Textile Dyeing

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Part 3

Edition 1

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What This Text Covers . . .

Here is an outline of the instruction text you are about to study. Refer to this outline while you are studying. It will give you a helpful general view of the contents of the text. You might also check off each item of the outline as you complete the corresponding section in the text. Later you can use the outline to help find those parts of the text to which you would like to refer again.

Textile Dyeing

PART 3

Dyeing of Synthetic Fibers

Dyes and Machinery Used

Synthetic Fibers and Dyes

1. As far as the textile industry is concerned, the most important development of this century is the development of the synthetic fibers. The first of these fibers to be produced commercially was rayon. Rayon, since it is pure cellulose, is very easy to dye. However, the synthetic fibers developed since the introduction of rayon have posed more difficult problems. Some new fibers were unable to find a market until they could be dyed pleasing and suitable colors with fastness properties. In other words, these fibers could not get by merely because they possessed such characteristics as outstanding wear, stable price, or silky hand.

2. Most dyeing procedures are developed by the fiber producers in cooperation with the dyestuff manufacturers. Some of the newer fibers have not yet been dyed to everyone's satisfaction. For certain fibers it may even be necessary to develop completely new lines of dyestuffs. The disperse, or acetate, dyes, for instance, were developed for dyeing acetate. These dyes have since become very important in the dyeing of other types of synthetic fibers and yarns.

The type of dye to be used and the dyeing procedure to be followed depend upon the fiber to be dyed. Therefore, a thorough study of each type of synthetic fiber is needed in order to understand the dyeing procedure. The future for synthetic fibers certainly looks very bright. But for the dyer there will be new problems to add to those he already has. New synthetics, combinations of different synthetics, and blends of natural fibers and synthetics will all add new problems. Trade publications and manufacturers' bulletins are excellent sources of information on all new developments.

Dyeing Machinery

3. The machinery used in dyeing synthetic fibers is essentially the same as that used in dyeing natural fibers. Just as has been explained in connection with cotton dyeing, there are machines for yarn dyeing and for piece dyeing. Some machines move the material through the dye liquor; others move the dye liquor through the material; and still others combine both of these principles.

In dealing with the synthetics, you must keep in mind that the material is extremely sensitive. Small amounts of metal or other substances from inferior, worn, or dirty dyeing machinery may cause much greater damage than they would cause in cotton dyeing. Most synthetics are comparatively weak when wet;

consequently, they must be handled carefully so as to prevent stretching. Temperatures and tensions must be controlled much more accurately than is necessary in cotton dyeing.

Rayon Dyeing

Affinity for Dyes

4. Rayon is a fiber produced from regenerated cellulose. The source of cellulose is wood or other types of vegetable growth. The cellulose mass is changed to a viscous liquid, from which the original name of rayon "viscose rayon," was obtained. Later, the viscous liquid is hardened to a solid after it has passed through spinnerets, which form the filaments. It is important to remember that this synthetic yarn is pure cellulose, and that cotton is almost pure cellulose. Because of the nearly identical chemical composition of the two fibers, it is reasonable to assume that cotton and rayon have practically identical dyeing properties.

When cotton is treated with caustic soda, as in mercerizing, its affinity for dyestuffs increases. In rayon production, the cellulose is treated in a caustic bath, sometimes called the steeping, or mercerization, bath. Consequently, its affinity for dyestuffs is high. The same dyestuffs that are used to dye cotton are used to dye rayon, but there may be a difference in the results obtained. The strength of the finished dyeings is greater for rayon that for cotton when equal amounts of dyestuff are used. Therefore, less dyestuff is used to obtain a certain shade in rayon than would be used to obtain the same shade in cotton.

Handling

5. Certain properties of rayon must be considered when it is handled in the dyehouse. Valuable goods may be damaged by exposure to harmful conditions.

Rayon is disintegrated by hot diluted acid and by cold concentrated acid. Strong solutions of alkalis cause swelling and reduce the strength of the fiber. Rayon is also attacked by strong oxidizing agents, but is not damaged by hypochlorite or peroxide bleaching solutions. The fiber is generally insoluble in organic solvents, but soluble in cuprammonium and some other compounds.

Rayon loses strength at heats above 300 F (degrees Fahrenheit) and decomposes at 350 F to 400 F. Rayon does not melt, but burns rapidly. It loses strength after prolonged exposure to sunlight and through aging. The fiber is resistant to moths but is attacked by mildew.

Preparation for Dyeing

6. In general, the same dyeing procedures used for cotton are applicable to rayon. However, rayon does not usually need the elaborate preparation for dyeing that cotton requires. The following scouring formula has been found satisfactory: To 100 gal (gallons) of water, add 1 lb (pound) to 2 lb of synthetic detergent

and 0.75 to 1 lb of soda ash. Scour at 180 F to 212 F for 30 min (minutes) and rinse thoroughly.

Direct Dyes

7. Dyeing with direct dyestuffs is usually carried out in a neutral bath with a liquor-to-material ratio of 20 to 1. Additions of 0.25% to 0.5% synthetic detergent, and of 5% to 20% common salt or 10% to 40% Glauber's salt, are made to the bath. (Unless otherwise stated, the percentages given in this formula and in succeeding formulas are based on the weight of the goods.)

The dyebath is usually started warm, and is then slowly raised to 200 F and held at this temperature for 45 min to 1 hr (hour). The steam is then shut off and the material run in the cooling bath for about 20 min longer to assure full exhaustion of the dyebath. The salt should be added in several portions after the temperature has reached 200 F. Finally, the dyeings are well rinsed and dried.

Aftertreated types of direct dyestuffs are often used to get improved fastness properties. The dyeing procedure itself is the same as that just given for regular direct dyes. This is followed by aftertreatments identical to those explained in Part 1 of *Textile Dyeing*. Diazo dyes, dyes aftertreated with formaldehyde and acetic acid, and dyes treated with the various developers may all be used on rayon.

Basic and Acid Dyes

8. In some applications in which brightness of shade is essential, either basic or acid dyestuffs may be applied to rayon. Because rayon is a cellulose fiber, it must first be mordanted. A cellulose fiber that has been mordanted will react with dyestuffs more or less as an animal fiber does.

To mordant the rayon, prepare a bath of 20-to-1 volume with 6% Katanol O solution and 3% soda ash. Treat the material in this bath for 30 min at or near the boil. Add 40% common salt, shut off the steam, and allow the material to remain in the cooling liquor for 2 to 4 hr.

After the material has been rinsed well, it is ready for dyeing. The dyebath consists of 2% to 3% acetic acid (28% concentration) and a small amount of a retarding agent, in cold water. The basic dyestuff is carefully dissolved with an equal amount of acetic acid (28% concentration) and added to the dyebath in several portions, preferably by straining through a cotton cloth. The acid dyestuff is dissolved in hot or boiling water. The dyebath is raised slowly to 160 F and the dyeing is continued at this temperature for approximately 30 min, after which the dyeings are rinsed and dried. The colors that can be obtained in this way are bright blues and greens.

