General Trends in the Coloring and Finishing of Textiles

D. HILDEBRAND, Bayer A.G., Leverkusen, West Germany

ABSTRACT

From the present situation in the textile finishing industry, it is evident that revolutionary innovations are not in sight and that attempts to work with new processes must first prove successful in special sectors. The dyestuff and auxiliaries market will depend on the price to the same extent as technical progress approaches an end point. The trend toward a splitting up of the market into fashion and nonfashion goods will intensify the regional shift in the production of standard qualities. Whereas in Western Europe and Japan the proportion of highly fashionable qualities is increasing and some are even exported, in the U.S. the parallel development of both types of goods will continue, as befits the size and multifariousness of this market.

INTRODUCTION

Colored textiles can be divided into washable and nonwashable, dress goods and home textiles, fashionable and nonfashionable articles. The textile dyer and finisher mainly depends upon short-lived consumer goods of personal consumption. Coloring and depth of shade, fabric construction, and bulk all change with the seasons and are governed by fashion. This applies particularly to the highly industrialized countries in temperate zones such as the U.S., Western Europe, and Japan.

Recent years have shown that phase differences in the fashion trends of these three regions are becoming smaller and smaller, with the result that we can now speak of a world fashion. This means that ups and downs in various areas of the world tend more to coincide with one another from a time point of view, and the stimuli provided by differing fashion requirements no longer balance each other out. Fashion over recent years in the classical industrial countries has shown preference above all for cotton with lively fashionable colors, combined with a worldwide stabilization of blue denim and a growth in corduroys. The importance of polyamide, on the other hand, has decreased in the clothing sector, with the possible exception of sports and leisurewear.

The field of knitted goods and hand-knit yarns is dominated by acrylic fibers, both alone and blended with wool. For high qualities, wool predominates. Fashionable colors are the decisive factor, and the nature of the goods makes this a domain of yarn dyeing. Even more strongly governed by fashion is the importance of acrylic printing.

The polyester fiber has become the cheapest mass consumption fiber on the market. By adding polyester, it became possible under favorable manufacturing conditions to reduce not only the weight of the fabric but also the price. Polyester/wool, polyester/cotton, and polyester/rayon staple make up the majority of the blends to be dyed. The texturizing wave for 100% polyester knit goods, which led to a worldwide boom in polyester, has leveled off. Cotton's present comeback in the countries where the synthetic fiber industry originated is based mainly on the fact that fashion has, to a certain extent, become tired of synthetic fibers. But independent of fashion trends there is still a desire for better wear comfort and easier care properties. The question now is what special factors, apart from the stimulus of fashion, are determining the trend in the dyeing and finishing of textiles and which are typical of the present time?

NEW DYESTUFF/FIBER SYSTEMS

Over the past two decades, color technology has undergone such huge changes through the appearance of new fibers and dyestuffs that the trend now is more toward consolidation of what already has been achieved than toward spectacular new developments.

Since the fiber-foaming polymers which we know today will, in the foreseeable future, also account for the principal share of fiber production, the economic incentive and technical necessity for developing new coloristic principles are rather low.

NEW METHODS FOR DYESTUFF APPLICATION

There is increased interest in finding new methods of dyestuff application. Whereas the development of new dyestuff/fiber systems was essentially stimulated by the chemical industry, the development of new methods of dyestuff application is often based on ideas from the textile finishing industry and machine manufacturers.

New systems for dyestuff application are: transfer printing, dyeing in the gas phase, foam dyeing, dyeing in an extremely short liquor, ink injection coloration system, minimum liquor application, and solvent dyeing.

Utilizing minimum-liquor application systems for continuous dyeing would probably mean a solution to the problem of migration, since with a liquor pickup of less than 30%, there is no migration of dyestuff particles on drying. Although the uniformity that has so far been obtained with minimum-liquor application is sufficient for finishing applications, it is not good enough for dyeings. The question regarding the importance of dyeing in organic solvents can, on the other hand, be generally considered as answered. The expectations placed in solvent dyeing as a new dyeing technology have, in short, not been fulfilled.

