When a dye colors fabric directly with one operation of impregnation, without the aid of an affixing agent, the dye is said to be a *direct dye* for that fiber. Direct dyes are the easiest to produce, the simplest to apply, and the cheapest in their initial cost as well as in application. They, however, like other dyes have their own limitations. One of these is the degree of *color-fastness*.

Fastness of color refers to its ability to remain unchanged. Different dyes of different colors have different degrees of fastness to various conditions. For example, a color that may have good fastness to laundering may have poor fastness to light. Color fastness may be affected by such factors as perspiration, dry cleaning, bleach, salt water, swimming pool additives, atmospheric gases, or air pollutants. Also, certain dyes may *bleed*, or run, when wet and may cause discoloration of other fabrics. Some dyes may *crock*, or rub off, due to the friction of wear.

Consequently, selection of the proper dye is crucial to its ultimate use. Fastness to light is important in draperies, for example, as they must stand strong light daily but do not need to be washed frequently. Fastness to washing is important in dress fabrics and household linens because they must undergo frequent washings. Therefore, both the kind of fiber to be dyed and the intended use for the fabric should be considered.

Once a color has been selected, it is essential that its formulation be kept consistent. Each batch that is dyed must have its *dye lot* number. Since variations can occur in such factors as chemical concentration, fiber structure, water content, or temperature and cause a slight change in color, each dye lot will be slightly different. Matching apparently the same color between two different pieces may become a problem. It is therefore important to use material from the same dye lot when piecing together such items as apparel or drapery.

Sometimes a color may be formulated by a dyer to match an existing color on a fabric. When two or more types of fabrics are dyed, particularly by different dyers, the colors may appear to match in one light (e.g., daylight) but will not match in another light (e.g., incandescent light). Such a condition is known as *metamerism*, or *color flare*. Prior testing should be made on samples to avoid this difficulty.

NATURAL DYES

Primitive people obtained dyes from flowers, nuts, berries, and other forms of vegetable and plant life, as well as from mineral and animal sources. These sources have provided such natural dyes throughout civilization. They are no longer used in quantity by the dyeing industry, but they are still used in Oriental countries to a certain extent for rug dyeing and in many parts of the world for native handicraft.

The principal vegetable dyes are fustic, sumac, catechu or cutch, madder, henna, saffron, logwood, indigo, and alizarin. Animal dyes, such as cochineal, squid sepia, lac, and Tyrian purple, are obtained from species of fish and small insects. Minerals provide such dyes as Prussian blue, chrome yellow, and iron buff.

SYNTHETIC DYES

Although synthetic dyes were first derived from coal tar in 1856, they were not developed in the United States to any great extent until World War I, when the supply of imported synthetic dyes was cut off. Since then, the United States has built up a dye industry that is unsurpassed. Innumerable dye compounds made from coal tar have now supplanted natural dyes. These synthetic dyes are constantly being improved as to beauty of color and colorfastness. Lasting beauty of color is an important factor in consumers' finished goods. Durability of color depends on (1) selection of the proper dye for the fiber to be dyed, (2) selection of the method of dyeing the fiber, yarn, or fabric.

The synthetic dyes may be categorized into sixteen classes. The classification is based upon the particular type of chemical composition of the dye and/or the method of its application (see Table 11-1 on pages 204–209).

Basic (Cationic) Dyes

The first coal-tar dye was a so-called *basic* dye. It was developed to give many bright shades for silk and wool. The chemical agent that binds the dye to a fiber, which otherwise has little or no affinity for the dye, is known as a *mordant*. Cationic dyes are used with a mordant for cotton, linen, acetate, nylon, polyesters, acrylics, and modacrylics. A fluorescent basic dye which imparts extremely bright shades has been developed in a wide range of colors. It is suitable for acrylics and certain polyesters.

When used on natural fibers, basic dyes are not fast to light, washing, perspiration, or atmospheric gases; they tend to either bleed or crock. They give good fastness and bright shades to acrylics for which they are principally used. Basic dyes are frequently used as an aftertreatment for fabrics that have been previously dyed with acid colors.

Oxidation Bases

These are one of the oldest of synthetic dyes. Aniline black, one of the most intense and fastest blacks available, is an example of this group. Excellent browns are also available for printing. They are used primarily for cotton and can be applied with oxidizing agents and careful processings to wool, silk, and acetate.

Acid (Anionic) Dyes

Acidification of basic dyes led to the creation of acid dyes that are used mostly on wool and silk. They are also being more widely used for dyeing acetate, nylon, acrylics, modacrylics, and spandex. These anionic dyes have also been found useful in printing chlorinated wool and silk.

Acid dyes are inexpensive and fairly fast to light, but they are not fast to washing and have only fair fastness to dry cleaning. They have low resistance to perspiration.

Wool may be given increased fastness to both light and washing by boiling the fabric in a chromate solution after the first dyebath. This is called *afterchroming*.

Acid-Milling Dyes

A further development of the acid colors was the acid-milling dyes, which have superior wetfastness, good lightfastness, and less tendency to bleed onto surrounding white areas.

Acid-Premetalized Dyes

These are another outgrowth of the acid dyes. Carrying one or two molecules of chromium bound to the dye in their structure, they require a strong acid bath to get the color into the fabric. The metal improves the colorfastness, which is greater than for acid or acid-milling dyes. Acid-premetalized dyes are used a great deal on wool, nylon, and acrylics. The colors are good, though no brilliant blues or greens are obtainable.

Neutral-Premetalized Dyes

These dyes have one molecule of metal, usually chromium, bound to two molecules of dyes to improve fastness properties. The shades are not so bright as acid colors. These dyes are used on wool, silk, nylon, acrylics, modacrylics, and

TABLE 11-1 *PRINCIPAL CLASSES OF SYNTHETIC DYES AND THEIR CHARACTERISTICS*

DYE CLASS	*GENERAL DESCRIPTION*	*USES*	Light	Washing
Basic (Cationic)	First synthetic dye (1856); organic base dissolved in inorganic acid. Limited use today. Complete color range; colors bright	Cotton (with mordant), wool, silk, nylon, polyesters, acrylics, modacrylics. Direct printing on acetate; discharge printing on cotton	Poor; selected types excellent on acrylics	Poor on natural fibers; good on others in wide range of shades
Oxidation Bases	One of earliest synthetics; aniline black, still one of the most intense and fastest blacks available. Excellent browns for printing	Primarily for dyeing cotton; also wool, silk, acetate. Direct, resist, and discharge printing	Excellent	Very good
Acid (Anionic)	Originated from basic dye acidification; complete color range	Primarily for wool and silk; also acetate, nylons, acrylics, modacrylics, spandex; some rayon, polyester, and polypropylene. Printing on chlorinated wool, silk, acetate	Generally very good; range poor to excellent	Poor
Acid-Milling	Similar origin to acid dyes. Complete color range; duller than acid dyes	Same as acid; also stock and top dyeing	Generally very good; range poor to excellent	Good
Acid-Premetalized	Require strong acid bath; based on structure of one or two molecules of chromium to one molecule of dye; metal assists dye fastness; blues and greens duller than acid dyes; tendency to dye unevenly on nylons	Suitable for carpeting, decorative fabrics, women's wear	Good to excellent	Fair to good
Neutral-Premetalized	Derived from acid dyes based on structure of one molecule of metal (usually chromium) bound to two molecules of dye; shades fairly bright but less so than acid colors; fastness similar for various fibers	Wool, silk, nylons, acrylics, modacrylics, vinylidene-derived fibers; blends of these fibers due to similar fastness properties for various fibers	Very good to excellent	Fair to good
Mordant (Chrome)	Related to acid dyes; require addition of chrome derived from potassium or sodium bichromate; fairly complete color range but duller than acid dyes	Primarily for wool requiring maximum fastness: carpeting, decorative fabrics, men's wear; also silk, nylons, cellulose fibers. Printing on wool and silk	Good to excellent, depending on depth of shade, dyeing method	Good

	FASTNESS					
Hot Pressing	Dry Cleaning	Gas Fading	Staining (Bleeding)	Perspiration	Crocking	Seawater
Not affected	Mostly poor; good on acrylics	Not affected	Bleeds easily on wool, silk; good resistance on man-made fibers	Generally poor; some blues good; good on acrylics	Good resistance on acrylics	Very poor; good on acrylics
Not affected	Very good	Not affected	Very good	Good	Very good	Not affected
Not affected	Good	Not affected	Bleeds easily; stains adjacent fibers	Fair	Excellent	Fair
Not affected	Good	Not affected	Good resistance; generally will not stain adjacent fibers	Fair to good	Excellent	Good
Not affected	Good	Not affected	Generally good resistance to staining other fibers	Good	Good to excellent	Fair to good
Not affected	Good	Not affected	Generally good resistance	Good	Good to excellent	Good to excellent
Not affected	Fair to good	Not affected	Considerable staining of adjacent fibers, particularly silk, nylons; more resistant to cellulosics	Generally good; some greens fair	Fair to good	Good

TABLE 11-1 *PRINCIPAL CLASSES OF SYNTHETIC DYES AND THEIR CHARACTERISTICS*

DYE CLASS	*GENERAL DESCRIPTION*	*USES*	Light	Washing
Substantive Direct	Dye cellulosics directly; some dye wool, silk, nylons; union dyes for cotton/wool blends. Complete shade range; colors duller than basic or acid dyes	Primarily for cellulosic fabrics. Some good for cotton/wool blends; some for better quality fabrics. Much used for printing on dischargeable dyed backgrounds	Good to excellent	Poor
Developed	Dyes processed using copper salts, copper resin compounds to develop new dye in fiber. Used for cellulosics, wool, silk, nylons. Complete shade range; colors duller than basic or acid dyes	Same as substantive dyes	Good to excellent	Fair
Azoic (Naphthol and Rapidogens)	Also known as insoluble azos and ice colors; ice helps to reduce temperature of bath to facilitate dyeing. Complete shade range; yellows, reds, blacks most used. Bright shades at moderate cost	Primarily for cotton goods; limited use on acetate, nylons. Extensive printing use since colors are dischargeable and work with other groups	Good to excellent, depending on type, shade, depth	Good; some sensitive to chlorine bleach
Disperse	Developed for acetate (1922). Insoluble in water; supplied in paste or finely powdered form; particles disperse in water and dissolve in fibers. Good shade range	Primarily for acetate; also triacetate, nylons, polyesters, acrylics, modacrylics, olefins, as well as cellulose fibers. Wide use in apparel, decorative fabrics. Used for dyeing and printing	Fair to excellent, depending on fiber	Fair to good; better on polyesters than on acetate or nylons
Sulfur	First created in 1879. Generally insoluble in water. Complete shade range except for true red; colors not bright	Applicable to stock, yarn, piece goods; used for heavy woven and knitted cotton goods as well as linen and jute. Some printing	Poor to fair for yellows and browns; good to excellent in darker shades	Poor to good; most sensitive to chlorine bleach
Vat	Synthetic indigo original (1879). Insoluble in water; require reduction to apply. Incomplete but adequate shade range	Primarily for cotton; also wool. Generally for workclothes, outerwear, sportswear, decorative fabrics, awnings. Much used for prints	Generally excellent	Good

(*Continued*)

	FASTNESS					
Hot Pressing	Dry Cleaning	Gas Fading	Staining (Bleeding)	Perspiration	Crocking	Seawater
Good	Good	Not affected	Good resistance	Good	Very good in most shades on cotton, rayons	Poor to good, depending on color
Good	Good	Not affected	Good resistance	Good	Very good in most shades on cotton, rayons	Poor to good, depending on color
Good	Good	Not affected	Fair, sometimes stain adjacent whites; some bleed in peroxide bleach	Generally good	Depends on dyeing technique and aftertreatment	Good
Some color change possible	Good	Poor to good resistance, depending on fiber. Blues and violets on acetate very sensitive, less sensitive on nylons and polyesters	Stains wool badly	Good	Good	Good
Good	Good	Not affected	Fair to good, depending on shade, depth, aftertreatment	Good	Poor to good, depending on shade, depth	Good
Generally good; some color change with certain dyes	Good	Generally not affected; a few are susceptible	Good resistance	Good	Fair to good, depending on dye, depth of shade	Good

TABLE 11-1 *PRINCIPAL CLASSES OF SYNTHETIC DYES AND THEIR CHARACTERISTICS*

DYE CLASS	GENERAL DESCRIPTION	USES	Light	Washing
Reactive	First available in 1957; several varieties. Form chemical combination with fiber, distinguishing class from others. Produce brightest shades on cotton	Primarily for cotton apparel, decorative fabrics for bright colors; where good all-around fastness is important. Applicable to stock, yarn, piece goods, printing. Some suitable for wool, silk, nylons, acrylics, and blends	Good to very good on most fibers; poor to moderate on nylon	Good; generally sensitive to chlorine bleach
Pigment	Generally organic coloring materials; all insoluble in water with no affinity for fiber. Fixed on fiber with resinous binders and cured at high temperatures. Complete shade range in bright colors	Primarily for printing cotton of all weights; also wool, rayon, acetate, nylons, polyesters, olefins	Very good to excellent	Good
Optical Brighteners (Colorless Dyes)	Also called fluorescent whiteners. Brightness caused by absorption of ultraviolet light and reflection of visible blue light. Applied during bleaching or in the final finish (before resin finish or with the resin)	Much used on cotton; also wool, acetate, nylons, acrylics	Fair	Varies but generally improves with buildup of whiteners in household detergents

Data based upon Dye Chart originally prepared by *Textile World.*

vinylidene-derived fibers. Since the generally good fastness properties are similar for all these fibers, the neutral premetalized dyes are used for their blends.

Mordant or Chrome Dyes

These dyes are related to acid dyes but are more complex. They require the addition of sodium or potassium bichromate in the dyebath or after the dyeing is completed to obtain the mordant or binding action of the chrome. They are the fastest dyes to wet processing available for wool and are therefore principally used for wool requiring maximum fastness. They are also used with less effective fastness for cotton, linen, silk, rayon, and nylon. They provide a wide range of colors that are duller than the acid dyes.

Substantive Direct Dyes

This group is one of three types of direct dyes, all of which dye cellulose fibers directly and without a mordant in bright, full shades. Some direct dyes may be used on wool, silk, and nylon. They are applied to cotton or rayon from a water solution, and when salt is added, the color

FASTNESS						
Hot Pressing	Dry Cleaning	Gas Fading	Staining (Bleeding)	Perspiration	Crocking	Seawater
Not affected	Good	Not susceptible	Good resistance	Good	Good	Good; some fair, particularly in chlorinated pool
Good	Good if properly bound	Majority not susceptible; a few sensitive	Good	Good	Good for light to medium shades; very poor for dark shades	Good
Not known to be affected	Not known to be affected	Not known to be affected	Not affected	Not known to be affected	Not known to be affected	Not known to be affected

is forced out of solution into the fiber. The dye colors often have only fair fastness to light, poor fastness to washing, and are not very bright. They are often referred to as *commercial colors*, a term that indicates that the dyes are not the best available for the purpose.

Developed Dyes

This is another group of direct dyes. In addition to their primary use for cellulose fibers, they are also used to color wool, silk, and nylon. The process requires a base to be dyed on the goods. This is followed by a *diazotizing* process, whereby the dye is chemically changed and treated with a fresh set of chemicals, called *developers*, that form the completed dye. Developed dyes are fairly fast to washing because they have been literally built into the fiber.

Azoic Dyes

This is the third group of direct dyes that is further identified as naphthol and rapidogen types. They are quite fast to washing and vary from poor to excellent lightfastness. Azoic dyes are used to a very great extent on cotton and for special purposes on nylon and acetate.

The method of applying these dyes is somewhat similar to that of developed dyes, as it involves diazotizing. The fabric is first immersed in naphthol, which impregnates the fibers; it is then dipped into the diazotized color bath. The dyeing is followed by thorough soaping and rinsing. Naphthol or azoic dyes are sometimes referred to as *ice dyes* because ice is frequently used to bring the dyes to a low temperature and assure efficient dye formation. A complete color range is available, but these dyes are used primarily for bright reds, yellows, and blacks.