Acid and basic dyestuffs often used alone or in combinations for dyeing rayon are listed in Table 1. When these dyestuffs are used in combination, acid dyes are combined with other acid dyes, and basic dyes are combined with other basic dyes; acid dyes are never combined with basic dyes in the same bath. The Colour

TABLE 1

BRIGHT DYES FOR RAYON

Dyestuff	C. I. Name
Basic Dyes	
	BASIC
Auromine O	Yellow 2
Brilliant Green	Green 1
Victoria Pure Blue BO	Blue 7
Methylene Blue	Blue 9
Acid Dyes	
	ACID
Guinea Green BA Ex. Conc.	Green 3
Alkali Fast Green 10G	Green 22
Formyl Violet S4BA	Violet 17
Brilliant Milling Blue B	Blue 15

Index (C. I.) names appearing in the tables in this text are taken from the Colour Index, a joint publication of the British Society of Dyers and Colourists and the American Association of Textile Chemists and Colorists.

Another method of obtaining brightness is to top a direct dyeing with basic dyestuffs. This procedure sometimes results in better light fastness than can be obtained by using the straight basic dyes. Topping is done after the regular direct dyeing has been completed in the usual manner. A small amount of one of the basic dyes is dissolved in a cold bath with 2% to 3% acetic acid (28% concentration). The material is treated at a temperature of 110 F to 120 F for 15 to 30 min, after which the dyeings are rinsed and dried.

Machine Dyeing

9. Skeins of rayon yarn and rayon ribbon are dyed with the usual skein-dyeing machinery. Rayon piece goods are dyed on the jig, on the reel, or by running through a padder.

In the dyeing of filament rayon on the package machine, great care should be taken in the winding. A spongy package, wound on a suitable winder with very low tension, is recommended. Slow-exhausting direct dyes of maximum solubility are used.

A typical dyeing cycle would be as follows: Set the bath at 120 F, adding sufficient soda ash to bring the pH (hydrogen ion concentration) between 7.2 and 7.5. Add one half of the previously dissolved dyestuff, with the flow from the inside out for about 5 min. Then add the second half with the flow reversed. The direction of flow continues to shift every 5 min. Dyeing temperature continues at 120 F for 10 min, and then increases to 140 F for 10 min, to 160 F for 10 min, and to 180 F for 10 min. Then, during each of the next two 10-min periods, at 180 F, 3% common salt, based on the weight of the goods, is added. Finally the material is given a cold rinse.

Naphthols

10. The procedures for dyeing rayon with naphthols are almost identical with those for dyeing cotton with them. The only difference occurs during the final soaping procedure. To obtain normal fastness requirements, the material should be treated hot for 30 min in a bath containing 1% nonionic synthetic detergent, 1% organic sequestering agent (sodium salt of ethylene diamine tetra acetic acid), and 1% soda ash per 100 gal of liquor.

Some naphthol combinations impair the luster of rayon if it is soaped above 160 F, and others require the addition of 2% sodium hydrosulfite to the bath in order to develop the correct shade. To determine the most satisfactory procedure, preliminary trials should be run prior to dyeing. Usually, the rayon is slightly coarse after the dyeing is completed and requires treatment with a softening agent to give it the proper hand.

Vat Dyes

11. Vat dyestuffs are applied to rayon by the same methods with which they are applied to cotton. However, the dyestuffs are more rapid exhausting on rayon. This is a very important point and one that you must remember.

When dyeing rayon cakes on the package machine, extreme difficulties are sometimes encountered, due to the tight winding of the cakes. The following developments have served to improve this method of dyeing: 1) the improved mechanical design of the machine to permit better flow of the liquor through the cakes; 2) the production of very fine vat dispersions, which penetrate rather than filter out; 3) the improved retarding agents that control the rate of exhaust; 4) the use of higher temperatures, which promote diffusion; 5) the possible use of solvents, which will improve diffusion by lowering the degree of aggregation of the dyes.

Piece goods can be dyed by the usual methods: pigment padding, jig, pad-jig, and continuous dyeing. The leuco esters of vat dyes (indigosols) may also be utilized to obtain good dyeing results on rayon. The procedures are the same as for cotton.

Rayon Staple

12. The dyeing of rayon staple can best be illustrated by a practical example. Let's assume that the stock is to be used in carpets. The lot consists of 750 lb of rayon stock, and the dyeing is to be carried out in a Franklin raw-stock machine.

The dye liquor contains 8 lb Indanthrene Brown BRA paste, 2.5 lb Indrathrene Brilliant Green BN pure double paste, 1 lb Indanthrene Golden Orange GA double paste, and 2.5 lb Peregal O, in 1000 gal of water.

The pump is turned on and the stock packed into the cold pigment-dye liquor. This operation is completed in 10 min and followed by circulation of the liquor in one direction, from the inside out, for 10 min. Then 25 lb of caustic soda and 25 lb of sodium hydrosulfite are added. The steam is then turned on and the temperature is gradually raised to 140 F over a 20-min period. The direction of the circulation is changed every 10 min. Dyeing is continued at 140 F for an additional 5 min.

The dye liquor is then partially drained off and followed by a cold-water rinse. The dyeings are then oxidized with peroxide and acetic acid at 120 F. A final scouring at 160 F with a nonionic detergent and soda ash completes the dyeing process.

Cuprammonium Rayon

13. Cuprammonium rayon, often abbreviated *cupra,* is a regenerated cellulose fiber similar to rayon. It is produced in the United States by the American Bemberg Corporation under the trade name *Bemberg.* The chemical properties of this fiber are very similar to those of rayon. The outstanding feature of cupra is its fineness, that is, the small diameter of the individual filament.

Cuprammonium has good affinity for direct dyestuffs. It may be dyed with all dyestuffs and processes suitable for dyeing cotton and rayon. Like rayon, the strength of cupra declines when the fiber is wet. Because of this, and because it is generally used in delicate, sheer woven or knitted fabrics, it must be handled very carefully.

Cotton and Rayon Blends

14. The dyeing of rayon-cotton blends is relatively very simple, since both fibers have affinity for the same classes of dyestuffs. Thus the same dyeing techniques can be used for these blends as for rayon alone. One point to note is that the rayon will generally dye to a fuller, or deeper, shade than the cotton. This is a general rule which is valid not only for direct dyes, but also for naphthol, sulfur, and vat dyes. Only one-color effects can be created on this blend.

There is one exception to the rule concerning dyes giving a fuller shade on the rayon, and that is Direct Fast Turquoise 8GL, C. I. Direct Blue 86, which is always weaker on the rayon. The dyes listed in Table 2 are those direct dyes which will yield the closest union on both the cotton and the rayon. It is well to remember, however, that no matter how similar the component fibers may be, no blend can be dyed to an exact uniform shade with all dyestuffs.