In all these new processes the dyestuff is made to go onto the fiber without the assistance of water or with only very small amounts of water. The transfer medium is the gas phase, the textile auxiliary phase, a solvent, or a highly concentrated aqueous liquor. Of the given processes, transfer printing, foam dyeing, dyeing in an extremely short liquor, and the ink injection coloration system are already being used in practice and are gaining increasing economic significance.

COST DEVELOPMENT

The main problem in the present-day coloring and finishing of textiles is thus not a lack of innovation. In the industrialized countries, the most important problem in modern color technology is the constantly deteriorating profit situation for the dyer and the finisher.

Personal	**45 %**
Dyestuffs and Chemicals	**20 %**
Energy and Water	**10 %**
Depreciation and Average Costs	**25 %**

FIG. 1. Breakdown of dyeing costs in West Germany.

	Personal %	Dyes and Chemicals %
West Germany	45	20
USA	40	20
UK	40	25
Australia	37	40
Italy	35	25
Japan	35	30
Argentinia	28	39
Mexico	22	30
Singapore	20	50
South Africa	17	38
Taiwan	16	52
South Korea	12	40

FIG. 2. Relation between personal costs and dyestuff and chemical costs in different countries.

It is virtually impossible to counter the cost pressure by further methods of rationalization. Essentially, this must be done by manufacturing highly fashionable qualities and adopting a flexible market attitude. But even the fashion market is limited. The main factor in the cost structure of the textile finishing industry in industrialized countries is the constantly growing proportion of wage costs. In the future, however, we must expect water and energy costs to rise more rapidly than wage costs. The trend for process technology in textile finishing will therefore be to favor methods that prevent a further increase in the share of water and energy. It is hardly likely that an improvement in the cost structure could be achieved by the mass production of standard qualities, since there are many low-wage countries that already can call on the same machinery but whose water costs are low.

The cost pressure in the finishing industry of the classical textile countries has led to a decline in the prices of dyestuffs, which could not be absorbed by new developments. This raises the question to what extent an attractive market for new developments exists anyway in the dyestuff sector. Yet a fashion and quality-conscious textile finishing industry will only be able to hold its own if the broad technical service of the dyestuffs industry is maintained for it. This, in turn, will depend on the price level of the dyestuff market and thus on the finishing industry itself.

ECOLOGY

The factors determining the trend for the coloring and finishing of textile materials are, however, not only the rising wage and energy costs, but above all the heavier and heavier ecological burdens. Finding a way of complying with the ecological regulations (some of which, as matters stand, are justified and some exaggerated) is gradually becoming more important for the existence of the textile finishing industry in the industrialized countries than the improvement of their processes as regards the product. This refers particularly to the wetting and dispersing agents, detergents, thickeners, emulsifiers, leveling agents and retarders, carriers, oxidants, reducing agents, agents for improving fastness, solvents, crosslinking agents, binders and softening agents, hydrocarbons, urea and salts, all of which are used in dyeing, printing, or finishing.

The trend resulting from the ecological regulations toward dyeing and finishing processes that are more acceptable to the environment relate mainly to the type and quantity of auxiliaries and salts used such as high-temperature dyeing instead of carrier dyeing, chrome-free residual liquors in wool dyeing, pigment printing free of white spirits, transfer printing, and chloride-free resin finishing processes for cellulosic fibers.

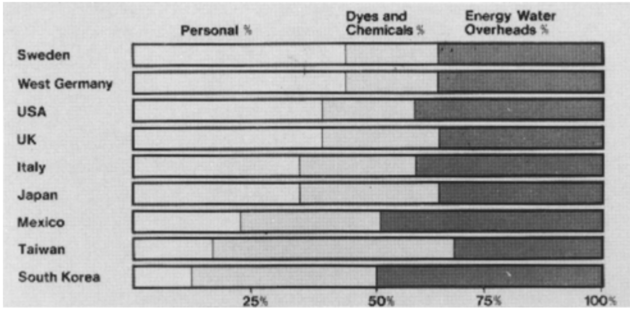

FIG. 3. Relation between personal and dye and chemical costs in different countries.