Disperse Dyes

These dyes were developed originally for dyeing acetate fibers and have since found wide use in dyeing triacetate, nylon, polyester, acrylic, modacrylic, and olefin, as well as cellulose fibers. While they are not soluble in water, they are supplied in a finely ground form that will disperse in water. The particles will dissolve in the fibers and, by this action, the fabric is dyed. Disperse blacks are usually made by a process similar to the one described for developed direct dyes.

Other shades are dyed just as are direct dyes except that salt is never added to the dyebaths. The disperse dyes have one weakness, particularly in the blue shades: they are generally susceptible to nitrous oxide gas in the atmosphere and will gradually fade to a pink color. Inhibitors applied at the dyehouse can slow down the fading process. Peculiarly enough, disperse blues applied to nylon do not gas-fade. The disperse dyes as a class are fairly fast, except that the ones least sensitive to gas-fading on acetate are the least lightfast.

Sulfur Dyes

Sulfur dyes, first made in 1879, are used for cotton and linen. These dyes are fast to washing, light, and perspiration, but they have one weakness: excessive chlorine bleaching will strip the color.

Sulfur dyes are insoluble in water and must be made soluble with the aid of caustic soda and sodium sulfide. (One or two manufacturers produce sulfur dyes that have been made water-soluble.)

Sulfur dyeing is done at high temperature and with a large quantity of salt, which helps to drive the color into the fabric. After immersion in the dyebath, followed by rinsing, the fabric is oxidized to the desired shade by exposure to the air or, chemically, by the use of potassium bichromate and acetic acid. The oxidizing process must be carefully controlled because penetration of the dye is retarded by premature oxidation. Also, oxidation changes sulfur to sulfuric acid, which may be harmful to the fabric. Excess chemicals and excess dye must be completely removed by thorough washing. Sulfur dyes penetrate more thoroughly than any other dye because of the high temperature and the alkalinity of the dyebath. They are excellent for khaki and for the heavy piece goods used in workclothes. Sulfur dyes produce dull colors, such as navy, brown, and black. They are used for black more than any other dye. If stored for a great length of time, fabrics become tender.

Vat Dyes

The first synthetic vat dye was an indigo created in 1879. Vat dyes are the fastest dyes for cotton, linen, and rayon. They also may be applied to wool, nylon, polyesters, acrylics, and modacrylics with the use of a mordant. Vat dyes are not only resistant to light and to acids and alkalies, but are also equally resistant to the strong oxidizing bleaches used in commercial laundries. In this respect, vat dyes excel sulfur dyes, which are not fast to chlorine washing.

A label stating that a garment is vat-dyed is not a guarantee that the fabric is absolutely fast to washing if it is of brilliant color. The name "Indanthrene" on labels indicates that a special type of dye has been used that is particularly fast to light and to washing. This type was among the first of the synthetic vat dyes.

The old-fashioned method of fermenting and steeping indigo in a vat gave vat dyes their name. They are prepared today on the same principle, but they are chemically purer and the process is shorter. Vat dyes are expensive because of the initial cost as well as the method of application. They are insoluble pigments; but they are made soluble in water by the use of a strong reducing agent, such as hydrosulfite dissolved in the alkali, sodium hydroxide. The fabric is immersed in this solution. Subsequent exposure to air or immersion in an oxidizing bath (bichromate) restores the dye to its insoluble form as a part of the fiber.

Reactive Dyes

This class of colors was the next significant development (1957) in dyes. There are now several varieties of reactive dyes, which actually react with fiber molecules to form a chemical compound. While these dyes were first designed for cellulose fibers, types are now available for wool, silk, nylon, acrylics, and blends of these fibers. Some advantages of reactive dyes are their excellent fastness to light and washing and their brilliant shades, which are rivaled only by acid dyes on silk.

There are several chemical ways of combining the dye with cellulose fibers, and all have about the same potential. The dyes can be applied from alkaline solution in a one-step process of pad and dry, or they can be applied from neutral solutions and then alkalized in a separate run. Heat is also used to develop the shade. In all cases, the fabric is well soaped after dyeing to remove any unfixed dye (color that has combined with the water in the dyebath and is of no value in the dyeing of the goods).

Pigment Dyes

These dyes utilize a technique of coloring that has become increasingly important. The colors, confined to light shades, bright colors, and such metallic colors as gold, are usually applied to cotton cloth but are also used on fabrics of wool and manmade fibers. Actually, they are not true dyes because they have no affinity for the fiber and are applied and held to the fabric with resins, which are then cured at high temperatures.

Pigment dyeing gives excellent lightfast colors and generally good all-around fastness. However, if the shade is too deep, the color will crock. Great improvements in the pigments and resins have made it possible to dye in much darker shades than was possible at first.

Optical Brighteners (Colorless Dyes)

These so-called dyes are also called *fluorescent whiteners* or *optical brighteners*. The whiteness is really caused by absorption of ultraviolet light and reflection of visible blue light. Optical brighteners are available for cotton, acrylics, wool, acetate, and nylon. They may be applied during bleaching, before resin finishing, or with the resin.

Though lightfastness varies, it is generally fair depending upon the compound and the fiber to which it is applied. Washfastness also varies but is generally good; further brightness buildup occurs from washing cotton fabrics in household detergents.

SELECTION OF DYEING METHOD

Textiles may be dyed at any stage of their development from fiber into fabric or certain garments by the following methods:

Stock dyeing, in the fiber stage

Top dyeing, in the combed wool sliver stage

Yarn dyeing, after the fiber has been spun into yarn

Piece dyeing, after the yarn has been constructed into fabric

Solution pigmenting or dope dyeing, before a manmade fiber is extruded through the spinneret

Garment dyeing after certain kinds of apparel are knitted

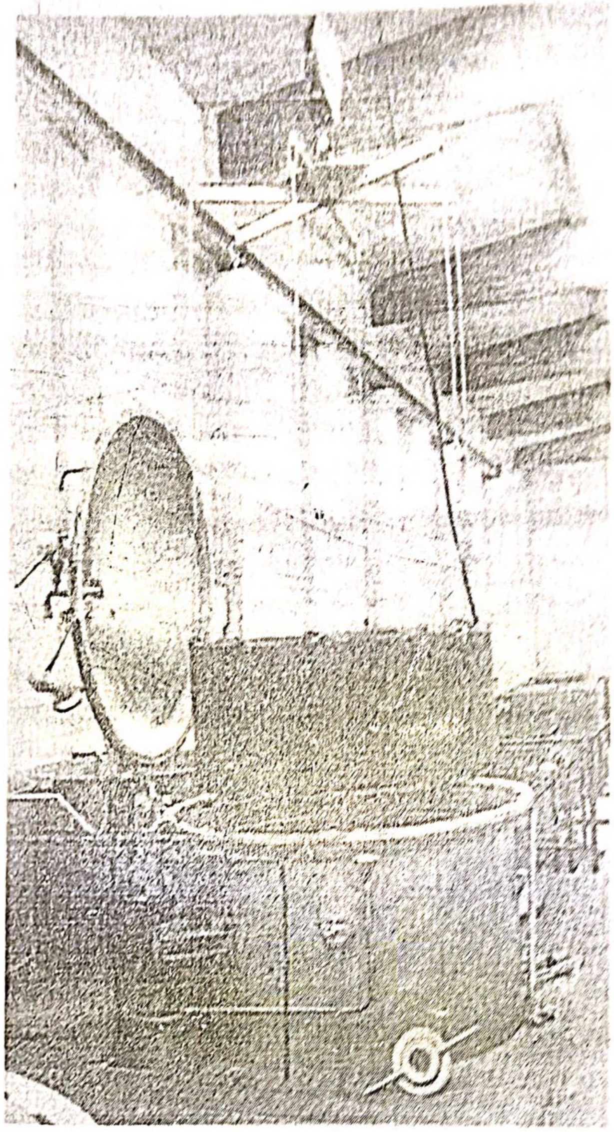


Figure 11-1 Staple fiber packed onto a carrier being placed into a vat for stock dyeing. *(Courtesy Obermaier Gmb H & Cie. KG)*

Stock Dyeing

Stock dyeing refers to dyeing a staple fiber before it is spun. There are two methods. The older and widely practiced procedure is that of removing the packed fiber from the bales and then packing the stock in large vats and circulating dye liquor through the mass of fiber at elevated temperatures (see Figure 11-1). The newer method, *bale dyeing*, which is applicable to wool and all types of manmade fibers, is that of splitting the bale covering on all six sides, placing the entire bale in a specially designed machine (the covering and straps need not be removed), and then forcing the dye liquor through the bale of fiber (see Figure 11-2). This latter method obviously saves time and labor costs.

Although the dye liquor is pumped through the fiber in large quantities, there may be areas where the dye does not penetrate completely. However, in subsequent blending and spinning operations, these areas are so mixed with the thoroughly dyed fiber that an overall even color is obtained. In stock dyeing, which

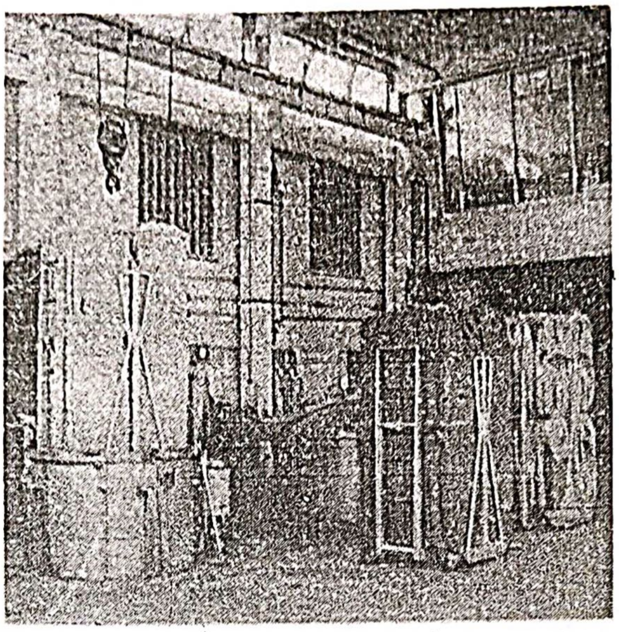


Figure 11-2 At left are four stacked bales of staple fiber being placed in a vat for bale dyeing. At right are stacked bales after dyeing. The ones at the extreme right have been dyed with the bale coverings split but not removed. *(Courtesy Obermaier Gmb H & Cie. KG)*

is the most effective and expensive method of dyeing, the color is well penetrated into the fibers and does not crock readily. Stock-dyed fiber does not spin as readily as undyed fiber because it loses some of its flexibility, but lubricants added in the final rinsing overcome most of this difficulty.

Woolens are often stock-dyed. The completeness of this method is reflected in the expression "dyed in the wool," which is used to attribute the quality of thoroughness. Stock-dyeing produces mixture effects and color blends, of which oxford suitings and tweed homespuns are examples.

Top Dyeing

One step nearer to the finished yarn than stock dyeing is what is called *top dyeing* in the worsted industry. *Top* is wool that has been combed to take out the short fibers, then delivered from the combs in a ropelike form about 1¼ inches (30 mm) thick. The top is wound on perforated spools and the dye liquor is circulated through it. Very even dyeing is possible with this method.

Yarn Dyeing

When dyeing is done after the fiber has been spun into yarn, it is described as yarn dyeing. There are several methods of yarn dyeing. The purpose is to have the dyestuff penetrate to the fibers in the core of the yarn; this is similar to the penetration of the fibers in stock dyeing. Cloth made of dyed yarns is called yarn-dyed.

Yarn-dyed fabrics are usually deeper and richer in color. Yarn-dyed fabrics intended for laundering must be quite colorfast, or bleeding could occur. The primary reason for dyeing in the yarn form is to create interesting checks, stripes, and plaids with different-colored yarns in the weaving process. Chambrays, for example, are usually woven with a colored warp and white filling. Other combinations of different-colored yarns are checked gingham, shepherd's check, plaid, seersucker, and heather mixtures.

Skein (Hank) Dyeing. Yarn may be prepared in skein, or hank, form and then dyed. The loose arrangement of the yarn allows for excellent dye penetration. The skeins are hung over a rung and immersed in a dyebath in a large container (see Figure 11-3). Skein dyeing is the most costly method of yarn dyeing, but the color penetration is best and the yarns retain a softer, loftier hand. Skein-dyed yarn is used to a considerable extent for suiting and dress goods.

Package Dyeing. Yarn wound on spools, cones, or similar units and then dyed is re-

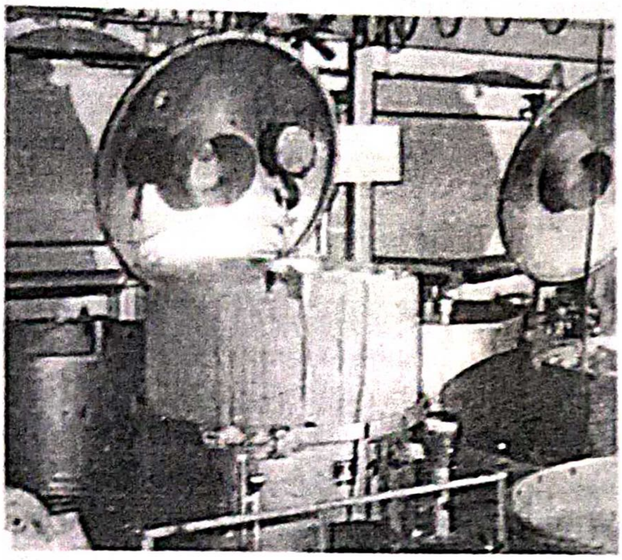


Figure 11-3 Skein dyeing is done by draping hanks of yarn over rungs and immersing them in vats. *(Courtesy Louis P. Batson Company)*

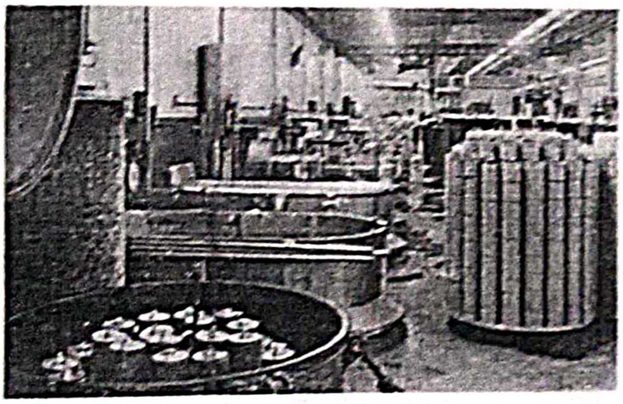


Figure 11-4 Another form of yarn dyeing is package dyeing, whereby the packages, or spools of yarn are stacked on a rack (right) and then immersed in a vat of dye (left). *(Courtesy Burlington Industries, Inc.)*

ferred to as *package-dyed yarn* (see Figure 11-4). The packages of yarn are stacked on perforated rods in a rack and then immersed in a tank wherein the dye is forced outward from the rods under pressure through the spools and then back through the packages toward the center to penetrate the entire yarn as thoroughly as possible. Most carded and combed cotton that is used for knitted outerwear is package-dyed.

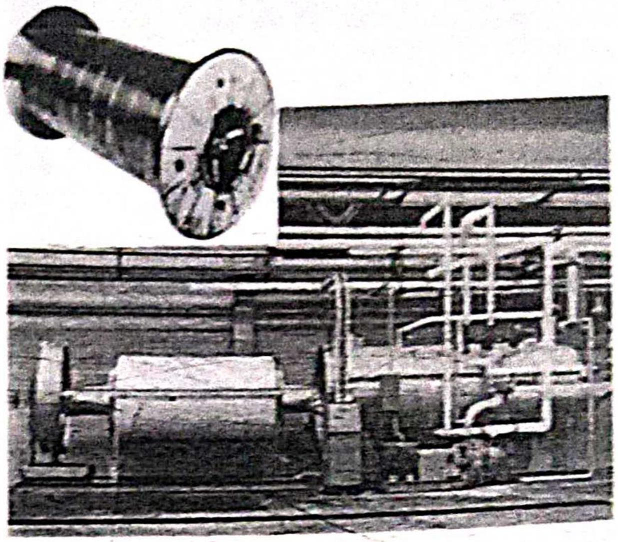


Figure 11-5 Warp-beam dyeing, a form of yarn dyeing, is done by steeping the yarns on a warp-beam in a dye vat. Note the perforations in the warp-beam cylinder through which the dye is forced and circulated to obtain thorough yarn dyeing (see insert). *(Courtesy Gaston County Dyeing Machine Co.)*

Warp-beam Dyeing. This method is similar to package dyeing but is more economical. Yarn is wound onto a perforated warp beam, immersed in a tank, and dyed under pressure. It is used when fabrics are to be woven with dyed warp yarns (Figure 11-5).