Fortisan Dyeing

15. Fortisan is a filament fiber of high tensile strength marketed by Celanese Fibers Company. It is made by saponification of cellulose acetate fiber under high tension, by which process a regenerated cellulose fiber of highly oriented structure is produced. This fiber has little or no elasticity and thus is not suitable for wearing apparel; however, its characteristics make it suitable for woven tape and parachute lines.

Among the dyestuffs that may be applied to this fiber are direct dyes, developed direct dyes, and some sulfur and vat dyes. A precausticizing treatment

TABLE 2

DIRECT DYES FOR COTTON-RAYON BLENDS

Dyestuff	C. I. Name
	DIRECT
Stilbene Yellow 5G	Yellow 6
Chrysophenine G	Yellow 12
Chlorantine Fast Yellow FF	Yellow 28
Pontamine Fast Yellow 4GL	Yellow 44
Chrolantine Fast Yellow RLSW	Yellow 50
Amanil Fast Orange WS	Orange 29
Erie Bordeaux B	Red 13
Benzo Fast Scarlet 4GS	Red 24
Trisulfon Brown M	Brown 1
Congo Brown G	Brown 6
Direct Catechine G	Brown 25
Calcomine Brown B	Brown 31
Amanil Catechin 3G	Brown 74
Amanil Green LT Ex.	Green 1
Erie Green MT	Green 6
Diazo Black BH	Blue 2
Niagara Blue G Conc.	Blue 8
Trisulfon Blue RW	Blue 22
Durofast Blue 3GLL	Blue 100
Visco Black N	Black 19
Amanil Fast Black L Conc.	Black 51

increases the dye affinity somewhat, but the affinity is not high in any case. Depth of dyeings is considerably less than on rayon or cotton, and the amounts of dyes and chemicals must be increased over those normally used on rayon, cotton, or Avril.

Modified Cellulosics

16. Many fibers have appeared on the market in the last ten years, a number of which are derived from viscose rayon. In most cases, however, their molecular structure has been modified by introducing resins in the manufacturing process. Some of these fibers are Avril, Avlin, and Avron (American Viscose), Topel and Corval (Courtaulds), and Zantrel (American Enka). These fibers swell less than rayon in wet treatments, and thus hold their shape better in washing. For the same reason, they absorb dyes with more difficulty than rayon, and do not yield shades as full or as bright in dyeing.

It might be said, as a general rule, that the same dyes are used for the modified cellulosics as for cotton, but that full bright shades are more difficult to obtain.

Avril is sometimes found in blends with cotton or rayon. The same dyes are used for such blends as for the cotton or rayon itself.

TABLE 3

DYES FOR ACETATE

Dyestuff	C.I. Name
Disperse Dyes	
	DISPERSE
Setacyl Yellow G	Yellow 3
Eastman Fast Yellow 4RLF	Yellow 34
Amacel Yellow CW	Yellow 42
Nacelan Orange GR	Orange 3
Eastone Orange 3R	Orange 17
Artisil Scarlet GP	Red 1
Celliton Fast Pink RF	Red 4
Amacel Rubine 3B	Red 5
Celanthrene Fast Pink 3B	Red 11
Interchem Pink BLF	Red 15
Celliton Fast Red GGA Ex. Conc.	Red 17
Artisil Violet BP	Violet 4
Cibacete Sapphire Blue G Ex. Conc.	Blue 1
Amacel Blue BNN Supra	Blue 3
Artisil Blue Green G	Blue 7
Developed Disperse Dyes	
	DISPERSE
Cellitazol NS Conc.	Black 1
Acetamine Diazo Black 3B	Black 2
Amacel Black JRW	Black 9

Acetate Dyeing

Properties of Acetate

17. An ester of cellulose fibers, called acetate or acetate rayon, was introduced into the textile industry after World War I. Since that time, acetate has grown in popularity until today it is one of the most widely used of the synthetic fibers. The reason that acetate has been so widely accepted is that acetate fabrics have excellent hand, drape well, and resist moths as well as mildew. These factors make the fiber desirable from an economic standpoint.

Acetate is spun from cellulose acetate. The cellulose is changed into an ester of cellulose in the process. This is dissolved in a solvent, and extruded through a spinneret. The solvent evaporates, leaving the filament to solidify. The old name "acetate rayon" is still used, but the shorter form "acetate" is legally recognized and more common.

Acetate may be in either continuous-filament or staple form. The staple may be crimped to give improved spinning properties and softness to the ultimate yarn. The fiber may be lustrous and bright, or may contain finely dispersed particles of titanium dioxide as a delustering agent. The delustering agent is usually added to the cellulose acetate solution and does not inhibit the action of dyestuffs. However, the depth of dyeing may appear to be less on delustered acetate than on bright acetate. In some instances, an additional amount of the dye may have to be used to get a deeper shade.

Disperse Dyes

18. With the development of acetate came the development of an entirely new class of dyestuffs, which have an affinity for this fiber. Some characteristic acetate dyes, or disperse dyes as they are now more commonly known, are listed in Table 3. Disperse dyestuffs may be purchased under many brand names besides those mentioned in the table. Some manufacturers employ two or three names, since this very popular group of dyes is used not only on acetate, but on Arnel, nylon, Orlon, Dynel, and polyester fibers.

Most disperse dyes are water-insoluble organic substances. The dyestuff is dispersed in water into fine particles that have an affinity for cellulose acetate. The dye particles seem to form a homogeneous mixture within the fiber.

Among the important disperse dyes of the type just discussed are certain anthraquinone and azo dyes.

Acetate does have a certain affinity for acid, direct, and chrome dyes from aqueous solutions, but not enough for extensive use. Acetate, by surface saponification with hot alkali, will adopt an affinity for dyes very similar to the affinity of rayon. However, because of the difficulty in controlling saponification, it is not often applied in practical dyeing.

Selected amino bases can be dispersed to the extent that they have affinity for acetate and are later diazotized and developed to form an azo dye on the fiber. Blacks and navy blues are the only types of azo dyes often used for acetate dyeing.

Forms of Material

19. Acetate is usually dyed in the piece goods form as taffetas, satins, crepes, and mixtures for suiting fabrics. Knitwear and yarn skeins are not too common, but are occasionally dyed. A considerable amount of acetate is printed either by screen or by roller printing for the tie, scarf, dress-goods, and sport-shirt trades.

Crepes and soft fabrics that are not subject to crease marks are dyed in the rope form on reels. Flat goods, such as taffetas and satins, which are subject to creasing, must be dyed on the jig in full width. Knitwear may be dyed in a rotary machine similar to laundry wheels. Yarn may be dyed in a package machine, or in skein form in any one of the usual skein-dyeing machines.

Preparation for Dyeing

20. Prior to dyeing, acetate is scoured for 30 min to 1 hr in a bath, at temperatures between 160 F and 180 F. The scouring bath contains 1 lb to 2 lb synthetic detergent, and 4 to 6 oz (ounces) aqueous ammonia 26 Bé (degrees Baumé) or 4 oz tetrasodium pyrophosphate per 100 gal of water.