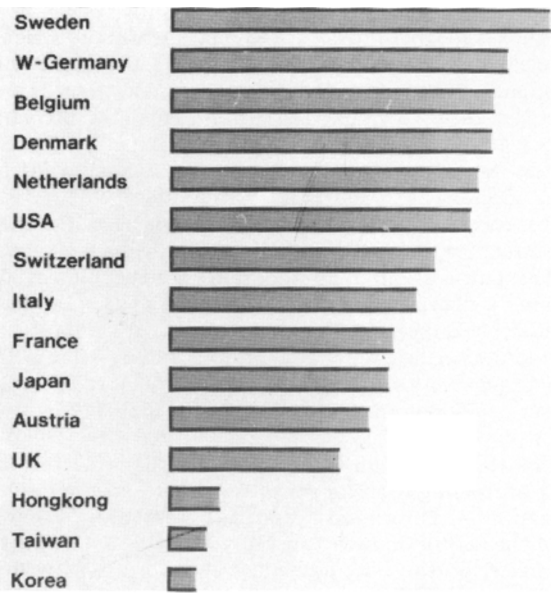

FIG. 4. Personal costs of the textile industry in different countries calculated on basis DM.

The solvent dyeing based on perchloroethylene, which was created to answer the call for environmental protection, did not achieve any practical importance because it offered neither economic nor ecological advantages over the HT short-liquor technique and the development of jet dyeing by rapid-dyeing methods. It can be concluded from this that even under ecological pressure the tendency to modify the basic conception will remain small as long as the possibilities contained in present-day processing techniques and dyestuff principles have not been fully exhausted.

DYESTUFF DEVELOPMENT AND DYESTUFF FORMULATION

Since new dyestuff developments are hardly able to open up new coloristic possibilities, the trend lies mainly in the rearrangement of existing ranges with regard to application technology and cost. The pressure of the finishing industry on the price of dyestuffs, for example, led to a decrease in the share of lower color strength anthraquinone dyestuffs in favor of the azo dyestuffs. This was made possible by new azo blue and red types having a clarity and color strength previously unattained in the azo sector. Furthermore, there is a strengthening of the trend from the dyestuff requiring a multistage application technique to one that can be applied in one stage, e.g., with cotton: mordant dyes→direct dyestuffs requiring aftertreatment→naphthol dyestuffs→reactive dyestuffs; or with wool: chrome mordant dyestuffs→afterchroming dyestuffs→metal complex dyestuffs→reactive dyestuffs.

Formation of the final color shade and levelness of a dyeing can thus be directly followed and controlled by the dyer. The increasing appearance on the market of dust-free cold-soluble powder types, liquid types, granules, dyestuff blends in standard shades, and combination dyestuffs for blended fabrics is in line with this simplification of technology. Whereas the dyestuff seller still puts his dyestuffs together as far as possible in the form of complete ranges, the dyestuff consumer is tending to move away from this idea. In a particular shade, most sales are contested by only a relatively small number of dyestuffs on the market, which are selected purely for price reasons from a variety of product lines. This trend toward general combinability and interchangeability is most advanced with the disperse dyes, vat dyes, sulfur dyes, acid and direct dyes, and least advanced with the reactive dyes. The shift in the dyestuff market from a manufacturer's to a buyer's market is also becoming clearer. Since a competitive product exists for virtually every shade, the manufacturer is reduced to offering his customers such things as standardization of shade, delivery guarantee, toxicological purity, and fastness guarantee.