Space Dyeing. Yarn that is space-dyed is dyed at intervals along its length. One procedure is the knit-deknit method in which the yarn is knitted on either a circular or flat-bed knitting machine set to produce the desired size of loop. The knitted cloth is then dyed, and it is subsequently deknitted. The dye penetrates the loops of the yarn but since it does not readily penetrate the areas of the yarn where it crosses itself, alternating dyed and undyed spaces appear. Variations in hue and heather effects are possible in the fabric subsequently produced.

Another technique, the *OPI Space-Dye Applicator*, produces multicolored space-dyed yarns. It was designed for use on knitting and carpet yarns. The yarns are dyed intermittently as they run at high speeds of up to 1000 yards (900 m) per minute through spaced dyebaths with continuous subjection to shock waves produced by compressed air assuming supersonic velocities. The compression effect resulting from this shock wave creates a residual humidity in the yarn sufficiently low to avoid the need for intermediate drying before subsequent operations of winding, etc.

Piece Dyeing

The great bulk of dyed fabric on the market is dyed in the piece. This method gives manufacturers maximum flexibility for their inventories to meet large or small demands for a given color as fashion requires. Where yardage warrants it, fabrics are dyed in continuous-range machines. Small lots of fabrics of all fibers are dyed in batches. Piece dyeing is thoroughly satisfactory as regards levelness, penetration, and overall fastness, assuming that the proper dyes have been used.

Fabric may be piece-dyed whether it is composed of only one kind of fiber or yarn or of blends of different fibers or combinations of different yarns. When the fabric is made of one kind of fiber or yarn, then dyeing is relatively uncomplicated because the one appropriate dye is used. However, when the fabric contains a blend of fibers or combination of different yarns, then special procedures are required which employ different dyes that are each specific for the particular fibers used. These procedures are called *union dyeing* and *cross-dyeing*.

Union Dyeing. This process of dyeing piece goods made of different fibers or yarns in one color may be readily accomplished. Although different fibers may require different dyes to obtain the same color, this may be done by putting the appropriate color dye that is specific to each type of fiber into one dyebath.

Cross-Dyeing. Cross-dyeing of goods may be accomplished in any one of several ways. The results produce varied effects. One method is a combination of stock dyeing or of yarn dyeing with subsequent piece dyeing. Cross-dyeing produces varied effects. For instance, either the warp or the filling yarns may be stock-dyed or yarn-dyed, one set of yarns being left undyed. The fabric is piece-dyed after weaving; thus, color is given to the undyed yarn in a second dyebath, and the yarns that were originally stock-dyed or yarn-dyed acquire some additional coloring, which blends with the piece-dyed portion of the fabric.

If yarns of vegetable fibers have been combined with yarns of animal fibers in a fabric that is to be piece-dyed, two separate dyebaths must be used. The fabric is dipped into both solutions, each of which affects the fiber for which it has an affinity. This provides colorful effects.

A mordant can be included in a single dyebath to cause the dye to adhere to the fiber for which it does not have an affinity. Thus, the more expensive method of cross-dyeing, requiring two dyebaths, need not be used.

Still another method of cross-dyeing is to immerse a fabric composed of two different types of fibers into one dyebath containing two different dyes, one specific for each of the fibers. For example, a fabric composed of viscose rayon and acetate yarns may be cross-dyed in this manner. When the fabric is removed from the dyebath, the viscose rayon yarns will be one color, and the acetate yarns will be another color.

The several methods of piece dyeing are described below.

Beck Dyeing. Long lengths of cloth that are to be dyed on a continuous process are very often beck-dyed, or box-dyed, by passing the fabric in tension-free rope form through the dyebath. The rope of cloth moves over a rail onto a reel which immerses it into the dye and then draws the fabric up and forward to the front of the machine. The process is repeated as long as necessary to dye the material uniformly to the desired intensity of color. Much of the original softness and fullness of the fabric is retained with beck dyeing and it is therefore widely used for woolen and worsted woven goods and knitted fabrics.

Jig Dyeing. This method utilizes the basic procedure of beck dyeing. However, in jig dyeing, the fabric is held on rollers at full width rather than in rope form as it is passed through the dyebath (see Figure 11-6). This procedure places some tension on the goods, causing flattening and a loss of fullness. If there is uneven tension on the material, a slight variation in shade may appear either from the center of the fabric to the selvage, or from one end to the other.

Jig dyeing is less costly than beck dyeing. It cannot be done on fabrics where a soft, full hand is required and it cannot be used for knitted or stretch fabrics which should not be subjected to tension.

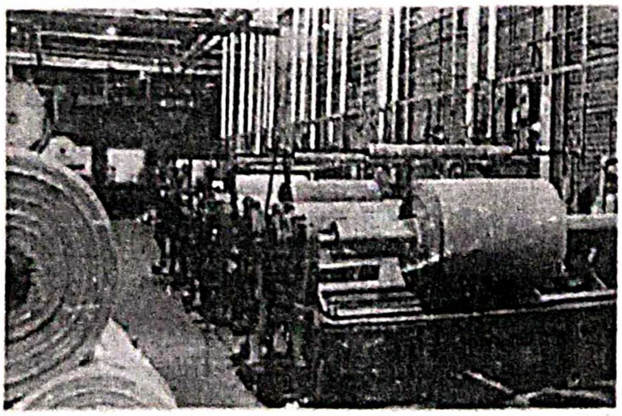


Figure 11-6 Fabric may be piece-dyed on a jig, where the cloth is immersed into troughs of dye and subsequently rewound into rolls. *(Courtesy Burlington Industries, Inc.)*

Pad Dyeing. Like jig dyeing, *padding* dyes the fabric as it is held at full width. The fabric is passed through a trough containing dye and then between two heavy rollers which force the dye into the cloth and squeeze out the excess. It is generally done on a continuous dye range which can accommodate a large amount of fabric. The material is run in one operation through a pad, into a heat or steam chamber to set the dye, then successively into a washer, a rinser, and a dryer.

Cold Pad-batch Dyeing. This technique is a variation of *pad dyeing*. It is used for wool piece-goods to overcome certain disadvantages of beck dyeing them in light, bright shades. Wool fabric is immersed in the dye liquor at room temperature. After the excess liquor is squeezed out by the pad rollers, the roll of fabric is wrapped to prevent drying. It is then rotated slowly for up to 48 hours to obtain uniformity of dye application. The fabric is then washed in a mild alkaline solution to remove the liquor additives and unfixed dyes. Finally the cloth is extracted and dried.

A faster system may be used for cotton and cotton/polyester fabrics utilizing reactive dyes. The dyestuff and alkali are combined in one bath through which the fabric is passed. Excess liquor is squeezed out on the mangle and the fabric is batched on rolls which are then covered with plastic sheets to prevent evaporation. It is subsequently washed, preferably on a perforated beam wash for efficiency and reduction of water consumption. The method uses less energy, less water which results in less pollution, is as fast as the continuous range system at less capital expenditure, yet has the desired stability and rapid fixation while providing reliable and consistent shade.

Beam Dyeing. This method is similar to the warp-beam dyeing of yarn. In this instance, fabric is wound on a beam. However, only lightweight fabrics of relatively open construction, such as tricot, can be beam-dyed because the dye liquor cannot circulate through more compactly constructed material. Beam dyeing does not subject the fabric to stress or tension. It is rapid and economical.

Jet Dyeing. Fabric may be jet-dyed by placing it in a heated tube or column where jets of dye solution are forced through it at pressures of up to 300 pounds (2070 kPa) per jet. The dye is continually recirculated as the cloth is moved along the tube at speeds of up to 300 yards (275 m) per minute. The fluid moves faster than the cloth so that the cloth floats through the tube without touching the walls. This method is not only fast but also very thorough, and crease and rope marks may be avoided.

Vacuum Impregnation. Imparting color to fabric by vacuum impregnation differs from the methods described above in that it depends upon an initial lack of air followed by the use of normal air pressure to impregnate the fibers with the dye. It is based on certain important principles. One of these is that air entrapped in the substrates of the textile fibers in the fabric and in the folds of the fabric itself hinders the passing of dye through to the fiber sites. Also, normal atmospheric pressure can be substituted for the higher pressures generally used, and the concomitant cost of developing and using the higher pressures is eliminated.

In the vacuum impregnation process, air is evacuated from the dye tank to near-zero pressure, the fabric is then covered with the dye liquid while it is in this vacuum state, and then the system is opened to allow return to normal atmospheric pressure. As a result, there is instantaneous wetting, virtually complete saturation of the fabric, and impregnation of the dye into the fibers. The high degree of saturation and impregnation occurs because the swift change from the vacuum to normal atmospheric condition causes the liquid dye to rush in and fill the voids, unhindered by the resistance of the entrapped air. In effect, when the vacuum condition is suddenly changed to normal or even a bit higher, the pressure created is so comparatively great that the dyestuff is literally forced into the fiber.

The vacuum impregnation technique has special value for fabrics made of fibers that are not easily wetted, since the coloring is primarily dependent on the sudden pressure that causes the penetration of the dye into the fibers. The method can be applied subsequent to certain finishes, such as wrinkle-resistant resins, because they do not block the dye impregnation process.

Foam Dyeing. The technique of applying dyestuff suspended in liquid that is foamed with a special mixer and applied to the fabric is a relatively recent development and, in fact, is still being refined. The primary motivation for this method of dyeing (and for foam application to various finishing processes) is the desire to conserve energy in steaming and dyeing; other considerations are to reduce water consumption and pollution.

The method is based upon the fact that the foam, which has a high volume and high viscosity, makes it possible to apply relatively small quantities of concentrated dye liquid as compared to pad dyeing. Foam dyeing is accomplished, essentially, by feeding, with the aid of a trough and a doctor blade, a uniform layer of foam of exactly defined thickness on an applicator roll. The foam is pressed into the fabric as it comes in contact with the roll for about 180 degrees. The front and back of the fabric can be simultaneously dyed in one pass. Heavy pile fabrics and carpets can also be foam dyed.

In addition to the advantages cited, there are others. Dyestuff additives to facilitate dyeing can be reduced in certain formulations, coloration is uniform, dye fixation is much faster, and greater dye yields can be achieved. However, maintenance of uniformity of foam composition, air, and liquor with constant temperature control can present problems. Also, the quantity of foam production and its consumption by the fabric require careful balance, otherwise moisture content and distribution change. Furthermore, not all dyestuffs or additives can be used with foam.

Solvent Dyeing. All the dyeing techniques discussed in previous sections depend upon dissolving the dyestuffs in water. These aqueous solutions have their limitations with regard to such factors as the relative dye solubility in water, dye liquid viscosity, the water permeability of the fiber, and local water pollution. Recent techniques have used other liquids, such as ammonia, perchlorethylene, and trichlorobenzene, which have been found to be superior dye vehicles. These liquids are better dye solvents, and they penetrate better a wide variety of manmade fibers. Furthermore, there is a saving of energy and its cost because high temperatures for drying are not needed, the exhausted solvents are recoverable, are thereby nonpolluting, and are a less expensive means of dyeing.

To improve further the dye penetration, a machine called the Pulsar that was invented in Italy utilizes sets of continuous rapid impulses in the solvent medium which hits both sides of the fabric in rhythmic alternation driving the dye into the fabric. The material is moved by gravity and vibration of the pulsators. Tension, stretch, and surface distortions are eliminated. Conveyor belts carry the fabric to a suction dryer. Both open-width and tubular fabrics can be dyed.

Solution Pigmenting, or Dope Dyeing

During the production of manmade fibers, a great deal of time and money can be saved if the dye is added to the solution before it is extruded through the spinnerets into filaments. This method also gives a greater degree of colorfastness. A process called *solution pigmenting*, or *dope dyeing*, has been used for manmade fibers ranging from rayon through saran and glass fiber. Effective results have been obtained. The pigment colors are the fastest known—much faster than any of the customary dyeing techniques. Therefore, where warranted, they are to be preferred when fastness to almost any known factor is important.

Chip Dyeing. Special dyes may be added to the polymer for the production of such fibers as nylon prior to melt-spinning of the chips. The dyestuffs are resistant to the reducing action of the polymer under high temperatures. Such dyes will not fade, crock, or run.

Garment Dyeing

Certain kinds of nontailored apparel, such as hosiery, pantyhose, and sweaters can be dyed as completed garments because they are each made of a single component and will not be readily distorted. However, allowance must be made for anticipated shrinkage. A number of garments are loosely packed into a large nylon net bag. The bags are then put into a *paddle dyer*, which is a tub with a motor-driven paddle that agitates the dye bath.

Garment dyeing is an economical method and is used when practical. It also reduces the risk of building an inventory that could be affected by changes in color fashion.

IDENTIFYING DYEING DEFECTS

Imperfections from the dyeing process sometimes occur. They may be due to imperfections in the yarn or fabric construction, faulty preparation of the fabric before dyeing, poor dye selection, or improper dyeing or postdyeing procedures. The following are the most common dyeing defects.

Barré is a horizontal shaded band running across the width of the fabric. It may be caused by variations in the size of the filling yarn and by differences in tension of either the filling or warp yarns of a woven fabric (see page 123 regarding knitted fabric).

Bleeding is a loss of color when the dyed fabric is wetted or immersed in water. The water becomes colored and may cause discoloration of other fabrics. This is usually due to either improper dye selection or poor dye fastness.

Crocking is the rubbing off of color. It may rub onto another fabric (and may be difficult to remove). This may be due to inadequate scouring (washing) subsequent to dyeing.

Off shade refers to a color that does not exactly match the standard or prepared sample. This may be due to faulty dye formulation or application, or it may be due to variation in dye lot.

Shade bar is a horizontal band of a different hue running across the fabric. It may be caused by a change of filling bobbin in the loom or a loom stop and startup.

Shading is a variation in color tone either horizontally or vertically. It is generally due to uneven tension on the fabric, for example as may sometimes occur in jig dyeing.

Stained fabric indicates a discoloration caused by a foreign substance, dirt, grease, oil, or sizing residue on the fabric being dyed.

Stained (unclear) cross-dye may occur in a cross-dyed fabric of white and a color. The dye of the colored yarns may stain the white ones. This is usually due to poor dye selection and fastness.

Streaked fabric indicates either a stain or uneven dyeing caused by folds in the fabric during the dyeing process.

TESTS TO DETERMINE COLORFASTNESS

Beauty of color in any fabric is of no value to the consumer unless the dye may be considered fast under the conditions in which the fabric will be used. Color must meet such tests as washing, ironing, steaming, perspiration, strong light, and dry cleaning. The U.S. government tests fabrics for colorfastness to maintain and enforce trade standards. The consumer may also test fabrics for colorfastness at home.

Garments will retain a fresh, new appearance and give additional wear if they are properly cleaned at home or at a commercial cleaner in accordance with the results of the tests to which samples of the garment's fabrics have previously been subjected.

Fastness to Washing

The usual method for determining fastness to washing is to wash and then iron under a white cloth a sample of the fabric while it is still wet. If the dye bleeds on the cloth, the color cannot be considered fast. Home washing is not a rigorous enough test for fabrics that will be washed in commercial laundries. A better test is to immerse the sample in water containing a bleach, such as Clorox, because similar strong compounds are used in the laundries.

Fastness to Pressing

To test for fastness to ironing, iron the sample with a very hot iron. After the sample has cooled, compare it with the original fabric. If the color is unchanged, the fabric is fast to ironing.

To test for fastness to steaming, place a sample between the folds of a white cloth, and steam it over a teakettle. If the color is fast, it should be unchanged, and no dye will show on the white cloth.

Fastness to Light

To test for fastness to light, cover half a sample of fabric with opaque paper and expose it to outdoor light for perhaps twenty days. Then compare both halves. If the exposed portion shows perceptible fading, the fabric is not fast to light. A more specific time for exposure cannot be given, because the intensity of sunlight varies in different localities. Usually, resistance to exposure of twenty days is considered good.