The disperse dyestuffs are water-insoluble substances in powder form. They must be carefully dispersed in the dyebath to prevent spotting of the material. The dyestuff is best prepared by first pasting it in a small amount of water, with the addition of a small amount of leveling or penetrating agent, at 120 F to 130 F. The well-dispersed paste is then further diluted with water and stirred again. An open steam pipe should not be used to raise the temperature of the slurry. The water for the dyebath should be heated sufficiently before adding the paste. The dyestuff is then added to the dyebath through a fine mesh or sieve, which will strain out all particles which have not been properly dispersed.

Dyeing Procedure

21. After the acetate goods have been prepared, they are entered into a dyebath that has been set with 0.5% to 1.5% penetrating or leveling agent. The dyestuff is then added in several separate portions. The temperature of the dyebath is usually from 160 F to 190 F. The lower temperature is generally used for bright acetate, and the higher temperature for the delustered type.

The dyeing is continued for about 1 hr, more or less, depending on the depth of shade desired and the type of equipment used. A closed machine will provide a more constant temperature and a quicker complete exhaust of the dyestuff than will an open machine. After the dyeing is completed, the goods are washed and rinsed to remove any traces of loose dye.

Developed Dyes

22. The developed types of dyestuffs are prepared and the goods dyed in the same manner as recommended for the regular disperse dyes. A few characteristic developed dyes for acetate are listed in Table 2. The temperature of the bath is usually between 160 F and 190 F, depending on the individual dyestuff. After dyeing, the material is well rinsed in cold water before diazotizing.

Diazotizing is carried out in a fresh, cold bath. Care should be taken to prevent direct sunlight from reaching the material during diazotizing and coupling. The bath is prepared with 5% sodium nitrite, and 10% hydrochloric acid 32 Bé or 5% sulfuric acid 66 Bé, on the weight of the goods. The diazotizing time is 30 min at a temperature below 80 F.

A diazotizing bath, when prepared as explained, should turn 1) Congo-red indicator paper and 2) starch-iodide paper to a bright blue; the first because of the acidity, and the second because of a safe excess of nitrous acid. A bath in good order has an unmistakable odor which you will learn to recognize. Both hydrochloric and sulfuric acids work satisfactorily, but hydrochloric acid attacks metals faster. Stainless-steel equipment should be used if possible. Excessive metal attack can cause decomposition of the diazotized dye. After diazotizing, the material should be rinsed in cold water and coupled immediately.

Coupling

23. After the dye has been diazotized, it must be coupled to bring out the shade and the fastness properties. For this reaction Developer BON (2-hydroxy-

3-naphthoic acid) is used. The developer is dissolved in hot water with a 50% solution of caustic soda in a ratio of 2 to 1, that is, twice as much developer as caustic soda. Another method of bringing this developer into colloidal solution is to boil it for a few minutes in water without alkali; the water must contain twice as much sodium acetate crystals as developer. The developer is also available in the form of its sodium salt, which is soluble directly in water.

The dissolved developer is poured into the warm developing bath, which already contains 1% to 5% acetic acid (28% concentration) on the weight of the material. The developing bath at this point must have a *p*H of about 3.5. If the bath is not sufficiently acid, more acetic acid is added, or up to 1% of formic acid (85% concentration). The dyeings are coupled for 30 min between 140 F and 160 F. The dyeings are then rinsed and soaped to bring out the final fastness properties.

One-Bath Developed Black

24. It is possible to dye a developed black on acetate in one bath. This process has proven successful on acetate yarn in package machines, on acetate tricot in Burlington beam machines, and on acetate piece goods on the jig. One such dyestuff is Amacel Black A1B.

The procedure for a 1000-lb beam of acetate tricot on a beam machine is as follows: After scouring the material, set the bath at 130 F, and disperse and add to the bath 5% or 50 lb of Amacel Black A1B. Run the pump 10 min. Raise the bath to 175 F and run the pump 30 min. Add 9 lb acetic acid (56%), and run the pump 10 min; add 9 lb acetic acid (56%), and run the pump 10 min; add 9 lb acetic acid (56%), and run the pump 60 min. Drop the bath, but do not rinse. Fill with water and set at 95 F. Add 4% or 40 lb sodium nitrite dissolved in water, and slowly add 3% or 30 lb hydrochloric acid, 18 Bé, diluted with water. Run 30 min at 95 F. Drop, rinse, and scour well with 3 lb nonionic detergent, 5 lb soda ash, and 5 lb sodium hydrosulfite. Rinse well and frame.

Fastness Properties

25. The fastness to washing of most of the disperse dyestuffs is fairly good, and considering that most of the garments finally made from the dyed material are to be dry-cleaned, the wash fastness can be considered quite satisfactory. A weakness that is peculiar to the blue and violet shades is a tendency of the anthraquinone type of dye to be affected by acidic fumes often present in the atmosphere, causing the shade to redden after a time. This tendency may be overcome in some instances by aftertreating the dyeings with an antifume or gas-fading retardant. A few types also *sublime*; that is, a dyestuff on one piece of goods stains another piece of goods when stored in close contact. Progress is being made by the manufacturers of the dyestuff to overcome these weaknesses.

Acetate-Rayon Blends

26. The dyeing of acetate in the presence of rayon may present a problem,

because disperse dyestuffs have a tendency to stain rayon. When clean rayon is desired, any one of four methods of aftertreatment may do the job.

Method 1. Dissolve 5 to 6 oz of Blankit I (General Dyestuff Corporation) in 100 gal of water. Run 15 to 20 min at 120 F. Rinse well, acidify with acetic acid, and rinse again.

Method 2. Make two baths, the first with 1 oz to 1.5 oz of potassium permanganate per 100 gal of water. Run 10 min cold and then rinse well.

Prepare the second bath with another 100 gal of fresh water. Add 2 to 3 oz of sodium bisulfite, and 1 oz to 1.5 oz of sulfuric acid, 66 Bé. Run 15 min at 120 F and rinse thoroughly to remove all traces of acid.

Method 3. Add 2 lb of synthetic detergent and 1 gal of sodium hypochlorite solution (containing 12% active chlorine) to 100 gal of water. Run 20 to 30 min at 80 F. Rinse, acidify with acetic acid, and rinse well again.

Method 4. Add 2 to 3 lb of synthetic detergent to 100 gal of water. Run 20 to 30 min at 80 F. Rinse well.

The method to be used depends largely on the dyestuff, since some dyestuffs clear more easily than others. Dyestuff manufacturers' color cards will supply the necessary information as to the best clearing method for each dyestuff.

Naphthols on Acetate

27. The dyeing of naphthols on acetate yarn or piece goods involves an inverse process. The diazotizable base and the naphthol are dyed in the same bath, and the coupling is completed by treating in a second bath with nitrous acid solution.

The extraordinary affinity of the naphthols and bases on acetate, and the excellent yield of these dyes in color value, make them particularly suitable for dyeing this fiber. Even the naphthols of low substantivity on cotton exhibit high affinity on acetate. Dyeings of light and full shades are level and readily reproducible. The fastness to washing and cross dyeing is very good, and the fastness to light is high in many combinations. The amount of soaping necessary to delevop the shades completely and to promote best light fastness is not detrimental to the fiber.