The automation of methods in garment manufacturing requires a previously uncalled-for level of standardization. Particularly important for the use of a class of dyestuffs are the rapid transferability and reproducibility of the shade. Standardization of the dyestuffs thus makes it necessary to measure and record an ever-increasing number of properties.

For the dyer and printer too, further speeding up of order processing is no longer possible without the increasing utilization of colorimetric and technical control methods. Since the textile industry in the industrialized countries is dependent on the time advantage it has over the importers, the times needed for executing orders must be further reduced. The result is that the coloring stage is moved to the end of the textile manufacturing process. The financial risk of the dyer and finisher thus becomes greater, and any complaints become more and more expensive.

FASTNESS REQUIREMENTS

The concept of fastness has dominated the coloring of textiles for 100 years. The term fastness is still an important characteristic for evaluating a color, though it has lost a certain amount of topicality because it is now more or less taken for granted. The hard-won lightfastnesses of vat dyestuffs on cotton awning fabrics are today reached without difficulty by basic dyestuffs on acrylic fibers. This also applies to the required wash fastness with cotton washables by reactive dyestuffs.

The critical fastness properties for the consumer and the detergent industry are the wetfastnesses. This does not mean to say, however, that the problems of light and wetfastness have been solved or could all be satisfactorily solved in the future. This applies particularly to washable dyeings. For example, the limited chlorine wash fastness of reactive dyeings on cotton causes no problems under European washing conditions, but for the U.S. it is often inadequate. This may explain why the U.S. cotton dyer has not followed the reactive trend to the same extent. The peroxide wash fastness of reactive dyeings is highly dependent on the shade. This means that, with a number of shades, adequate fastness to chlorinated water and peroxide can be achieved, though the attainable level is appreciably below the optimum of corresponding vat dyeings. Because of the limited stability of the reactive dyestuff copper complexes on exposure to light in the wet condition and in contact with sequestering agents, the vat dyestuff will be able to retain its position with brown and navy blue shades in washables. The development of jet dyeing has been of benefit to vat dyeing in this respect, since the smaller amounts of hydrosulfite needed make it possible to reduce appreciably the dyeing costs for vat dyestuffs.

For the present-day dyer, printer, and finisher, however, the fastness to processing is more important than the fastness in use. It frequently is determined by the practicability of more economical production concepts, especially with the dyeing, printing, and finishing of blended fabrics.

Particularly important fastness properties are, for example, the fastness to decatizing of cationic dyestuffs on acrylic fibers, the resistance to deterioration on boiling, and fastness to sublimation of disperse dyestuffs, and the behavior of reactive dyeings on resin finishing or of wool dyeings on fabric setting and pleating.

Since what is chemically possible as regards the fastness properties generally has been reached, small and even minimal differences become essential sales arguments.

In contrast to this, complaints from the consumer are usually based on inadequate afterwashing of dyeings, not paying attention to catalytic fading and not testing the effect of resin finishers. The inexplicable contradiction in the consumers' attitude of the coming generation as regards fastness is the uninterrupted success of indigo in blue denim. A decisive factor in evaluating the wash fastness of textiles is also the method of adding household detergents as well as the temperature and liquor ratio of the domestic wash.

Where inadequate wash fastness exists, the goods are being increasingly provided with labels for the consumer indicating the limitations in washing treatment. The main problem is therefore often the fastness to perspiration and the staining of polyamide. Reactive dyeings and prints are often not sufficiently cleaned up, with the result that bleeding out occurs on the first wash without the adjacent cellulosic fabric becoming stained. The problem of the first wash is, however, generally accepted by the consumer in Europe and he does not complain. The wetfastness – and especially the fastness to perspiration – can be improved with the aid of reactant resin finishes. A significant factor for reactive dyeings will continue to be the acid stability on storage and subsequent fixation. Since this property is in demand particularly with prints and yarn-dyed qualities, the importance of the acid-stable reactive dyestuffs will increase.