This test is performed in a much shorter time in textile testing laboratories by the use of the Fade-Ometer, an apparatus having very strong electric lamps or a special carbon-arc light (see Figure 11-7). If a fabric can withstand an exposure of forty hours in this machine with no perceptible loss of color, it is said to have superlative fastness to light. A fabric has good fastness to light if it withstands an exposure of thirty hours.

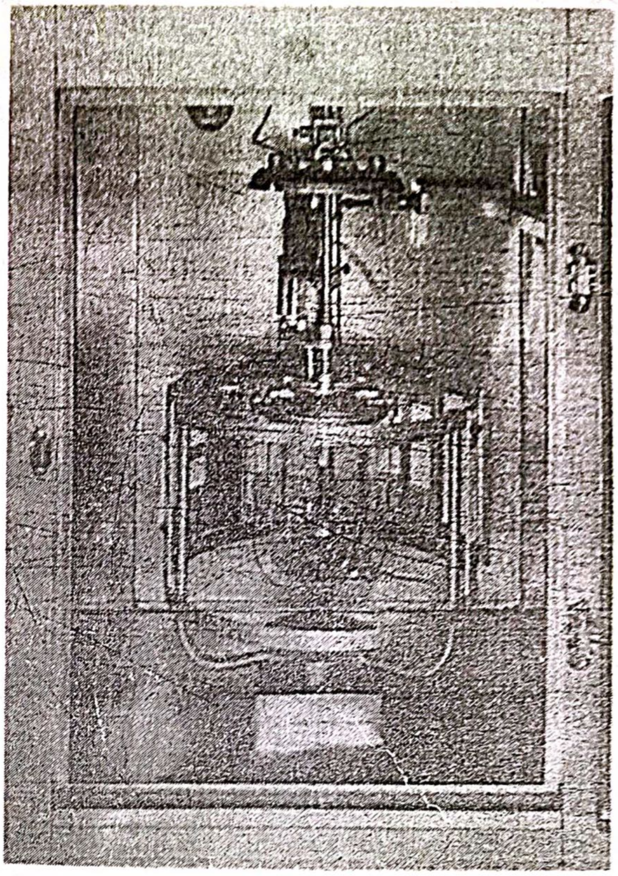


Figure 11-7 The Fade-Ometer is used for testing colorfastness to sunlight. Samples of fabric are exposed to the rays of the machine for a period of hours or days. After removal, the samples are compared with an unexposed piece of fabric to determine the extent of loss of color. *(Courtesy Atlas Electric Devices Co.)*

Fastness to Perspiration

To test for fastness to perspiration, soak a sample of the dyed fabric for ten minutes in a weak acid, such as a dilute acetic acid solution. Do not rinse. Roll the sample in a piece of undyed cloth. Permit gradual drying, and leave the material rolled for a few days. If comparison with the original color shows that the shade of the dyed fabric has changed, or if the dye appears on the cloth in which the sample was rolled, the color is not fast to perspiration.

The effects of both acid and alkaline perspiration can be determined by the standard government test, which recommends the use of two solutions. *For acid perspiration:* 10 grams sodium chloride; 1 gram lactic acid, USP 85 percent; 1 gram disodium orthophosphate, anhydrous. Make up to 1 liter with water. *For alkaline perspiration:* 10 grams sodium chloride; 4 grams ammonium carbonate, USP; 1 gram disodium orthophosphate, anhydrous. Make up to 1 liter with water. Samples of the dyed fabrics are placed against pieces of undyed cloth and left for a few days in each solution. The pieces of dyed fabric and undyed cloth are then squeezed and allowed to dry. Any staining denotes poor fastness to perspiration.

Fastness to Crocking

To test for fastness to crocking, rub dry and wet samples against a white cloth. If the color does not rub off on the white cloth, the color is fast to rubbing or crocking (Figure 11-8).

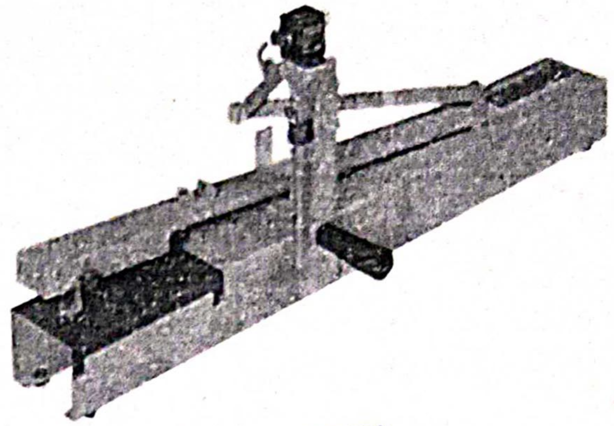
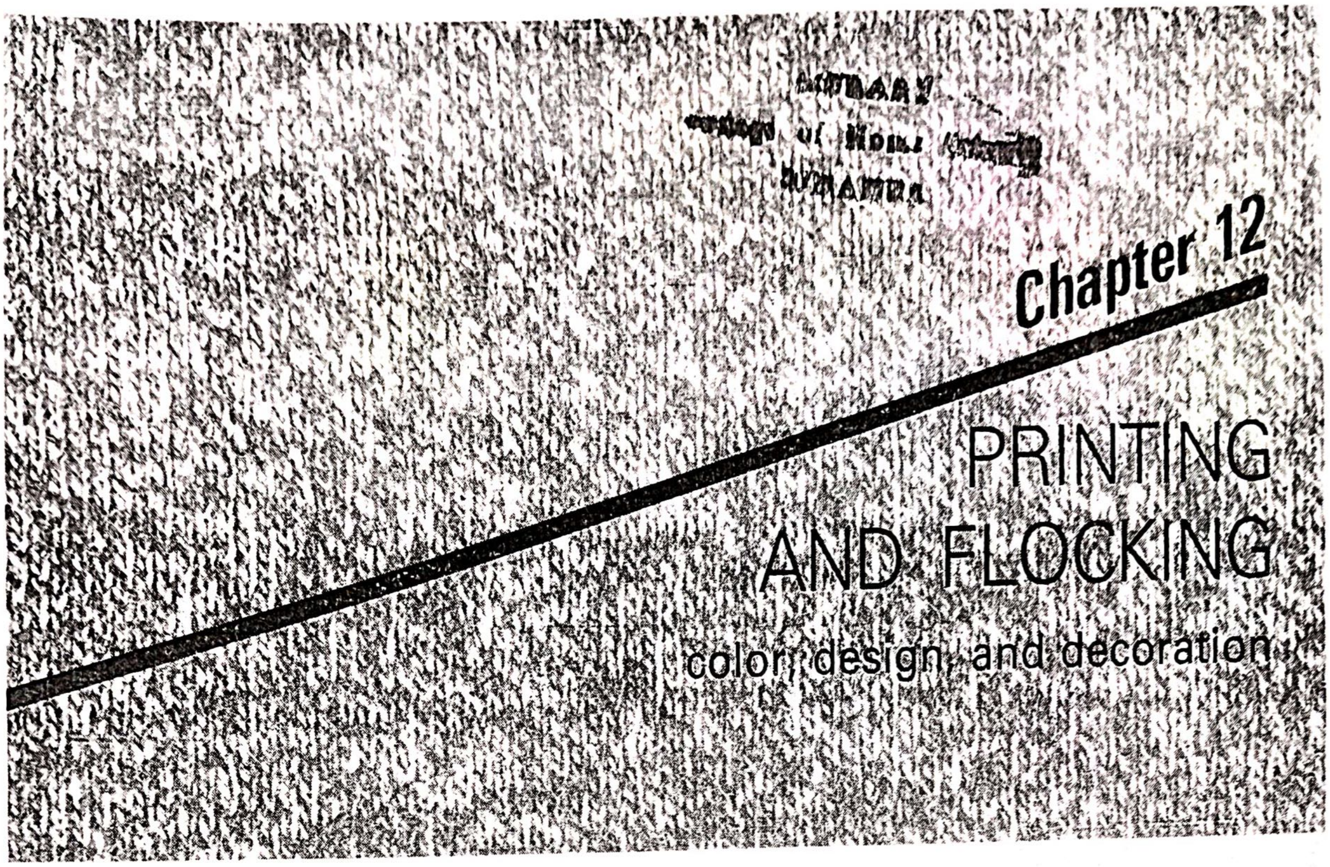


Figure 11-8 This Crockmeter drags one colored fabric across another to determine if dye will rub off. *(Courtesy Atlas Electric Devices Co.)*

Fastness to Gas Fading

Flames from heating appliances cause nitrogen in the atmosphere to unite with oxygen, forming nitrogenous compounds that cause some acetate dyes to lose color if the fumes come in contact with the fabric. This is known as *gas fading* or *acid fading* in acetate; blue is especially susceptible. An antifume finish of an alkaline nature can be applied to a fabric to minimize gas fading by the use of an inhibitor in the dye. Fabrics can be tested to determine the permanency of their antifume finish by exposure for about twenty hours in a chamber containing the combustible fumes of a gas burner.



Chapter 12

PRINTING AND FLOCKING

color, design, and decoration

The yarns produced in the spinning process create some form of decoration in the fabric. In the formation of the fabric, decoration is also obtained by the pattern of the construction. The checkerboard pattern of the plain weave, the variations of the basket weave, the diagonal of the twill weave, and the luster of the satin weave produce simple designs. This type of decoration becomes more elaborate as fabric construction advances to the use of the third dimension in the pile weave, to the open-mesh lacelike effect of the lappet weave, and to the intricate effects of the Jacquard weave, as well as to the various knits and other types of fabric formation.

When fabric passes through finishing operations, it may be given lustrous effects that contribute further to its final appearance. Other finishing processes create the additional effects of soft napped surfaces and the crinkled designs seen in matelassé, seersucker, and similar crepes. Dyeing makes an important contribution to fabric decoration by the many beautiful colors it produces and the color harmonies obtained by combinations of the various dyeing methods. Fabric can be still further enhanced by printing color designs on the finished cloth.

DISTINGUISHING PRINTING FROM DYEING

To know whether a fabric has been dyed by immersion or whether the color has merely been printed on the cloth, examine the outline of the design. On the printed fabric, the outline or edges of the design are sharply defined on the right side. The entire design seldom penetrates to the back of the cloth.

On sheer fabrics, the design may show up favorably on the reverse side because dyestuffs will penetrate sheer construction. Such fabrics may intentionally simulate woven designs, which use yarn-dyed warp and filling. Examine some of the raveled yarns. If the design has been imprinted, the yarns will show areas on which the color is not equally distributed.

DYES USED FOR PRINTING

Most classes of dyes are adaptable to one or more of the various types of printing. The choice depends on the purpose for which the goods will be used, the fiber or fibers involved, and what the potential customer would be willing to pay. Good fastness properties in prints are available, and there is no reason why the consumer should settle for less than satisfactory fastness.

Of the various dye classes, the *vat*, *reactive*, *naphthol*, and *disperse* colors will generally produce the needed fastness properties for most purposes. Another class, called *pigment* colors, are not truly dyes but are of utmost importance in printing. These colors are fixed to the fiber by means of resins that are very resistant to laundering or dry cleaning. (Pigment prints can be identified by their relatively stiffer and less permeable areas resulting from the resin.) The pigments themselves are among the fastest known colors to all normal influences. For light to medium shades they are unbeatable; but for full or dark shades they are impractical because the colors are not really absorbed by the fiber and will crock, or rub off. This problem may be solved by improved resins, better pigments, or more effective anticrock agents.

For cotton printing, vat and reactive dyes are generally used. Pigments and some naphthols are also used. Very cheap prints can be made with basic colors mixed with tartar emetic and tannic acid, but today's domestic market has scarcely any room for such prints. Silk is usually printed with acid colors; wool, treated with chlorine to make it more receptive to color (and to prevent shrinking), is printed with acid or chrome dyes. Fabrics of manmade fibers are generally printed with disperse and cationic dyes.

METHODS OF PRINTING

One form of applying color decoration to a fabric after it has otherwise been finished is called *printing*. Fabric that is to be printed must be singed, bleached, and cleaned. There are three basic approaches to printing a color on a fabric: direct, discharge, and resist.

Direct Printing. The most common approach for applying a color pattern is *direct printing*. It may be done on a white fabric or over a previously dyed fabric, in which case it is called *overprinting*. The dye is imprinted on the fabric in paste form, and any desired pattern may be produced. The dyes are usually dissolved in a limited amount of water to which a thickening agent has been added to give the necessary viscosity to the print paste. Originally, corn starch was much favored for this purpose in cotton printing; today, gums or alginates derived from seaweed are preferred because they are easier to wash out and do not themselves absorb any color (which would be subsequently washed out in the final soaping and printing). Furthermore, the gums allow better penetration of color, which is important to good printing. Most pigment printing is done without thickeners, as such; the thickening is obtained by mixing together resins, solvents, and water to produce the necessary viscosity for printing.

Discharge Printing. Another approach for applying a color pattern is *discharge printing*, but its use has been declining. The fabric is dyed in the piece and then printed with a chemical that will destroy the color in designed areas. Sometimes the base color is removed and another color printed in its place, but usually a white area is desirable to brighten the overall design. When properly done, discharge printing is thoroughly satisfactory; however, the discharged areas may literally fall out of the fabric if the goods are not thoroughly washed after printing (a rare situation today). The usual method of producing discharge prints is to print the design, such as polka dots, with a paste containing a reducing agent. A steaming follows and then there is a good washing to remove the by-products of the reaction.

Resist Printing. A third approach to obtaining a color pattern is *resist printing*. Bleached goods are printed with a resist paste—a resinous substance that cannot be penetrated when the fabric is subsequently immersed in a dye. The dye will affect only the parts that are not covered by the resist paste. After the fabric has passed through a subsequent dyeing process, the resist paste is removed, leaving a pattern on a dark ground. In the discharge method, the fabric is first dyed and the color is then extracted by an imprinted chemical; in the resist method, a resist paste is first imprinted and the fabric is then dyed. The durability of the fabric is not affected by the resist method.

Each of these approaches is used on one or more methods of application described below.

Block Printing

The oldest method of printing designs on fabric is block printing by hand. It is not commercially important today because it is too slow—printed fabric cannot be produced inexpensively in large enough quantities by the handblocked method. Block printing has usually been done in countries where labor is less costly than in the United States. Today, fabric is block-printed only in comparatively short lengths of material. Block printing is found chiefly in decorative pieces for the home or in expensive linens for upholstery purposes.

To make blocked prints, the design must first be carved on a wooden or metal block. The dyestuff is applied in paste form to the design on the face of the block. The block is pressed down firmly by hand on selected portions of the surface of the fabric, imprinting the carved design as many times as desired on a specific length of cloth. To obtain variation of color in the same design, as many additional blocks must be carved as there will be additional colors. The portions of the design that will appear in different colors must be separately imprinted by hand before each design is complete. The more colors used, the more valuable and expensive the blocked print will be, because of the enhanced beauty of design as well as the labor involved in the hand printing.

Handblocked prints can be recognized by noting slight irregularities in the detail and in the repetition of the design and by comparing areas for slight variations in color. These irregularities are now imitated by machine printing, however. They give machine prints the characteristic appearance of expensive handblocked prints.

Roller Printing

Roller printing is the machine method of printing designs on cloth by engraved rollers. It turns out color-designed fabrics in vast quantities at the rate of 1000 to 4000 yards (914–3658 m) an hour. This method of producing attractive designs is relatively inexpensive when compared with any hand method. It is a machine counterpart of block printing. In roller printing, engraved copper cylinders or rollers take the place of the handcarved blocks. Just as there must be a separate block for each color in block printing, so must there be as many engraved rollers in machine printing as there are colors in the design to be imprinted. With each revolution of the roller, a repeat of the design is printed.

Originally, the design for each of the rollers was engraved by hand with an awl; then a skilled craftsperson duplicated the artist's design onto copper rollers. Today, the engraving is frequently done by *pantograph* transfer. Separate photographs on individually sensitized copper plates are taken for each color of the design. An artist then paints the appropriate color of the pattern on each plate. The engraver traces the outline of the design on the plate with one arm of a pantograph, which simultaneously cuts the design (with a diamond needle on its other arm) into the curved surface of a copper roller. Next, a chemical resistant is coated over the areas of the roller that will print the color, and the roller is treated with acid. The acid etches the unprotected areas, which form the design pattern to be used for color printing.