The naphthol is dispersed in warm water and added to the dyebath. The fast-color base is dissolved in hot water and also added to the dyebath. The fast-color base is highly acidic, so that only dispersible naphthols which remain in good dispersion in the acid bath can be used. Shades can be matched, when required, by mixing the fast-color bases.

When dyeing acetate skeins in long liquor, or acetate knit goods in the beck, dye the naphthol and fast-color base together for 30 min at 180 F.

When piece goods are being dyed on the jig, or when yarn is being dyed in package form on the machine, the short liquor ratio may cause an adverse reaction between the dispersed naphthol and the acid of the fast-color base. In these cases, it is advisable to dye the naphthol on first, then the fast-color base in a second bath, followed by the diazotization in a third bath.

Temperature control is important. The naphthol is dyed at 180 F. The fast-color base is likewise dyed at 180 F. After the components are exhausted, the bath is dropped and the material is rinsed cold.

Diazotization is carried out in a fresh bath with 5% sodium nitrite and 10% hydrochloric acid concentrate for 30 min, starting at 110 F, and gradually heating to 160 F to 170 F. The soaping follows a rinse.

The soaping is an integral part of the development of the shade. It is recommended that soaping be carried out with 2% soap on the weight of the material, or a good detergent with soda ash at a *p*H of 10.5 at 170 F to 180 F for 20 min.

The following fast-color bases are soluble in hot water:

Fast Yellow GC Base
Fast Orange GC Base
Fast Scarlet GC Base
Fast Scarlet RC Base
Fast Red KB Base
Fast Red RC Base
Fast Garnet GBCP Base

The base can be pasted with alcohol to facilitate its solution in the hot water. When fast-color bases not listed here are used, it is advisable to first dissolve them in as little methyl alcohol as possible, and then to emulsify this solution into water with the aid of Turkey Red oil.

Arnel

28. Arnel is a triacetate cellulose. Its properties are different in many respects from those of acetate, which is essentially the diacetate of cellulose. It has unusual resistance to saponification and can be ironed at higher temperatures than acetate; the dyeing rate of disperse dyes on Arnel, however, is slower than on acetate.

Like acetate, Arnel is resistant to dilute solutions of weak acids. It is unaffected by boiling; that is, it does not hydrolyze or become dull. It is unaffected by the usual dry-cleaning solvents.

In general, the same dyeing equipment is used for Arnel as for acetate. The use of disperse dyes in dyeing, followed by a heat treatment of the fabric, gives Arnel a high degree of wash fastness. This wash fastness, however, cannot be obtained with the line of dyes normally applied on acetate.

Dyeing accelerants, or carriers, may be required in heavy shades. Generally, it can be stated that longer times are required to exhaust disperse dyes on Arnel, but the long time and high temperatures have no weakening or dulling effect on the fiber. Accelerants which are recommended are Marnel 82 and tripropyl phosphate.

TABLE 4

DYES FOR ARNEL

Dyestuff	C. I. Name
Disperse Dyes	
	DISPERSE
Amacel Yellow GLF	Yellow 33
Interchem Yellow HDLF	Yellow 42
Lenra Yellow CW	Yellow 42
Artisil Orange RFL	Orange 21
Artisil Scarlet GP	Red 1
Latyl Scarlet FSW	Red 56
Eastman Fast Blue B-GLF	Blue 27
Latyl Brilliant Blue BG	Blue 60
Lenra Blue RLS	Blue 70
Disperse Developed Dyes	
	DISPERSE
Acetamine Diazo Black RB (BON)	Black 1
Setacyl Diazo Black BNS (BON)	Black 7
Eastman Diazo Navy Blue RB*	. . .

*Developed with BON, Eastman Diazo Navy Blue RB produces a navy blue; developed with phloroglucinol, it produces a black.

29. Certain considerations enter into the selection of dyes for Arnel. The dyes must be stable at the dyeing temperatures, which are 204 F to 208 F, or higher; they must show level exhaust rate and good pile-on; and they must have good fastness properties to sublimation, light, washing, and the atmospheric conditions which induce gas fading and ozone fading. A list of dyes which meet these conditions is given in Table 4.

The procedure for jig dyeing a deep brown on 100% Arnel with accelerant is as follows:

Scour three ends at 195 F with
- 1.0% oleate soap
- 0.5% Syntex A
- 0.5% soda ash

Rinse two ends at 150 F.

Set dyebath with
- 4.0% Marnel 82 carrier
- 0.5% Igepon T
- 0.25% Calgon

Add
- 0.8% Lenra Blue RLS
- 1.2% Interchem Yellow HDLF-40
- 0.9% Eastone Red NG-LF
- 1.0% gas inhibitor

Dyes must be dispersed in water before being added to dyebath.

Dye

2 ends at 140 F

2 ends at 175 F

16 ends at 205 F

Rinse well.

After dyeing, fabrics of Arnel must be heat set at temperatures of 400 F to 430 F to obtain the best properties. Heat setting reduces fabric shrinkage, raises the safe ironing temperature, imparts wrinkle resistance, and improves the wash fastness of dyeings.

30. Fabrics of Arnel and cotton in checks and stripes are popular. Such fabrics may be jig dyed or beck dyed, or they may be dyed continuously by a pad-steam method. The cotton may be dyed with the Arnel reserved (left white), the Arnel may be dyed with the cotton reserved, or the two fibers may be dyed different colors. Other popular fabrics are woven of Arnel/rayon or Arnel/Avril.

Where the one fiber is to be reserved, dyestuffs should be selected which stain the reserved fiber least. For dyeing the cotton portion, direct colors or fiber-reactive dyes are generally used.

For a solid shade on blends of Arnel/cotton or Arnel/rayon, the Arnel may be dyed in one bath and the cotton in a second bath, but usually the two fibers are dyed in one bath, using disperse dyes for the Arnel and direct dyes for the cotton or rayon. Such dyeings are given suitable aftertreatments to yield best fastness to washing of the direct dyes.

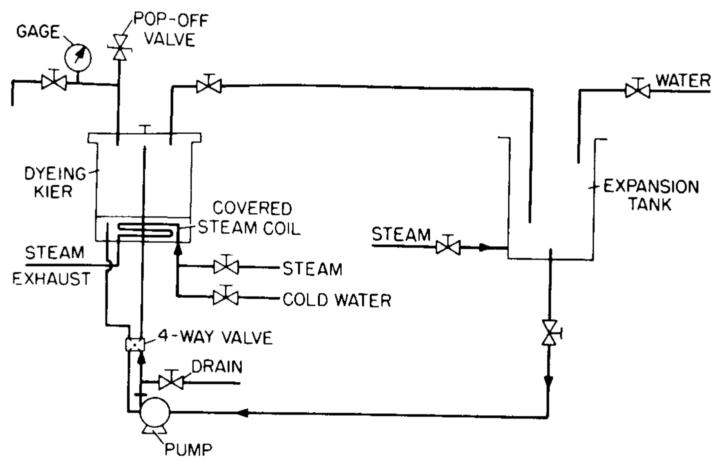


FIG. 1. HIGH-TEMPERATURE, OR PRESSURE-DYEING, SETUP

Pressure-Dyeing Equipment

Raw Stock and Yarn Dyeing

31. Raw stock and yarns were the first fiber forms to be dyed commercially by high-temperature, or -pressure, procedures. Mill operators found that much of their existing equipment could be adapted more or less readily to provide the advantages offered by dyeing at elevated temperature and pressure.