TEXTILE AUXILIARIES AND FINISHING METHODS

Without the use of detergents, dispersing agents, and auxiliaries, the wet finishing of textiles is impossible. The rule nevertheless applies: as much as necessary but as little as possible. The cost pressure hanging over the finishing industry has led to a reappraisal of auxiliary costs. The trend is toward saving auxiliaries or to giving preference to processes that work independently of auxiliaries, for ecological reasons as well.

On the other hand, to shorten the dyeing times by speeding up the heating and afterwashing conditions or by raising the padding speeds, etc., it is necessary in continuous dyeing to use fast-wetting surfactants. This also applies to the short-liquor technique, which contributes only slightly to a savings in the amount of auxiliary needed. Polyester dyeing has the greatest requirement of dispersing agents and auxiliaries, due both to the finishing of the dispersed dyestuffs and to the amounts of carrier needed. The carrier-free dyeing of polyester will therefore gain in importance alongside the HT dyeing method. On the other hand, pigment printing and transfer printing are processes with only a low auxiliary requirement. Since liquid dispersed dyestuff types contain far less dispersing agent than the powder types, the trend toward the liquid form also represents a saving in dispersing agents.

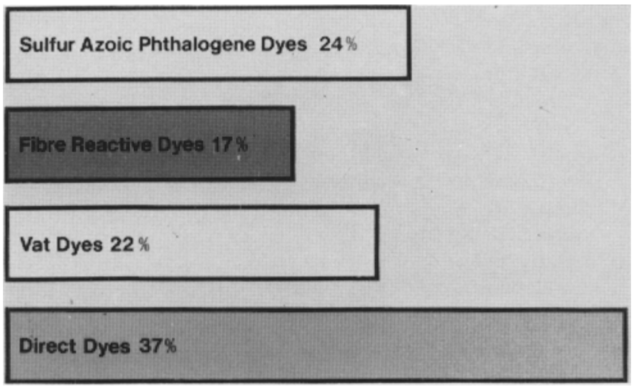

FIG. 5. Dyestuff consumption for cellulose fibers in West Germany.

In the endeavors to simplify dyeing processes, the use of dyestuffs that can be optimally combined or dyeing methods that can be controlled by means of pH and temperature will be given preference over a combination with auxiliaries specifically intended for the dyestuff and related to a particular range. Very limited fiber/dyestuff/auxiliary systems therefore will become increasingly of only temporary importance. Modern auxiliaries should generally be low-foaming, solvent-free, odorless, nontoxic, and biologically degradable.

Unlike textile auxiliaries, which only indirectly influence the quality of the goods, there is increasing interest in finishing agents that improve fabric quality. This applies not only to easy-care properties but also to wear comfort and products for improving the handle. Without crease-resist finishes, wash-and-wear finishes and softening treatments, the cotton boom would not have been possible. The future significance of fabrics of 100% polyester will depend on how successful manufacturers are in grafting on to a polyester fiber or simulating the desirable hydrophilic properties of cotton by means of a finish, without modifying existing processing methods or the accustomed fastnesses and care properties.

In line with the trend to introduce water-free processes for dyestuff fixation, interest also exists in the field of finishing for gas phase reactions and radiation-induced finishing methods. An interesting point for the manufacturers of crease-resist resins is the direct crosslinking of cotton piece goods with sulfur dioxide as the catalyst. Processes of this kind work without crosslinking agents containing nitrogen and avoid the formation of dichlorodimethyl ether, though they make particular demands on the acid and sulfite stability of reactive dyeings. For polyester fabrics, graft polymerization finishes with high- and low-energy radiation were developed specially for hydrophilic, antisoil, and antistatic finishing. Such processes have, however, as yet not attained much importance in industry.

THE DYEING OF SYNTHETIC FIBERS

The production of synthetic fibers is growing worldwide at a faster rate than the production of natural fibers. The proportion of synthetic fibers in dyeing and finishing will therefore continue to increase. The synthetic fiber with the largest dyestuff market is polyester.