Another method of reproducing a design on a roller is by photoengraving. A film of a photograph pattern is placed over a sensitized roller. After exposure, the roller is etched. This technique reproduces the photograph's detail and shading.

Each roller is polished for uniform smoothness so that the dye will spread evenly on the raised areas. They are then locked into precise positions on the machine for proper registration (alignment). The number of rollers used depends upon the number of colors in the design, and as many as sixteen rollers can be employed.

Each of the engraved rollers first comes in contact with a companion roller that has been submerged in the dye paste

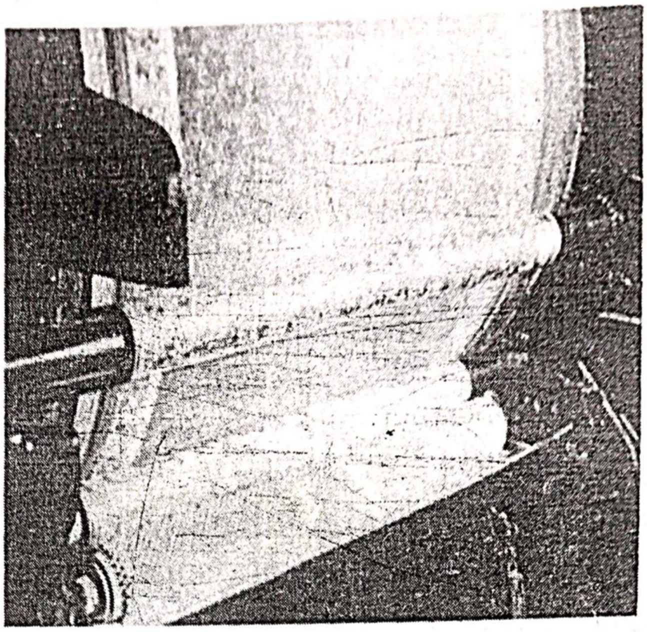


Figure 12-1 In roller printing, engraved copper rollers transfer print design to fabric. Note color pans and furnisher-rolls supplying color to the rollers. In the foreground are counterweights controlling doctor blades (hidden from view by copper rollers), which continuously remove excess color from the engraving. *(Courtesy United Piece Dye Works)*

to be used for its part of the design. A sharp blade, called the *doctor blade*, scrapes the excess dye from the surface of the roller. As the fabric passes between the engraved rollers and smooth cylinder rollers, the dye from the shallow areas is pressed on it. Behind and along with the fabric being printed is another fabric, called the *back grey*, which absorbs the excess print paste and prevents it from striking through and staining the smooth rollers (see Figure 12-1).

The printed cloth is immediately passed into a drying chamber and then into a steam chamber where the moisture and heat sets the dye. The back grey is eventually washed out and reused.

Duplex Printing

Duplex printing simulates a woven pattern by printing the fabric on both sides. The fabric may be passed through the roller printing machine in two separate operations or through a duplex printing machine in a single operation. Duplex printing produces an equally clear outline on both sides of the fabric. The design is applied so skillfully by careful registration of the printing cylinders that the result may be mistaken for a woven design. The difference can be detected by raveling a yarn.

Stencil Printing

Stencil printing originated in Japan. Its high cost limits its use and importance in the United States. In stencil printing, the design must first be cut in cardboard, wood, or metal. The stencil may have a fine, delicate design, or there may be large spaces through which a great amount of color can be applied. A stencil design is usually limited to the application of only one color and is generally used for narrow widths of fabric.

Screen Printing

Originally, this technique was referred to as *silk-screen printing* because the screens were made of fine, strong silk threads. Today, they are also made of nylon, polyester, vinyon, and metal. Screen printing is done with the use of either flat or cylindrical screens.

Flat Screen Printing. Originally, flat screen printing was done by hand. Now it is also done by machine. The artist's design is copied onto a series of very fine, flat screens, one for each color to be printed. Each screen's design may be drawn by hand and a coating of lacquer or other impermeable substance applied to all parts of the screen that are not part of its design. More usually, today, the design is photographed and a negative is used for each sensitized screen to opaque, or block out, those areas not part of the screen's color design. Each screen is then fitted onto a wooden or metal frame.

The fabric to be printed is attached to a backing spread on a long table. A screen representing one color of the design is set by hand over the fabric in the first position by metal brackets on the sides of the table to hold it in place (Figure 12-2*a*). The printing paste, or dye, is poured on the screen and forced through its unblocked areas onto the fabric with a rubber-edged squeegee (Figure 12-2*b*). The frame is then raised and placed on the next section of the fabric, and the operation is repeated until the entire length of the cloth is printed with that one color. This process must be repeated for each color to be used in the design (Figure 12-2*c* and *d*).

Whereas the hand screen printing is time-consuming and limited to relatively short lengths of 60 yards (55 m) of fabric, electronically controlled automatic machines can screen-print long lengths of cloth at rates of up to 450 yards (400 m) per hour. By this method, the back of the fabric to be printed is coated with an adhesive, which causes it to adhere to a backing on a rubber conveyor belt that serves as the tabletop for the printing operation. A series of flat screens, one for each color, are set in frames with automatically operated squeegees and are placed above the belt. As the fabric advances, the screens are automatically lowered to the cloth and the appropriate color is properly applied with automatically regulated squeegees. The cloth is continuously fed into an oven to be dried. The modern flat screen printing machine is very expensive, but it will print up to twenty colors in one run. The versatility and production rate of this method, however, compensate for its initial high cost (see Figure 12-3).

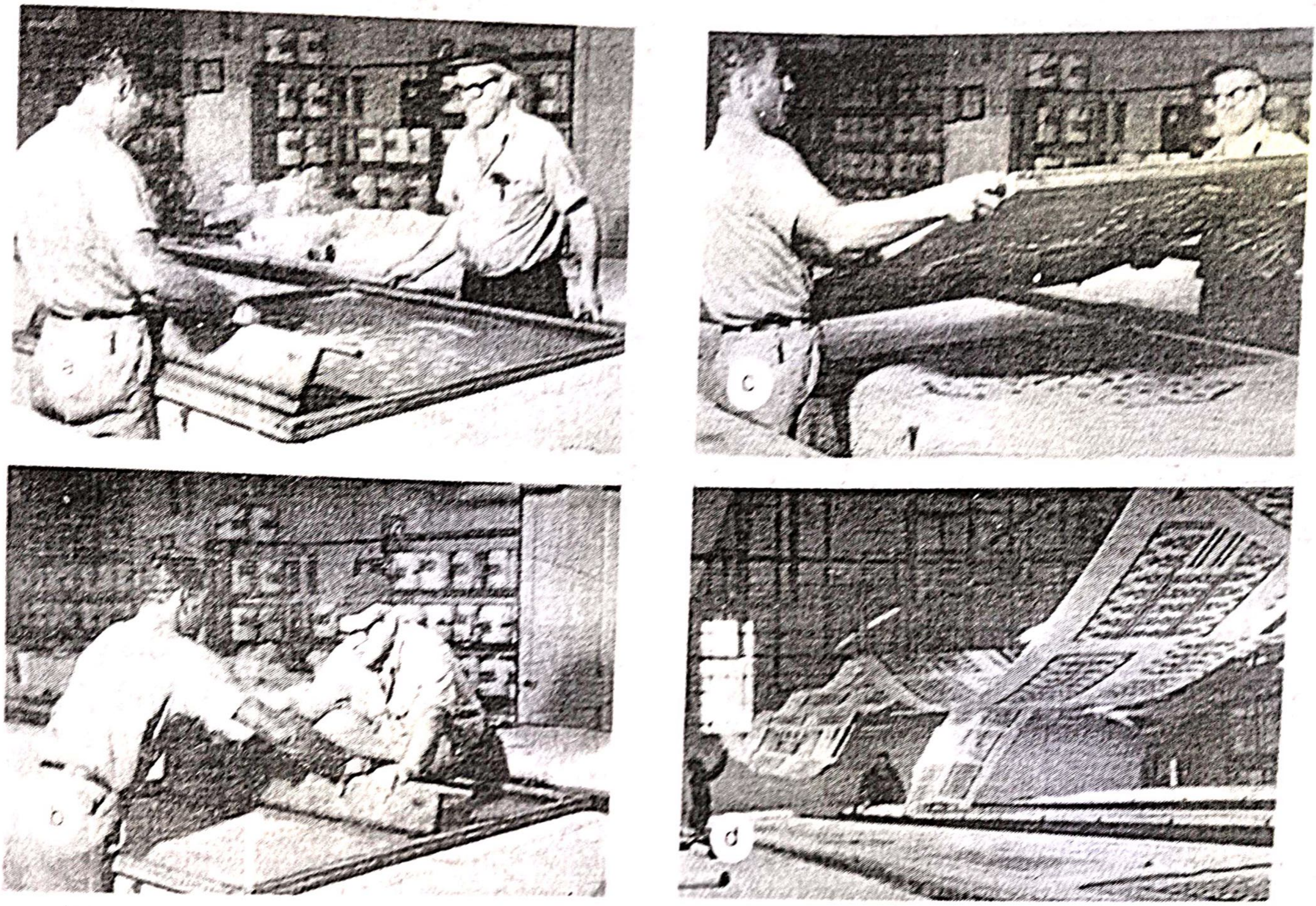


Figure 12-2 *(a)* In hand screen printing, the fabric to be printed is laid out on a table and a screen for each color of the design is precisely placed. *(b)* Two people work together passing the squeegee to each other as they force the dye through the screen. *(c)* Each screen of the series is progressively moved to succeeding sections of the fabric to repeat the same color of the design. *(d)* The hand screenprinted fabric is hung on a rack above the printing table to air-dry. *(Photos Courtesy CIBA-Geigy Corp. and Printex Corp.)*

The chief advantages of screen printing are that the colors can be produced in brighter, cleaner shades than are possible with roller printing and the designs to be repeated can be much larger. The technique also lends itself to experimental and creative designs. Short runs of unique designs provide an exclusive pattern often sought by couturiers and interior decorators. The process is slower than machine roller printing; therefore, it is not quite as economical for large-sized yardages. However, the automatic flat screen printing machines now available have cut down the cost differences considerably. Printers so equipped are no longer looked upon as small yardage operators. Most roller printing plants today have auxiliary flat screen printing machines for samples and intermediate-sized yardages that are not profitable on the roller machines.

In screen printing, it is possible to have designs consisting of squares, circles, and ovals because the areas not to receive the dye are painted out by the lacquer. If clearly defined geometric designs were attempted in cardboard or metal stencils, obviously, the cut area would fall away.

On a knitted fabric, such as jersey, flat, and rotary screen printing and transfer printing are the only printing methods that can be used. Other methods smear the dye, as a knitted fabric stretches when it receives the impact of the rollers.

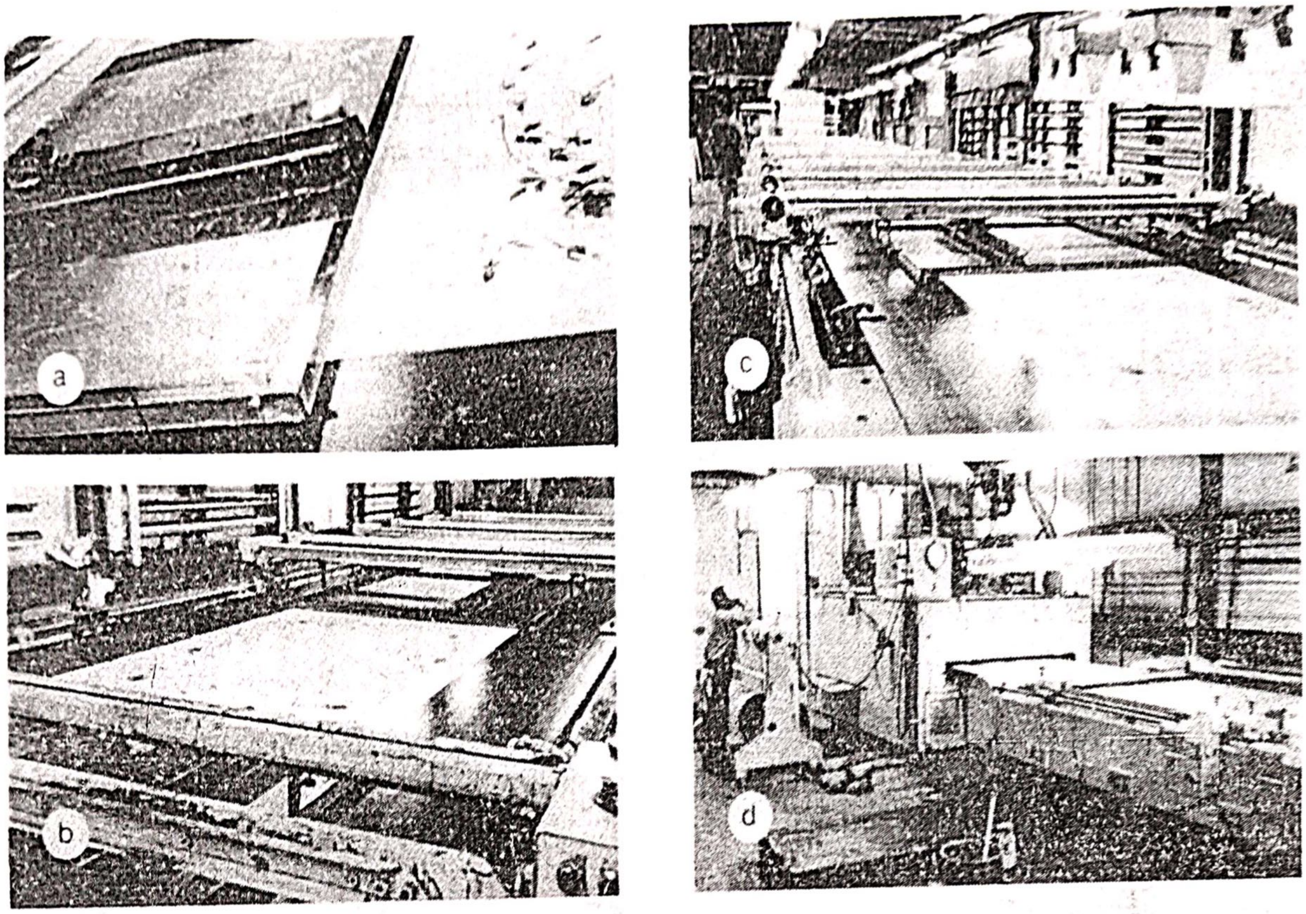


Figure 12-3 (*a*) In automatic screen printing, electronic controls set each screen on the fabric, release a measured amount of the appropriate color, and run the squeegee on a rail passing over the screen. (*b*) The fabric is automatically moved along on a conveyor belt successively from one screen to the next to receive different parts of the colored design. (*c*) The fabric passes under the last of a series of screens before being moved into the dryer. As many as twenty screens may be employed to obtain as many colors. (*d*) The automatic machine screenprinted design is inspected as it leaves the dryer. *(Photos Courtesy CIBA-Geigy Corp. and Printex Corp.)*

Rotary Screen Printing. A printing machine that utilizes seamless cylindrical screens made of metal foil was originally developed in Holland. This process is called *rotary screen printing*. The machine employs a rotary screen for each color, as in flat screen printing, and the design for each rotary screen is made in a manner similar to automatic flat screen printing. As the fabric to be printed is fed under uniform tension into the printer section of the machine, its back is usually coated with an adhesive, which causes it to adhere to a conveyor printing blanket. Some machines use other means of gripping the cloth firmly in place. The fabric passes under the rotating screens through which the printing paste is automatically pumped from pressure tanks. A squeegee in each rotary screen forces the paste through the screen onto the fabric as it moves along at rates of up to 100 yards (91 m) per minute. The cloth then passes into a drying oven, cured to set the color, and washed.