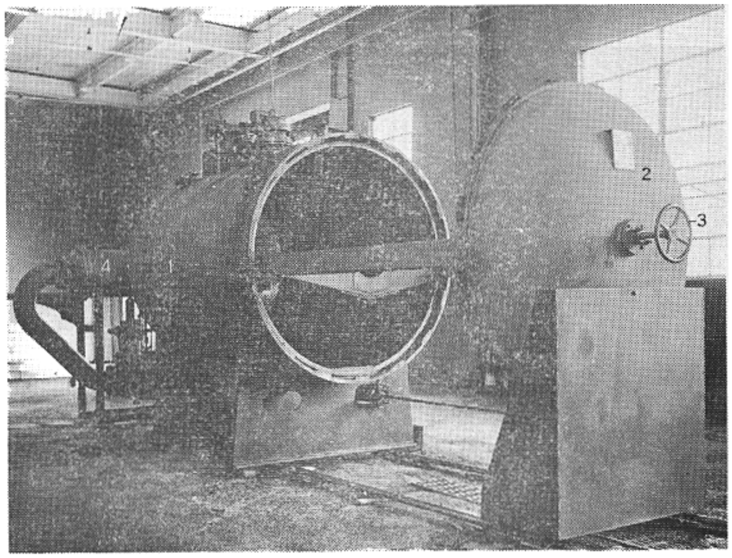
The high temperature is obtained by means of a suitable valve arrangement which allows the operation of a closed system. A typical setup for pressure dyeing is shown in Fig. 1. In the setup shown, the expansion tank is shut off from the circulating system, trapping the liquor in the kier where it can be heated to temperatures above the normal boiling point of water. Because the liquor in the expansion tank is not used in the dyeing, the volume of liquor in this tank should be kept as low as possible before the system is pressurized.

Today all manufacturers of package-dyeing and raw-stock-dyeing equipment offer a variety of machines for pressure dyeing. Some may have special devices installed to permit sampling of the material being dyed and making color additions without depressurizing the kier.

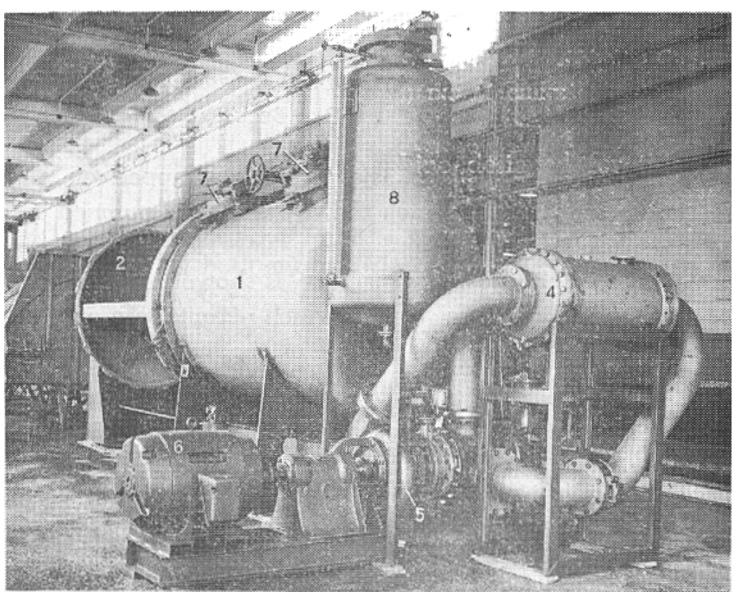
Piece Goods Dyeing

32. For the high-temperature dyeing of fabrics, new approaches are required because the becks and jigs normally used do not readily lend themselves to pressurization.

The Burlington Engineering Sales Company introduced one of the earliest machines for the pressure dyeing of piece goods. This unit consisted of a rectangular housing equipped with a bolted-down lid to permit the temperature to be raised slightly higher than the boil, about 235 F. This is considered the safe



(a)



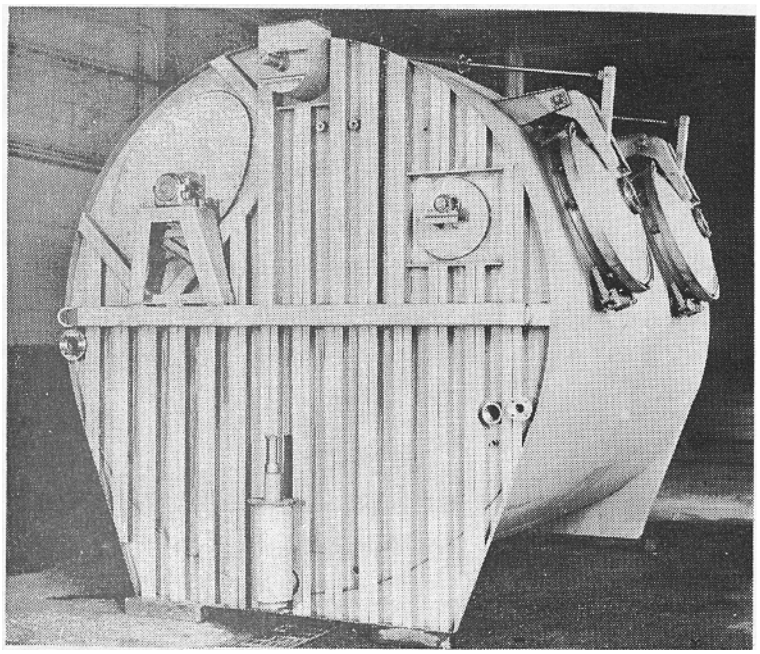
(b)

Courtesy of Burlington Engineering Sales Company

1. vessel
2. quick-opening door
3. locking and unlocking device
4. heat exchanger
5. pump
6. motor
7. inspection ports
8. add-expansion tank

(a) Front view
(b) Rear view

FIG. 2. HY-PRESS MACHINE



Courtesy of Burlington Engineering Sales Company

FIG. 3. LO-PRESS DYE BECK

maximum temperature for this unit. The fabric is wrapped on a perforated, hollow cylindrical beam through which the dye liquor is pumped in much the same way as in a package machine.