Whereas all other types of fiber are dyed with more than one class of dyestuffs, for normal polyester only disperse dyestuffs are used. Today, disperse dyes represent the largest category of dyestuffs with a world consumption of 65,000 tons. The price decline in the dyestuff sector has, however, hit disperse dyestuffs the heaviest. World consumption can be divided according to consumer regions and colors: the U.S. and Japan account for 55%, of which 12% are yellow, 9% orange, 19% red, 2% violet, 37% blue, 3% brown, and 18% black.

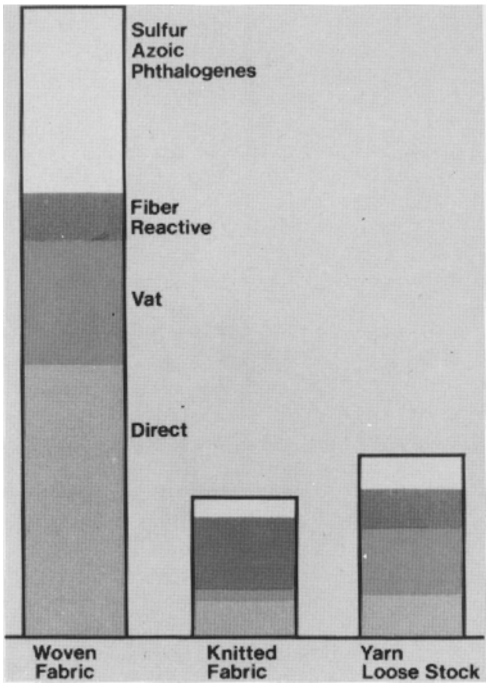

FIG. 6. Dyeing of cellulose fibers in West Germany.

Through the so-called rapid dyeing method and by increasing the dyeing temperature to 130-140 C, it already has been possible to reduce considerably the high dyeing costs of the exhaust process, which exceed those for virtually all other fibers. Dyeing of conventional polyester can therefore largely be regarded as technically complete. Whereas ionically dyeable polyester has attained only limited significance for multi-color effects, the trend of new developments is toward the carrier-free dyeable polyester fibers.

Polyester is the only synthetic fiber which can be dyed alone or in combination with cotton in a simple continuous process – the so-called thermosol method – with fixation times of 30-90 sec without changing its textile properties. The thermosol process, despite all the known disadvantages and unsolved problems, remains the simplest dyeing method for polyester and polyester/cotton piece goods. The thermosol method's share in polyester dyeing is stagnating in Western Europe and the U.S. The largest number of newly installed thermosol machines today is in Asia.

For knitted goods, however, a similar continuous dyeing method has not become established, neither via the dry heat fixation (thermosol) method nor via HT steam fixation in the suspension loop steamer or by means of a continuous pressure steamer. In view of the present available capacity of jet dyeing machines, the prospects for continuous dyeing of polyester knit goods are poor.

When all these factors are added together, it can be said that the volume of polyester dyeing worldwide will increase. The technicalization of the developing countries generally begins with the start-up of a polyester fabric production and finishing system for the outerwear sector. Dyeing is then carried out mostly by the thermosol method. With the opening up of new texturizing capacities in Eastern Europe and Asia, a West-East trend is nevertheless also evident with polyester knit goods. The share of polyester in textile finishing in Western Europe will, on the other hand, be increasingly determined by fashion wovens and knits with fancy cotton yarns and rayon staple blends, whereby the proportion of disperse/reactive dyestuffs will increase both in printing and in dyeing.