Rotary screen printing combines the advantages of roller and flat screen printing techniques (see Figure 12-4). Rotary metal screens are lightweight in contrast to the heavy copper rolls, and they cost less. They give color depth that is similar to or as good as that of flat screens. Prints

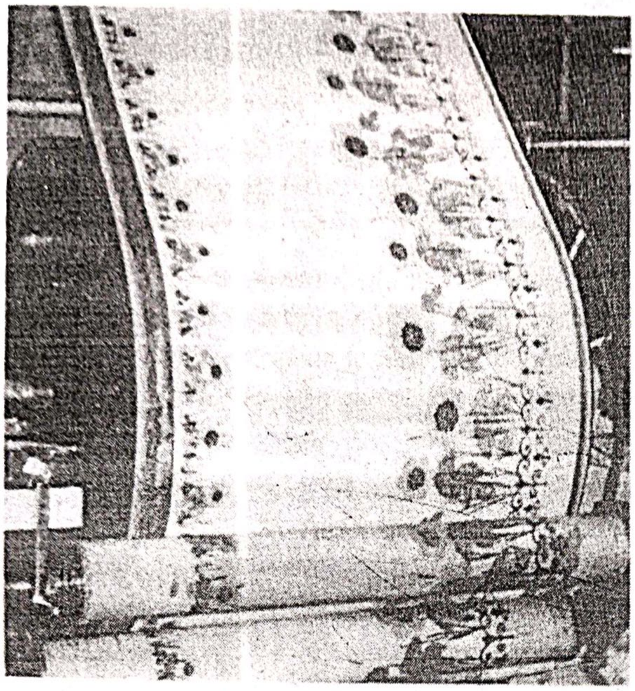


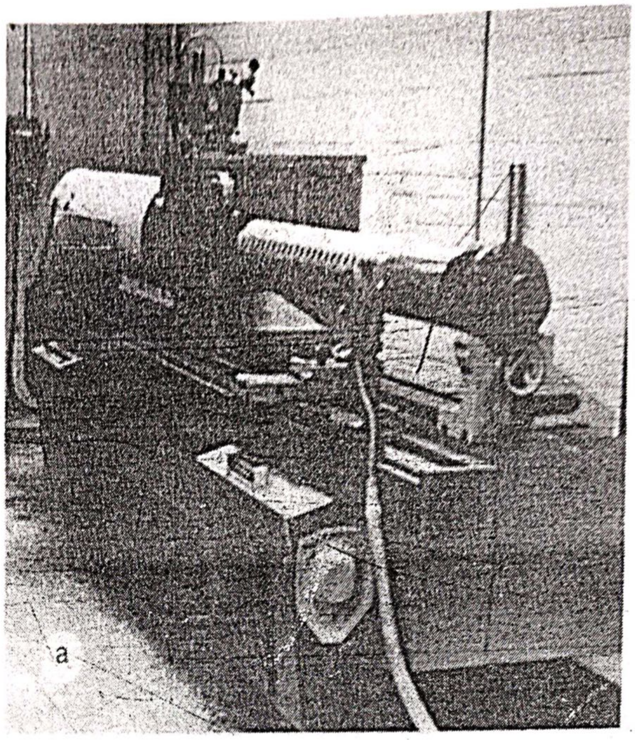
Figure 12-4 Rotary screen printing combines the basic principles of the roller and the screenprinting techniques. (*Courtesy* Textile World)

of various types and intricate designs with shades of up to twenty colors can be obtained with a high degree of accuracy and sharpness. Rotaries operate continuously rather than starting and stopping as the flats do. Production output is considerably higher than it is on flat screen machines.

Transfer Printing

Literally moving a design from one surface to another is known as transfer printing. A typical well-known technique is that of iron-on prints of emblems and decorations, which are generally made of pigments in a paraffin or thermoplastic base that can be melted and bound by heat and pressure onto a fabric surface. These pigment transfers are not very satisfactory because they make the cloth stiff and are not fast to laundering or light.

A more sophisticated and effective method of transfer printing is that of transfering a design intact by vaporizing it from the paper to a fabric. There have evolved two principal processes: *dry heat transfer* and *wet heat transfer* (see Figure 12-5).



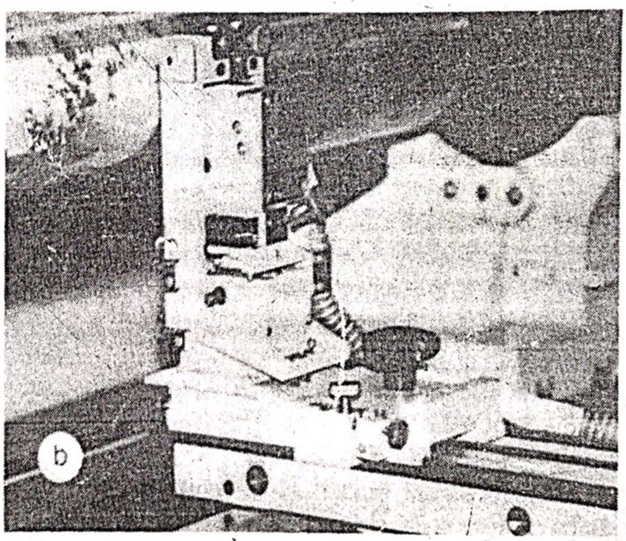


Figure 12-5 (*a*) A mechanical engraver used to cut a pattern into a cylinder for printing of dye on transfer paper. (*b*) Close-up of the stylus head engraving the cylinder. (*Courtesy Sublistatic Corporation of America*)

Heat transfer printing has many advantages. Production costs are reduced because such aftertreatments as steaming and aging are eliminated. Since the print is initially on the paper, the production of seconds is considerably reduced. Maintenance of printed fabric inventory (and space) is also reduced. Heat transfer prints generally have a better hand. Excellent prints with line definition, fine detail, and shadings can be achieved. A wide range of patterns in a great many colors, including rich and deep shades, may be produced (Figure 12-6). Tweed, chambray, and other effects can be printed on woven and knitted fabrics to give them textural appearances (Figure 12-7). Heat transfer printing can be applied to both woven and knitted fabrics, including circular-knitted goods around the circumference, without slitting the material. Transfer printing can also be done on cut-and-sewn and fully fashioned garments.

There are limitations to heat transfer printing. In some instances, short runs could be expensive. Color fastness is dependent upon the fiber and the system used, and therefore, correct dye selection for the pattern is imperative. Also, it is not always possible to get the same effects as with discharge or resist printing methods.

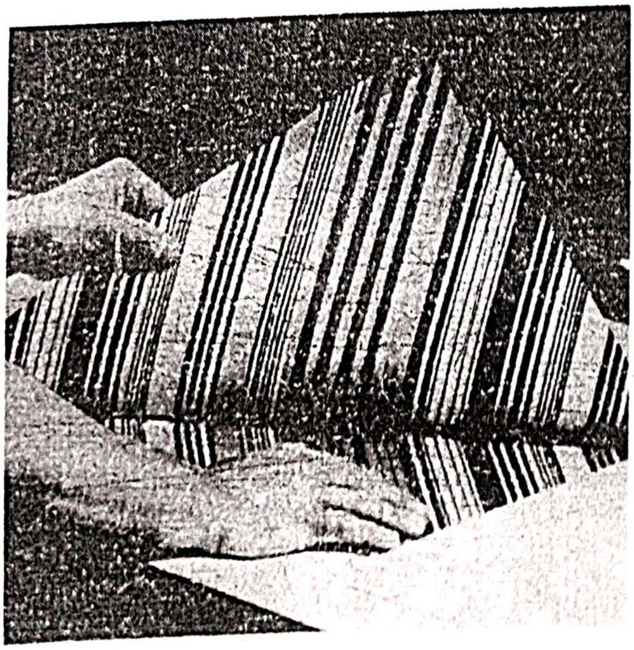


Figure 12-6 Separating a dry heat transfer printed fabric from exhausted paper. *(Courtesy Sublistatic Corporation of America)*

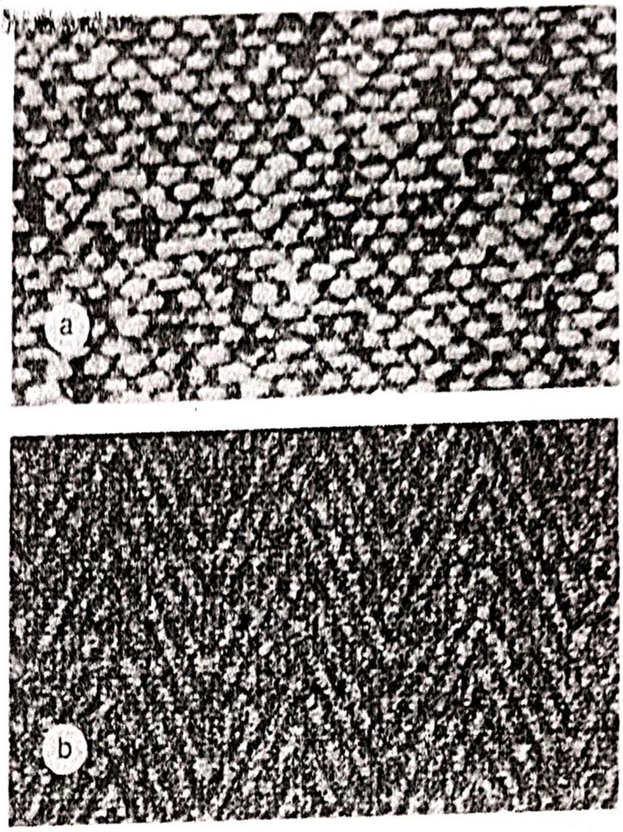


Figure 12-7 Examples of dry heat transfer prints on fabrics to simulate (*a*) tweed and (*b*) herringbone. *(Courtesy Sublistatic Corporation of America)*

Dry Heat Transfer Printing. In 1958, Noel DePlasse, director of the dyeing department at La Lainiere de Roubaix (now Prouvost-Masurel) of France, accidentally discovered while working on another matter that color can be transferred from one fabric to another by the application of dry heat. After 10 years of experimentation involving the collaboration of a dyestuff producer, a paper printer, and a machinery manufacturer, the Sublistatic Corporation, S.A., was formed. Commercialization began with the introduction of the Sublistatic process of heat transfer printing on garment pieces and garments made of polyester and other manmade fibers and was later extended to piece goods. A related process, Thermocrome, was introduced about that time in England.

While the original heat transfer printing process was very effective using disperse dyes for polyester, it had limitations of penetration and fastness for other fibers. Consequently, a variation of the technique was developed. There are, therefore, two heat transfer printing methods. The original process uses a *conventional heat system* and the second uses an *infrared heat vacuum system*.

Conventional Heat Transfer Printing. This method utilizes an electrically heated cylinder that presses a fabric against a transfer printed paper on a heat-resistant blanket held under tension. The dry heat causes the dye to sublimate (vaporize) in pattern form directly from the paper into the fabric. This system is very effective with disperse dyes on polyester fabrics, but requires modification of dyes and technique for other fibers.

Infrared Heat Vacuum Transfer Printing. This method operates at lower temperatures and pressures and is better suited to certain fibers, such as heat-sensitive acrylic and spandex. The system is also quite effective for dye penetration of pile fabrics, such as velours and carpets. The transfer printing is accomplished by passing the transfer paper and fabric between infrared heaters and a perforated cylinder, which are protected from excessive heat by a shield. As the paper and fabric pass by the cylinder, a partial vacuum is created by sucking air through the perforations. (There is no direct contact between the fabric and the cylinder, as this is prevented by a blanket.) The heated dye pattern sublimates in the partial vacuum, which has fewer air molecules to collide and therefore interfere with the transference of the dye.

Wet Heat Transfer Printing. The problems of dye and fiber applications of dry heat transfer printing, stimulated research for other approaches. Wet heat transfer printing techniques resulted. Two major systems are Fastran and DewPrint. The systems utilize heat in a wet atmosphere to facilitate the sublimation of the dye pattern.

The Fastran process is well suited for cotton and wool blends, as well as all-nylon fabrics. The goods are padded with an aqueous bath containing Fastran powder which contains sulfamic acid, a locust bean gum derivative that holds a moisture film over the material during transfer, and surfactant derivatives that facilitate high-level dye absorption. After the fabric or garment (placed on a plastic frame to hold its shape) is prewetted by the padding process with a solution of the powder, the transfer-print paper is placed over it and is covered with a silicone-rubber sheet. This sandwich is then placed in a steam or dielectric heated press where the heat converts the water to steam, which is sealed in by the silicone-rubber sheet. The print vaporizes and migrates from the paper to the fabric. The amount of color transfer is extremely high—that is, 90 percent or better. The process is completed with a simple afterwash. The Fastran process may also be used for dye-discharging from previously colored fabric, and fluorescent whitening.

The DewPrint process is well suited for cotton goods and may be effectively used for wool, wool blends, nylon, acrylic, and spandex, including both flat and pile fabrics. The material is padded with a proprietary emulsion, which aids the dye transfer from paper to fabric. It is then passed along with the printed transfer paper over a cylinder heated at a lower temperature than is used for dry heat transfer printing, as pressure is exerted with the aid of rubber and steel rollers distributed around the cylinder. The fabric is then washed to remove the emulsion assistant and is tenter dried.

Blotch Printing

Blotch printing is a direct printing technique whereby the background color and the design are both printed onto a white fabric. It is usually done in one operation. Any one of several methods of application, such as block, roller, or screen, may be used. Blotch prints can be made to simulate the more costly discharge and resist prints. However, since the latter are piece dyed and therefore the face and back are the same, the blotch prints can be identified by the lighter back.

TAK Dyeing

"TAK" is an acronym for a machine invented jointly by a German rug manufacturer, Textil Ausrustungs Gesellschaft, and a machinery supplier, Edward Kuesters. Although it was originally made to produce random color patterns on carpets, it can also be used for a wide variety of fabrics, such as terry cloth, velvet, and various upholstery materials.

The TAK dyeing process is a continuous technique for randomly dropping or sprinkling dye liquor on a fabric to produce multicolored patterns. Streams of dye run from a trough under a doctor blade into individual channels. The doctor blade oscillates, breaking up the streams into drops and scattering them over a predetermined width. As the drops fall toward the continuously moving open-width fabric, they hit protruding fingers, or drop cutters, which move across the width of the cloth on a rotating chain (see Figure 12-8). Two or more rows of drop cutters may be used, depending upon the desired pattern and color combinations. The fabric is then padded to force the dye into it.

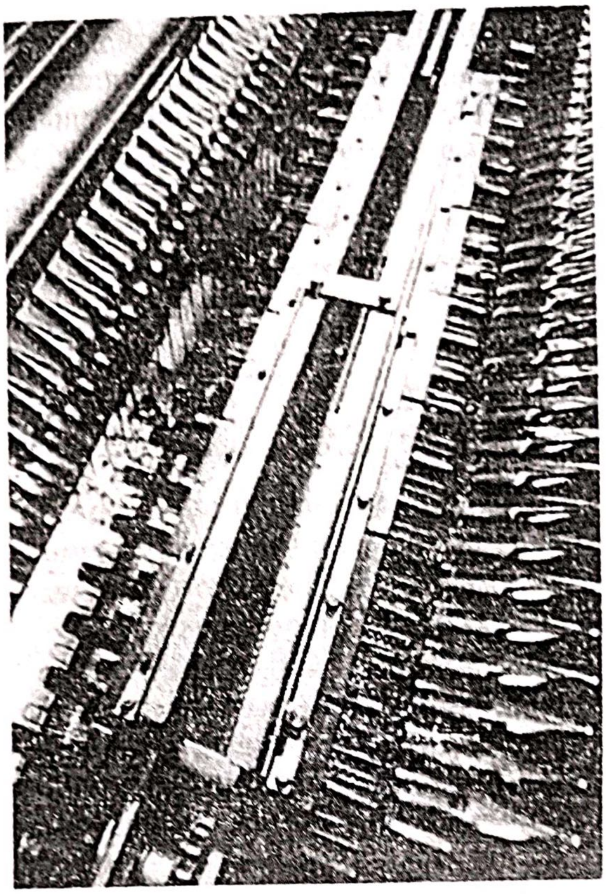


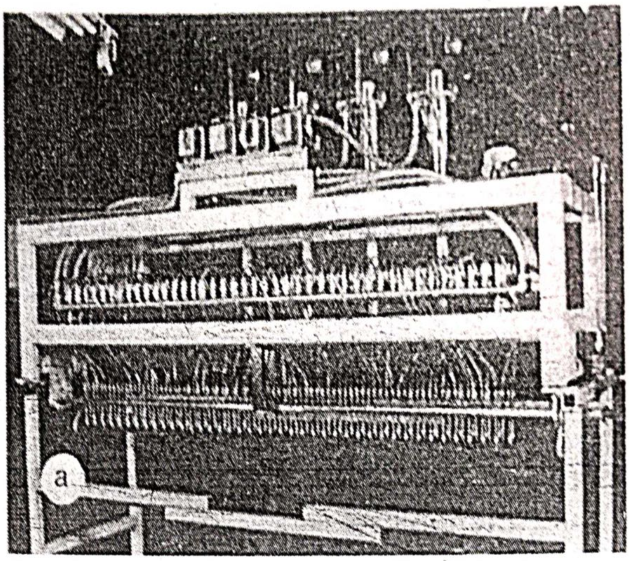
Figure 12-8 Close-up of the TAK process. Controlled streams of dye liquor fall from grooves onto drop cutters, and the drops hit the fabric which travels underneath this application. *(Courtesy* Textile World)

TAK dyeing can be done to gray goods or predyed material to achieve the pattern and desired background. The variety of patterns that can be obtained is infinite. Each pattern is dependent upon factors of the machine, the dyebath, and the fabric. For example, the machine may regulate the speed of the dye application, the speed of the fabric, the movement of the doctor blade, and the tilt of the drop cutter; the dye may vary according to its viscosity and its wetting agent; the fabric may vary in construction and in absorbency. These factors can all be noted, catalogued, and programmed for automated reproduction. The process is not only versatile, but it can also be used in place of some more expensive printing techniques at a considerable cost saving.