The improved model, the Hy-Press machine, is shown in Fig. 2, (*a*) and (*b*). It consists of a cylindrical pressure vessel *1* which permits safe operation at temperatures up to 300 F. The machine is capable of handling a batched beam 60 in. (inches) in diameter, and the one shown in the illustration is designed to handle cloth up to 64 in. wide.

The unit is equipped with a quick-opening door *2* and an automatic locking and unlocking device *3*. It has a heat exchanger *4* to heat and cool the dye liquor as needed. An 8 x 10 pump *5*, driven by a 75-hp (horsepower) motor *6*, has a capacity of about 3000 gpm (gallons per minute). The machine can develop a pressure of 50 psi (pounds per square inch). It has inspection ports *7* that can be opened to inspect the beam; however, the ports cannot be opened unless the pressure is removed from the vessel. A sample chamber, not shown in this illustration, allows swatches to be taken directly from the face of the beam for color-matching purposes. The combination add-expansion tank *8* allows dyestuff to be added under pressure or at atmospheric conditions.

Another development of Burlington is the Lo-Press dye beck shown in Fig. 3. This unit is used to dye synthetics and blends in rope form at temperatures up to 225 F. It has found wide use in the dyeing of woolen goods where temperatures in excess of 225 F are not desired. It is clamed to provide tremendous savings in carrier costs.

The Barotor, developed by Du Pont, is also designed for the pressure dyeing of fabrics, but has not enjoyed the popularity of the Burlington machine. In the Barotor, the dyeing principle differs in that the fabric is moved through the dye liquor by a series of movable bars and a rotor, from which the term "Barotor" was coined.

Pressurized jigs have been devised, but so far have failed to attract significant interest.

Another interesting development, at this time undergoing critical evaluation in this country, is the Svetema pad-roll dyeing machine manufactured by A. B. Svenska, Textilmaskinfabriken, Göteburg, Sweden. In this machine, the fabric is padded with dye and heated by radiant heaters as it passes to a steam chamber in which it is batched on a beam. The chamber is then closed and the humidity and the temperature are carefully adjusted. The moist beam rotates during the entire desired dyeing period.

Molten-Metal Dyeing

33. A process developed by the Waldrich Company in the United States and Standfast Dyers & Printers in England makes use of molten metal as the medium in which fixation of the dye takes place.

The metal used is a fusible alloy, that is, a metal with a melting point of about 160 F. The dyeing machine used in the molten-metal process is comparatively simple. The machine is U-shaped, and about 5 ft (feet) deep and 5 ft wide. The sides and the bottom of the U consist of two sheets of steel, so that there is a distance of about 1 in. between the two sheets. The cloth passes in open width down one side of the U and up the other, guided by rollers.

On the side of the machine at which the cloth enters is a dyebath made of stainless steel. The dyebath floats on top of the molten metal, which fills the bottom and the other side of the machine. The entry side is higher, because the dye liquor weighs only a fraction of the metal, so that the level is much higher. The temperature of the molten metal is maintained at 210 F to 220 F.

The cloth passes through the dye liquor, which is prereduced. As the cloth passes into the molten metal, the weight of the metal squeezes the surplus liquor out of the cloth. The heat of the metal develops the dye. As the cloth leaves the metal, it passes through a bath containing a salt solution, which removes the exhausted dyestuff. Oxidizing, washing, rinsing, and drying complete this continuous process.

The molten-metal process is suitable for vat dyes, direct dyes, and sulfur dyes that are free of loose sulfur.

Dyeing the Man-Made Fibers

Classification of Fibers

34. The man-made fibers are those which are completely synthetic; that is, they are not made from animal or vegetable sources. They are conveniently classified according to their chemical constitution. The following classifications will serve as a guide in subsequent discussions of these fibers.

Polyamide fibers. The generic name for polyamide fibers is nylon. There are various nylons, such as Nylon 6 and Nylon 66, depending on whether the fiber is manufactured from caprolactam (Nylon 6) or from adipic acid and hexamethylene tetramine (Nylon 66). Many nylons have been given trade names, such as Antron, Caprolan, Banlon, and Helanca.

Polyester fibers. There are two groups of polyester fibers, each of the two having different dyeabilities: 1) polyesters which are dyeable with disperse dyes but not with basic dyes, such as Dacron 51, 52, 54, 55, 56, 57 (Du Pont), Fortrel (Celanese Corporation), Kodel 4 (Eastman Chemical Products), Vycron (Beaunit Company), Terylene (I.C.I.), Blue C (Chemstrand); and 2) polyesters which can be dyed with basic dyes as well as disperse dyes, such as Dacron 62 and 64.

Acrylic fibers. There are two groups of acrylic fibers, the grouping depending on the affinity of the fibers for dyes. The first group consists of those acrylics which can be dyed with acid dyes, disperse dyes, and, to some extent, basic dyes. Included are Acrilan 1656 and 14 (Chemstrand), Orlon 28, 29, and 44 (Du Pont), Creslan 58 (American Cyanamid), and Courtelle (Courtaulds).

The second group consists of those acrylics which can be dyed with basic dyes and disperse dyes, but not with acid dyes. Included are Acrilan 16 (Chemstrand), Creslan 61 and 63 (American Cyanamid), Orlon 42, 72, and 75, and Orlon Sayelle (Du Pont).

Modacrylic fibers, or modified acrylics. These include Dynel (Union Carbide), Verel (Eastman Chemical Products), and Zefran (Dow Chemical).

Vinyl chloride fibers. In this class are Vinyon (Union Carbide) and Rhovyl (Rhodiaceta). The vinylidene chloride fibers include Saran and Velon (Firestone).

Olefin fibers. Herculon (Hercules Powder), Reevon (Reeves Brothers), and Enlon (National Plastics) are included in this class.

Each class will be discussed separately and comparisons will be made. Thus the dyeing properties of each class will fall easily into place.

Nylon Dyeing

Properties of Nylon

35. Nylon plays an important part in the development of synthetic fibers. It was the first successful fiber made wholly from chemicals. It was developed by chemists of E. I. du Pont de Nemours & Company from chemical compounds not

found naturally. Reactions of hydrogen, nitrogen, oxygen, and carbon produce the long-chain molecules, which are ultimately reacted to produce nylon salt. This salt is a hard mass which must be broken into small pieces, melted, and forced through spinnerets into the air to solidify the mass and form the filament. The filament is then stretched, and finally the yarn is thrown by methods resembling rayon processing.

Nylon fiber has advantages over some of the other synthetic fibers because it has great tensile strength, combined with a woollike feel in crimped staple and a silklike feel in filament form. The resistance of nylon to high temperatures, atmospheric conditions, and abrasion helped to gain wide acceptance for this fiber in many uses. Two features popular with the consumer are the elasticity and low water absorption of the fiber, which enable nylon goods to be washed and dried quickly without shaping, stretching, or ironing.

The dyeing of nylon developed rapidly. The affinity of nylon for disperse dyestuffs was found to be outstanding, and nylon's affinity for many acid dyes and direct dyes opened the way for a wider variety of shades and fastness properties. The development of a method for utilizing naphthols on nylon has produced brighter and heavier shades with good wash fastness.