The significance of polyamide fibers will remain in the

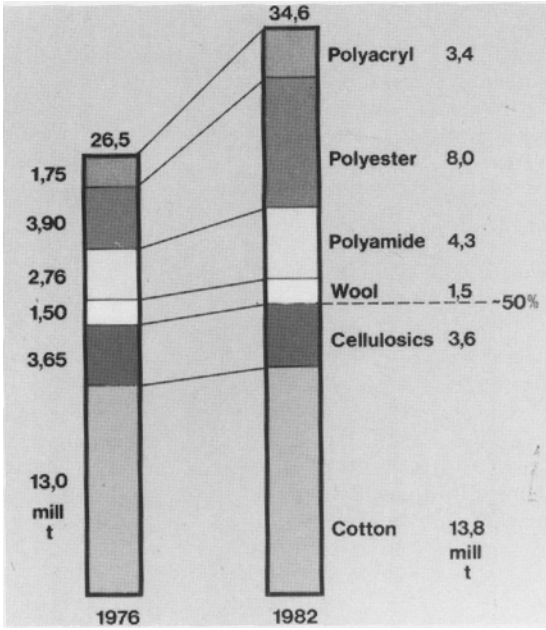

FIG. 7. Trends in textile fiber consumption.

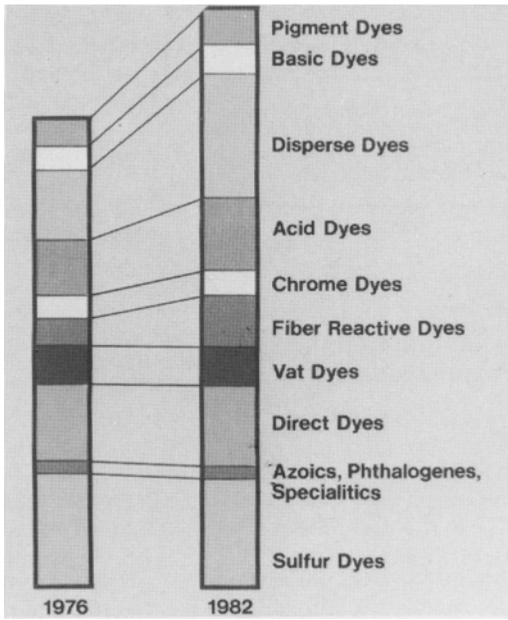

FIG. 8. Trends in textile dyestuff consumption.

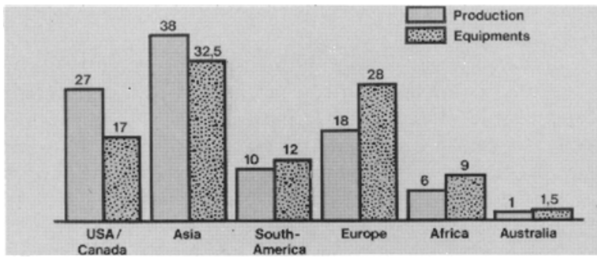

FIG. 9. Thermosol production and thermosol equipment.

sectors it serves at present; they will therefore not follow the same trends into the developing countries as the polyester fibers. The same is true of acrylics which, particularly in highly fashionable goods, will retain their importance in the northern industrialized countries. Unlike the dyeing of polyester with disperse dyes, acrylic dyeing with cationic dyestuffs has not yet reached a sufficient level of technical maturity to enable unproblematical application and general compatibility. Research will be working here to further simplify the dyeing process. The share of producer coloring will increase.

THE DYEING OF COTTON AND CELLULOSIC FIBERS

For the dyeing of cotton, there continues to be the widest variety of different dyestuff categories available. Cotton therefore has remained the most interesting fiber for both dyer and printer. The same is true of the finisher. The methods for pretreating and dyeing cotton used today will be further improved as far as machine technology is concerned and coordinated with the polyester processes. The earnings that can be made from the finishing process are better with cotton than with polyester and there is greater variety in the qualities of the goods.

The major group of dyestuffs worldwide are the sulfur dyes. The main problem with these is the ecological one. For every kg sulfur dyestuff, one must reckon with 1 kg Na_2S. Whereas vat dyestuffs will essentially hold on to their market share, we can expect a percentage decrease in sulfur dyestuffs.