Jet Spray Printing

Designs may be imparted into fabrics by spraying colors in a controlled manner through nozzles. There are several ways of accomplishing this.

Polychromatic Dyeing. As the term implies, polychromatic dyeing is a multicoloring process. The effect resembles printing but does not use printing machinery. The method, developed and patented by ICI Dyestuffs Div., applies several dyes in one operation in a manner that produces such designs as random splashes of several colors, tie-dye abstracts, and multicolored stripes. The application of the dyes is done by controlled direction of the flow of dye liquors onto continuously moving open-width fabric. The streams of dyes are applied through jets set in bars above the width of the cloth (see Figure 12-9*a*). The number of jets, their size, their placement, and fabric speed determine the pattern. The number of possible designs is enormous, and each can be reproduced again based upon the required factor combinations. The jets, which can be moved from side to side according to the pattern desired, direct the streams of dye over an inclined plane which directs the streams as they fall onto the fabric. The cloth then passes between heavy rollers where it is padded to force the dye through to the back of the material. The result is a predetermined multicolored pattern equally visible on both sides of the fabric, similar in appearance to duplex printing (see Figure 12-9*b*).



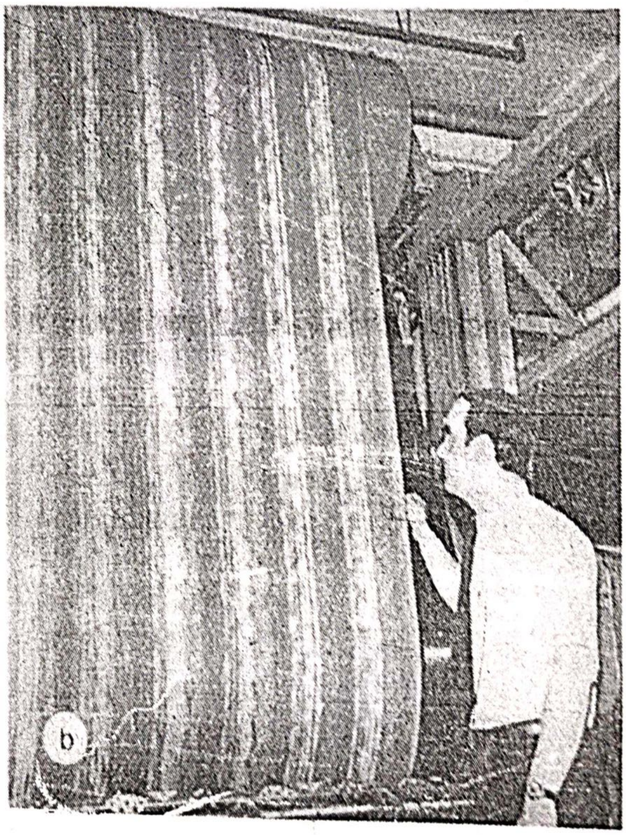


Figure 12-9 (*a*) As fabric is passed under the jets of this polychromatic dyeing machine, streams of dyes are ejected onto it producing multicolored patterns. (*Courtesy Harris Textile Machinery Co.*) (*b*) Random pattern achieved by polychromatic dyeing. (*Courtesy* Textile World *and Castle Creek Prints*)

The double-sided design is applicable to drapery and other materials where both sides of the fabric are to be exposed. The combination of thorough penetration of the dye and variable multicolors is also useful for a wide range of thick fabrics for such use as blankets, towels, corduroy, and velvet. The materials may be woven, knitted, tufted, or flocked of such fibers as cotton, rayon, nylon, and polyester.

Polychromatic dyeing has several other advantages. The process is fast; it can make designs at speeds up to 30 yards (25 m) per minute. It is versatile. It is economical because designs can be quickly set and altered once the patterns have been catalogued. No expenses need be incurred to produce screens, rolls, or other printing equipment.

Microjet Printing. Originally developed for carpets, microjet printing may be applied to other pile fabrics and material. The technique is, essentially, that of using rows of very fine jets to force dye into a fabric according to a predetermined pattern. There may be about 10 to 20 rows of jets per warpwise inch (25 mm). The operation of the jets is controlled by computer. Variations among machines exist. For example, the Millitron machine uses stationary rows of nozzles; the Chromotronic uses fewer jets per row but they are mounted on bars that can be moved across the width of the machine. By way of illustration, a general view of the Millitron operation can be given. A design is photographed and entered into a computer scanning unit that projects the image through another computer onto a cathode (TV) screen in color. The design is checked for accuracy and then fed onto a magnetic tape. The tape is then used to control the spraying of colors through small nozzles with fine holes positioned in a frame across the width of the fabric (or carpet). As the fabric passes under the fine jets, the required colors are sprayed directly into the selected areas. After printing, the fabric is steamed, washed, and dried.

Electrostatic Printing

A Swiss firm, Heberlein & Co., patented in England a process of mixing a finely powdered dye with a carrier, such as a natural or synthetic resin, that has high dielectric properties for electrostatic printing. The dye is spread on a screen bearing the design, and the fabric is passed into an electrostatic field under the screen, which is held about ½ inch (12 mm) above the cloth. The dye-resin mixture is pulled by the electrostatic field through the pattern area onto the material. The dye is initially fixed by infrared heat. The fixation is subsequently reinforced by whatever process is most suitable for the kind of dye used.

Photo Printing

In photo printing, the fabric is coated with a chemical that is sensitive to light. Any photograph may be printed on the fabric. The results are the same as when printing photographs on paper. All details can be reproduced if the photographer and technician are careful.

A sophisticated form of photo printing is the *cyamatic process* developed by Dr. Hans Jenny and commercialized by Koechlin Baumgartner and Cie AG. Oscillations of musical chords are caught on a quartz plate, the patterns that are formed on the plate are photographed, and the colored pictures are reproduced on fabric.

Differential Printing

The Du Pont Co., Ltd., of England developed a technique of printing tufted material made of yarns having different dyeing properties. This technique of differential printing is especially associated with screen printing of carpets tufted with differential dyeing yarns. Up to a ten-color effect is possible by judicious selection of the yarns, dyestuffs, and pattern. For example, the design can consist of a solid-color background with superimposed motifs, which may have contrast-color areas of differentially dyed colors.

Warp Printing

Warp printing is roller printing applied to warp yarns before they are woven into fabric. Fine white or neutral-colored filling yarns are generally used for weaving so that the design on the warp will not be obscured. This method produces designs with soft, nebulous, but striking effects. Great care must be taken to keep the warp yarns in their proper position so the outline of the design will be preserved. Warp printing is used for expensive cretonnes and upholstery fabrics.

A variation of warp printing is *Vigoureux printing* or *mélange*. Utilizing a variation of roller printing, horizontal or cross-striped designs are printed on the ropelike wool tops or slubbings. Subsequently, when the tops are spun into yarn, the stripes are attenuated and pulled apart so that they appear as scattered flecks of color in the woven cloth.

Batik Dyeing

The resist-dyeing process, whereby designs are made with wax on a fabric which is subsequently immersed in a dye to absorb the color on the unwaxed portions, is known as *batik dyeing*. It has been done in the Orient, notably India and to some extent in Japan, for many centuries. However, it is on the island of Java in Indonesia where the term "batik" originated and where high technical and artistic skill of batik print really developed. Originally limited to execution by noblewomen, the technique is now a flourishing industry, particularly as a cottage industry where natives do batik dyeing in their small houses.

There are two methods. The technically more difficult and more artistic designs are drawn by hand. The patterns are generally in geometric, floral, bird, or animal motifs, but the artist's imagination may introduce other fanciful designs. The motif is drawn on cotton cambric. Then melted wax mixed with a resin is traced on the areas not to be dyed with a *tjanting*, which is a small instrument made of a short, straight reed handle to which is attached a small, funnel-shaped copper cup with one or more spouts (see Figure 12-10*a* and *b*). When the tjanting is refilled by scooping the hot, liquid wax from a copper pan kept over a burner, the worker blows into the spout to eliminate any blockage and allow the wax to flow. The application of the wax must be done on both sides of the fabric. This hand method of making the design is a slow process, which may take as long as one month to produce 2½ yards (2.3 m). When an artist makes a large, individual picture which may be used for such purposes as wall hangings, it may take six months to one year to complete.

The faster method of designing is done with a *tjap*, or stamp, of a pattern made of fine copper strips soldered together. The tjap is pressed onto a pad of cloth saturated with liquid wax. The wax picked up by the stamp is then applied to the cambric (Figure 12-10*c* and *d*). The design may be intricate, but it is repetitious and limited in artistic quality. However, about 25 to 40 yards (20–36 m) of cloth can be printed in one day.

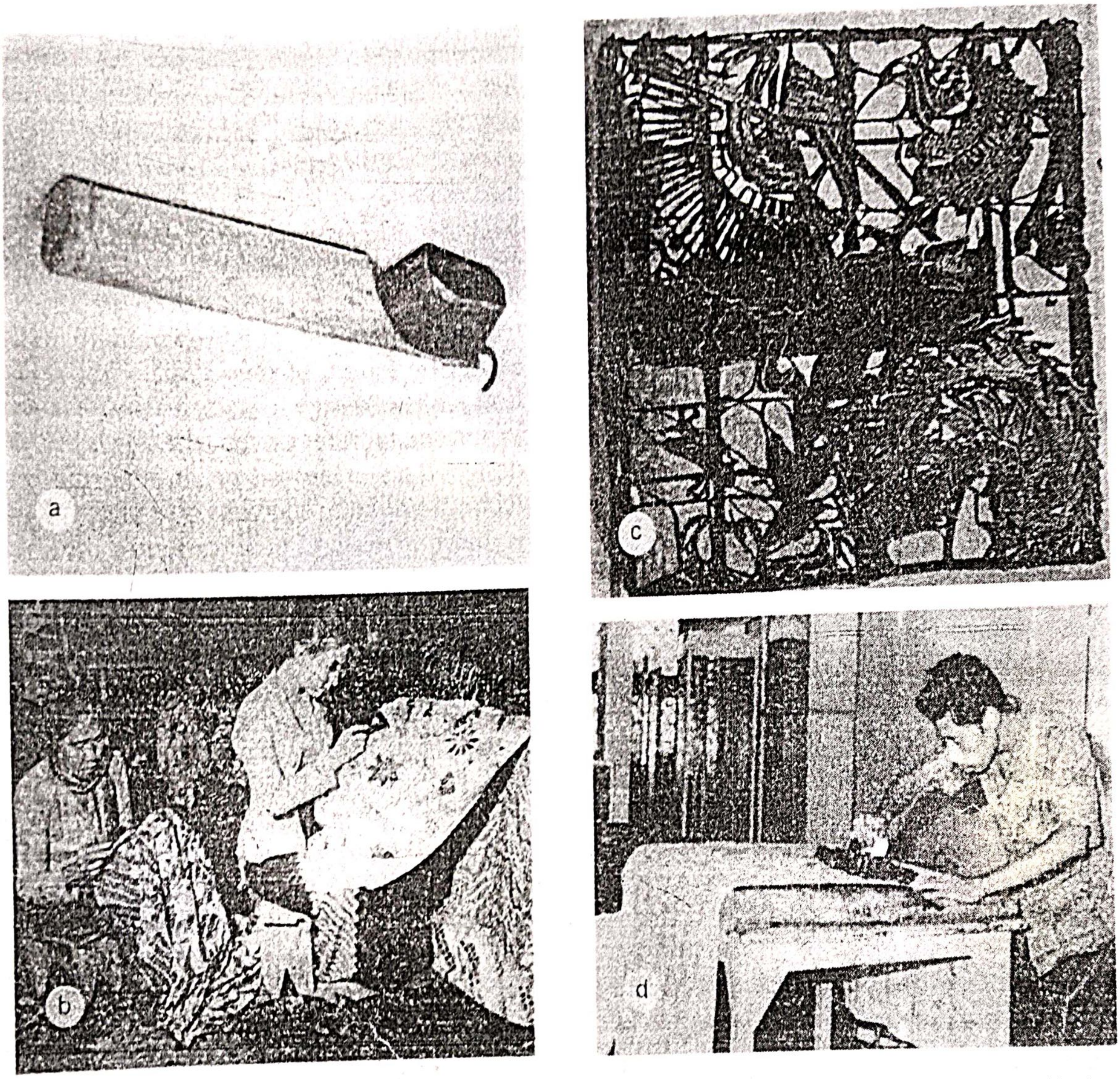


Figure 12-10 (*a*) The tjanting used for batik designs is held by the bamboo handle. The copper cup holds the wax and resin mixture, which passes through the narrow spout to trace the waxy substance forming the design on the fabric. (*b*) Using a tjanting, hand batik designs are slowly and carefully traced with melted wax which resists the dye when the fabric is subsequently put into a dyebath. (*c*) The tjap used for block batik dyeing is made of copper strips formed into intricate designs. (*d*) Using a tjap, a batik design is stamped repeatedly with melted wax which resists the dye when the fabric is subsequently dyed.

After each application of wax, the fabric is dipped into dye to obtain the particular color desired. Only that portion of the fabric that is not covered by the wax will absorb the dye, as the wax coating on the rest of the cloth serves as a resist. After the dye has been fixed and the material dried, the cloth is boiled and rinsed to remove the wax. Any traces of wax remaining on the fabric are then scraped off. This procedure is repeated as many times as there are different colors to be obtained to complete the design composition.

The primary colors used are red, yellow, and blue, although some designs are black and white. Various light and dark shades of brown, green, violet, orange, and pink are also used. Sometimes, in the last application of color, the wax is permitted to crack, and the last dyestuff partially penetrates the other dyed portions, producing the multicolored design characteristic of batik. The American method differs from the Oriental in that light colors are applied first, followed by the wax; the deeper shades are then built in. In the Oriental method, the dark shades are applied first, and the portions to be kept light are waxed.

There are three qualities of cambric that are used for batik-dyed fabrics. The best is *primisima*, or fine. The second, which is the most extensively used, is *prima*, or medium (moderately fine). The third is *mori biru*, or coarse.

Tie Dyeing

The results of tie dyeing are sometimes similar in appearance to batik, but the designs are made differently. The dye is resisted by knots that are tied in the cloth before it is immersed in the dyebath. The outside of the knotted portion is dyed, but the inside is not penetrated if the knot is firmly tied. Partial penetration occurs when the knot is not tight, causing gradations and irregularities of color that produce indistinct but attractive designs. The process is repeated as many times as desired by making new knots in other parts of the cloth and immersing the fabric in additional dyebaths. This gives a characteristic blurred or mottled effect, the result of the dyes running into each other. Like other hand methods, tie dyeing is expensive. Because the method creates interesting designs, the patterns are imitated in roller printing.

Ikat Dyeing

An ancient method of fabric coloration by tie-dyeing bundles of warp and/or weft yarns prior to weaving is *ikat*. It is believed to have originated in the Orient. In Japan it is called *kasuri*. The major centers today are Bali, Java, and Sumatra.

Ikat is a skilled art form. The colors, usually indigo, red, and brown, are placed along the length of the yarns in anticipation of the design that is to be woven. When the fabric is woven, the edges of the design have a blurred or shimmering effect not unlike a reflection on water. This is due to the slight penetration of the dye that may occur beyond the tie and to the stretching of the yarns on the loom during weaving.

Plangi Dyeing

Plangi is another ancient art form of dyeing. The major centers today are in Africa. It is a form of tie-dyeing by gathering, folding, or rolling the fabric, usually held with stitching, to form specific patterns.

Airbrush (Spray) Painting

Designs may be hand-painted on fabric, or the dye may be applied with a mechanized airbrush, which blows or sprays color on the fabric. Airbrush painting is used when surface coloring is to be done quickly and economically; for example, designs on tablecloths. Direct, acid, or vat dyes dissolved in water, alcohol, or other organic solvent may be used.

COMPOSITION OR PASTE DESIGNING

The rollers used to imprint color by means of dyes, chemicals, or resist pastes can

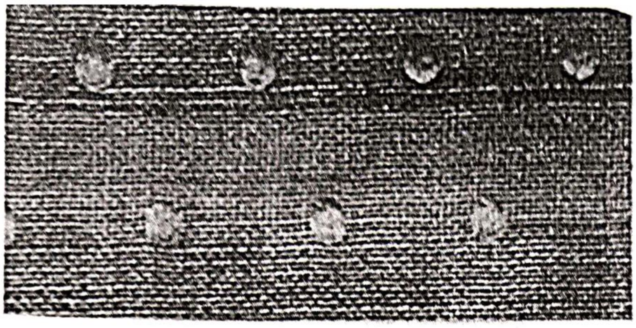


Figure 12-11 Pasted designs, like the dots in this fabric, may disappear in laundering if an inferior adhesive is used. *(Courtesy U.S. Department of Agriculture)*

also apply lacquer or colored paste to fabric as small designs. Modern adhesives make such designs very resistant to normal laundering. Substances that can be baked into the fabric are also used for this decorative effect. When this is done, the designs become so much a part of the cloth that they may be considered permanent, seldom being destroyed by washing or dry cleaning (see Figure 12-11).

FLOCKING

The technique of adhering minute pieces of fiber, called *flock*, to form designs on fabric has been used to a limited extent for about 600 years. It has become more widely used in recent years because of modern methods. Using a suitable adhesive (instead of a dye), a design is roller-printed onto a fabric. Then, flock of cotton, wool, viscose rayon, nylon, or acrylic is applied to the fabric in a manner that causes it to adhere in an upright position and produce a pilelike, velvet-textured design. The flock is usually of colored fiber, thereby adding to the decorative appeal (see Figure 12-12).

Cotton and wool waste fiber are often ground or random-cut into flock. However, since such production results in uneven and angular ends that do not affix as

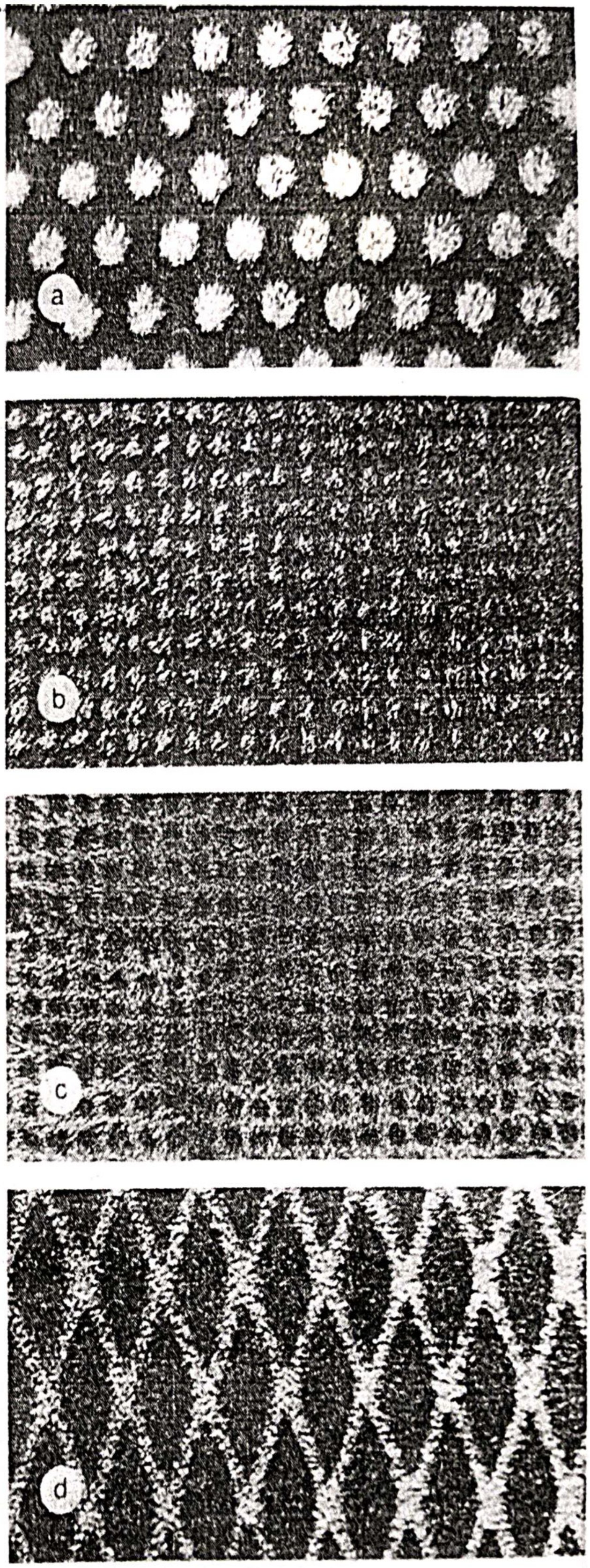


Figure 12-12 Pattern flocking, using different-colored flock and controlling the deposition of each to certain areas, can be done on a substrate that is coated with a design of an adhesive. *(Courtesy Modern Textiles Magazine)*

TABLE 12-1 ***DECORATION OF FABRICS BY PRINTING AND DYEING***

TYPE OF DECORATION	*HAND METHOD*	*MACHINE METHOD*
Direct printing	Dye applied directly onto fabric by carved block, stencil, screen, etc.	Dye applied directly onto fabric by carved block, engraved roller, screen, etc.
Discharge printing		Bleached goods first dyed; chemical bleach printed on fabric; color discharged
Resist printing	Yarn or fabric covered with substance to prevent dye from penetrating certain areas; dye applied	Resist paste put on fabric; fabric dyed; paste removed
Block printing	Design carved on blocks; dye applied to block; block pressed on fabric	Similar blocks pressed on fabric by machine; design tends to be more regular
Roller printing		Design etched on roller; companion roller transmits dye to etched roller, which transmits it to fabric
Duplex printing		Design printed back to back on both sides of fabric; gives effect of woven pattern
Stencil printing	Design cut in stencil; color applied over stencil	
Flat screen printing	Design sketched or photographed on sheer silk, nylon, polyester, vinyon, or metal screen; background of design opaqued; color applied to screen as stencil and forced through screen	Similar screens; up to twenty set in electronically controlled machine that regulates speed of operation, amount of dye forced through each screen, fabric movement
Rotary screen printing		Cylindrical seamless metal screen; dye paste forced through screen as it rotates on moving fabric
Transfer printing (a) Pigment transfer		(a) Pigment on design in wax or thermoplastic base transferred by heat and pressure from paper to fabric
(b) Dry/wet heat transfer		(b) Pattern of dye printed on paper sublimated to fabric with dry heat or wet heat atmospheric assist
Blotch printing	Direct application by block, screen, etc.	Direct application by roller, screen, etc.

TABLE 12-1 ***DECORATION OF FABRICS BY PRINTING AND DYEING*** *(Continued)*

TYPE OF DECORATION	HAND METHOD	MACHINE METHOD
Jet spray printing (a) Polychromatic dyeing (b) Microjet printing		(a) Streams of several dyes applied to continuously moving fabric (b) Rows of fine jets controlled by computer force dye into fabric in a predetermined design
TAK dyeing		Randomly sprinkled droplets of several dyes distributed on continuously moving fabric
Electrostatic printing		Dye attracted by electrostatic field through patterned screen onto fabric
Photo printing	Photographs printed on sensitized fabric	Cyamatic: oscillations from musical chords transformed into patterns on quartz plate, photographed, and printed on fabric
Differential printing		Screen printing of differential dyeing yarns of tufted fabric
Warp printing		Engraved rollers print design only on warp yarns; fabric then woven, using white or neutral filling yarn
Batik dyeing	Design put on fabric; wax deposited on background of design; fabric dyed; wax removed	
Tie dyeing	Fabric knotted or tied in parts with string; dipped into dye; fabric untied	
Ikat dyeing	Warp and/or weft yarns tie-dyed at intervals to be woven into predetermined design	
Plangi dyeing	Fabric tie-dyed to form specific design	
Airbrush (spray painting)	Dye sprayed with airbrush onto surface of fabric	
Composition or paste designing		Lacquer figures or colored paste glued or baked on surface of fabric
Flocking		Very short, usually colored fibers adhered to fabric in design effect, conforming to pattern of adhesive applied with roller

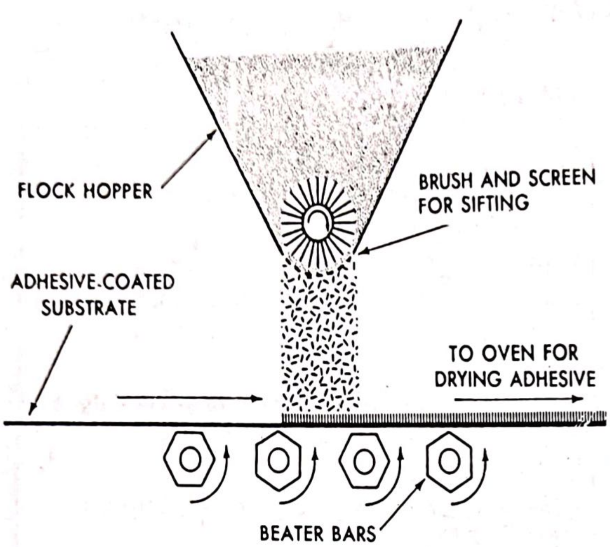


Figure 12-13 Schematic diagram of mechanical flocking. The beater bars' vibration of the fabric causes the flock to flow over the surface of the cloth, stand erect, and penetrate into the adhesive-coated fabric, producing an inexpensive pile design. (*Courtesy* Modern Textiles Magazine)

well as straight ends, precision-cut flock of rayon and other manmade fibers (such as nylon and acrylics) are preferred. The flock generally ranges in length from 2/25 to ¼ inch (2–6 mm).

Flocking may be accomplished by a *mechanical* method of beating the underside of the adhesive-coated fabric with rotating multisided beater bars as the flock is sifted onto the surface of the fabric. The fabric's vibrations, produced by the beater bars, cause the flock to flow over the surface of the fabric and stand erect those fibers that do not land flat on the adhesive. Continued vibration causes the erect fibers to penetrate deeper into the adhesive, and, as more fibers fall on the already erect fibers, they become similarly oriented and build up a pile effect (Figure 12-13). With this method (which has the advantage of being relatively inexpensive), the fibers become more deeply imbedded and, therefore, more permanently attached. However, since many fibers adhere at various angles, the flocking may not be as dense as desired.

The *Giroud process* is a different mechanical method (see Figure 12-14). Sheaves of fiber, such as tow, are fed into a device which holds the fibers vertically and cuts them into predetermined, uniform lengths. The cutting operation is regularly repeated causing continuous horizontal pressure against the fibers. While remaining aligned in a vertical position, the flock is continually moved horizontally in a feeding guide toward a conveyer belt on which is a fabric substrate coated with an adhesive. As the flock comes in contact with the adhesive, it is implanted in it to form a very erect, compact, dense pile superior to that possible by other methods. The flock may be cut to any length and may be made of any type of fiber, including glass and metal.

Another technique utilizes an *electrostatic* principle. As the flock is sifted onto the fabric, it passes through an electro-

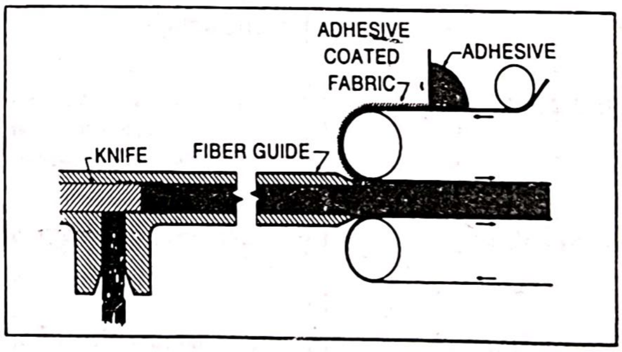


Figure 12-14 Schematic diagram of Giroud flocking process. Tow (bottom left) is fed into a channel of predetermined width where a knife slices uniform lengths of flock which are forced in vertical position along the fiber guide. Adhesive coating is applied to the fabric (top right) and the coated fabric meets the fiber which adheres to the cloth. The flocked fabric is subsequently returned and fed into a curing oven. (*Courtesy* American Dyestuff Reporter)

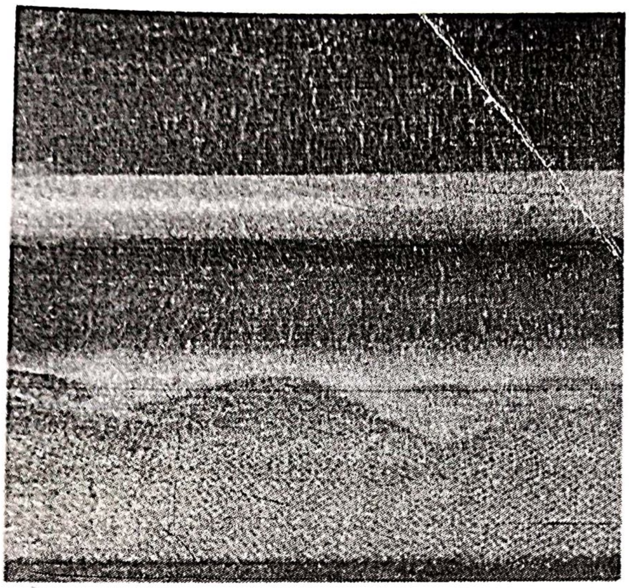


Figure 12-15 Closeup view of an electrostatic flocking unit showing nylon flock being propelled onto a woven jute substrate. (*Courtesy* Modern Textiles Magazine)

static field, or electrically charged air space. This directs and propels the fibers in the longitudinal direction of the current toward the fabric, which causes them to stick to the adhesive in an erect position (Figure 12-15). This method can produce a denser flocking because the fibers uniformly adhere upright to the fabric. However, it is a more expensive technique, requiring more complicated apparatus and better-quality flock.

Depending upon the background fabric, or substrate, the depth of the pile, the flock used, and the pattern, flocked fabrics may be created for various purposes. Flocking is used for household goods such as curtains, draperies, carpeting, and wearing apparel.

REVIEW QUESTIONS

1. How can spinning and weaving processes produce decoration (a) in fabrics, (b) in finishing processes?
2. What is meant by block printing?
3. Explain roller printing and duplex printing.
4. Differentiate between discharge and resist printing.
5. Why is the discharge-printed fabric the least desirable?
6. What is the difference between a blotch and a duplex print?
7. How could one determine whether a color design is printed or woven?
8. How do screen printing and stenciling differ?
9. Compare the methods of rotary screen printing and automatic flat screen printing.
10. What are the values of transfer printing?
11. Describe warp printing and its result.
12. How does Vigoureux printing differ from warp printing?
13. Compare and contrast the batik method and the resist method of decoration.
14. (a) How are composition or paste designs made? (b) Are composition and paste designs durable?
15. Describe tie dyeing, and explain why it is expensive.
16. (a) Describe the flocking techniques. (b) How effective and durable are they?
17. How can batik and tie dying imitated on a machine be detected?
18. What are the several methods of hand decoration with color?