Further growth worldwide is likely with the reactive dyes. With an estimated share of 11.4% of the dyestuff consumption for cellulose fibers of 241,600 tons, the consumption of reactive dyestuffs amounts to ca. 27,000 tons. Of this, 61.3% go to dyeing and 38.7% to textile printing. The proportion of reactive dyestuffs in the coloring of cotton is higher in Western Europe than it is in the U.S.

Yet even in Western Europe, the proportion of reactive dyestuffs in the coloring of cotton has not yet reached its limit. The main interest is in a dyeing range of 40-50 C, whereby the trend to the short-liquor technique and the cold batch process continues. Only in a few firms in Europe do they have the necessary yardages for a true continuous operation, though this is different in the U.S., Eastern Europe, Asia, and South America.

Because of the present patent situation, there is no recognizable stagnation in the field of reactive dyes. A further stimulation of the market through the introduction of dyestuffs in brilliant shades that have been optimized from the point of view of application technology can be expected, though a decline in prices will occur as the market becomes saturated. Reactive dyeing fits in with the fashion trend for clear wash-fast dyeings. Cotton's comeback is thus based not only on the fashion trend toward colorful knitted fabrics, but also is profiting from the jet dyeing machines developed for polyester dyeings, which are now taking over from winch beck dyeing even in the field of reactive dyestuffs.

THE DYEING OF WOOL

The dyeing of wool continues to be characterized by the necessity for maintaining quality and keeping fiber damage as low as possible. More recent trials are aimed at using finishing processes that work at low temperatures, such as dyeing below boiling point and the cold batch process. With the dyeing of chlorinated and shrink-resist finished wool, wool reactive dyes will gain further importance. The rest of the wool dyeing sector will continue to be dyed with the familiar types of dyestuff, with the trend toward the higher-quality dyestuff being maintained. It will nevertheless not be possible to do without the afterchroming dyes.

Despite various attempts, the chances for the continuous dyeing of wool have not improved, despite the fact that the required steaming times of 15-20 min are technically possible. The main problem is the familiar frosting, in other words, inadequate covering of the free fiber tips. The development of pressure steam fixation is no good because of damage to the fiber.

TEXTILE PRINTING

World production in textile printing is about 12 billion square meters. Textile printing was less affected by the recession in 1975 because developments in highly fashionable goods favored textile printing with its short times for executing the orders. A major domain of textile printing is pigment printing, especially for polyester/cotton. Since pigment printing without white spirit has started to make an impact, pigment printing also has become best suited to satisfy ecological regulations, since it requires no clearing up.

Printing with high-solids thickeners will, in the future, be more strongly affected by the effluent situation than dyeing, since the thickener accounts for 2-3% of the printing paste and this has to be washed out.

Effluent-free transfer printing is essentially restricted to 100% synthetic fabrics. With the aid of resin finishes, it is technically possible to produce transfer prints on polyester/cotton blends pretreated with resin, and acylation of the cotton also permits coloring with dispersed dyestuffs. Such pretreatment does, however, jeopardize the cotton touch of the fabric. There will, therefore, be no lack of attempts to print 100% polyester and then to give it a hydrophilic treatment. Whereas reactive printing on 100% cellulosic fibers has consolidated its share of 20%, pigment printing clearly dominates in the polyester/cotton blend sector. Disperse/reactive combinations are used only for high qualities. There are special washing-out problems here, which could be of interest especially to the detergents industry.

As far as reactive dyestuffs for textile printing are concerned, the trend is clearly with dyes having good washing-out properties and a high stability of the fiber/dyestuff bond to prevent subsequent staining of the white ground. The development of new dyestuffs with improved washing-out properties cannot yet be regarded as complete. Printing on acrylic, polyamide, acetate and wool, however, does not involve any technical problem and will remain with the dyestuffs and methods used at present. The HT suspension loop steamer has established itself as the universal fixation apparatus and will be even more widely used in future.