36. The term "nylon" does not identify any one compound or textile fiber, but refers to a broad class of chemical compounds (polyamides) which are used in such things as bristles, sheets, moldings, extrusions, and coatings, as well as textile fibers.

Several types of nylon are used in textiles. The original, or that first introduced to the industry, is Type 66 nylon, made from hexamethylenediamine and adipic acid. Type 6 nylon, based on caprolactam, was first introduced in Germany as Perlon and is now made by several United States firms.

The various nylons have different physical properties and minor differences in dyeability. For example, Type 6 nylon dyes more rapidly than Type 66, and with some dyes will give deeper shades. The discussions that follow treat Type 66.

Nylon can be quickly identified in the following ways: it melts before burning, and it is insoluble in acetone but soluble in xylenol and concentrated hydrochloric acid. A microscopic cross section shows solid, nearly perfect circles without any grooves or other indentations.

Preparation for Dyeing Nylon

37. Before dyeing, nylon is generally set at a temperature higher than any to be used in subsequent operations. This heat setting renders nylon wrinkle resistant and improves results during dyeing. Setting is carried out with either dry or wet heat. before or after scouring, depending on the cleanness of the goods.

The scouring of the goods is carried out for 30 min at 200 F in a bath containing 0.5 to 2 lb synthetic detergent, and 1 lb to 2 lb soda ash or tetrasodium pyrophosphate, in 100 gal of water. After scouring, the nylon materials are rinsed.

The goods may be extracted, but usually they are not dried until the dyeing is completed. Nylon is somewhat less strong when wet and stretches easily. Therefore, wet nylon materials must be handled very carefully.

Disperse Dyes for Nylon

38. The type of dyestuffs that was originally developed for dyeing acetate was also found very suitable for dyeing nylon. Warp streaks and filling bars are eliminated by the use of this type of dyes, and heavy shades which dye quite level are obtained. The dyestuffs are pasted with water and a synthetic dyeing assistant. Usually, the same detergent used for scouring is also used as the dyeing assistant. Pasting is continued until there are no lumps left and a fine dispersion has been formed. The paste is further diluted with warm water and then added to the dyebath through a fine mesh sieve or muslin.

Nylon piece goods that are dyed on the jig in open width are started at a temperature of 120 F in a bath containing 0.5 to 1 lb synthetic dyeing assistant. The dyestuff is added over two ends and the temperature is gradually raised from 180 F to 200 F. The dyeing is continued for 30 to 60 min, after which the material is thoroughly flush-rinsed to remove all loose dyestuff.

The ordinary open jig will not provide a sufficiently high temperature for heavy shades and long dyeing times; therefore, it is better to use a closed jig. The same general procedure of dyeing outlined for this jig is also applicable to the reel. Again a closed-type machine is recommended for a high-temperaure dyeing. The developed types of disperse dyes are treated on nylon in the same manner as on acetate.

Nylon may also be dyed on the package machine with disperse dyes. Care should be taken that the package is not wound too tight. The dyestuffs should be selected from the finest and most highly dispersed types which are recommended by the manufacturer for this work. The procedure for dyeing nylon in the package machine is much the same as that for the direct dyeing of cotton. The dyestuff is pasted in the prescribed manner and added to the machine in two or more portions, starting at a temperature of 120 F and increasing to 200 F, with the dyeing continuing for about 1 hr. The material should be well rinsed, and soaped lightly to give good fastness properties. Nylon knitwear is dyed in rotary wheels or open tubs by following the general procedure for applying acetate dyestuffs to nylon.

Direct Dyes

39. There are many selected direct and neutral-dyeing acid dyestuffs which can be applied to nylon without the use of acid or salt in the bath. The advantage of these types of dyestuffs is that with them a good union color is obtained in mixtures of nylon and cellulose fibers. The final wet fastness is considerably better than that produced with acetate dyestuffs.

In their application, the dyestuffs are well dissolved in hot water and added to the dyebath in several portions. No chemicals are necessary, but the addition of a synthetic dyeing assistant aids penetration and also acts as a leveling agent. Dyeing is carried out for 1 hr at 200 F, after which the goods are rinsed well. All forms of nylon can be dyed with these dyes; the type of machinery used depends on the form in which the nylon is to be dyed.

Acid Dyeing

40. Direct, acid, and premetalized dyestuffs can be applied to nylon in an acid bath. The different dyes exhaust much better in the presence of acid, and therefore a large number of the different types can be selected for use.

It is recommended that the goods be run for about 15 min, or two ends on a jig, at 170 F to 180 F. The liquor should contain a retarding agent, such as Peregal O, and from 0.5% to 1% formic acid. At least 15 min are necessary to distribute the acid and the agent evenly on the goods.

The direct, acid, or premetalized dyestuff is dissolved in hot water and added to the bath in several portions at 170 F to 180 F. Although the amount of acid necessary for good exhaustion of the dyestuff varies, the use of 1% formic acid (85% concentration) for light shades and 3% to 5% for heavy shades is generally adequate. The use of 0.5% to 2% retarding agent is recommended for the dye-
continued for the length of time necessary to obtain the desired shade, or degree
bath. The temperature is gradually raised to above 200 F, and the dyeing is
of exhaustion.

In jig work it is sometimes difficult to obtain a high enough temperature in the open types of machines. More formic acid, up to 5%, may be added in order to obtain proper exhaustion. Acetic acid (28% concentration) may be used in place of the formic acid in about a 2-to-1 ratio. The dyeing may then be soaped with 2 lb of synthetic detergent and 2 lb of soda ash per 100 gal of water at 160 F. This soaping will give additional wash fastness and brightness.

Chrome Dyes

41. When additional fastness to washing and perspiration is desired, chrome dyes may be applied to nylon. The color range is somewhat limited, with no bright reds and blues, yet the colors seem brighter on nylon than on wool. It is more difficult to chrome the dyestuffs to their normal shade on nylon than on wool, and only the top-chrome method is recommended.

For applying chrome dyes, the bath is set at 160 F with 1% to 3% acetic acid (28% concentration). The well-dissolved dyestuff is added and the temperature is gradually raised to above 200 F. The dyeing is continued at this temperature for 45 min. If necessary, to complete the exhaustion, 1% to 3% formic acid (85% concentration) is added. For development of the shade, 1% to 3% sodium bichromate is added in portions to the bath, and the chroming is carried out for 30 to 60 min at 200 F. The finished dyeing is rinsed well, and is then soaped with 2 lb of synthetic detergent and 2 lb of soda ash at 160 F.

Naphthols on Nylon

42. A development in the field of nylon dyeing is the application of the insoluble azo dyes to nylon fiber. In order to produce a good dyeing, an assistant had to be found. One such assistant, called Naphthol Assistant GCB, was developed by the General Dyestuff Corporation. The fast-color bases that are used for nylon are prepared in a specially dispersed form. They require only pasting and dispersion in water, without the use of other chemicals. Trade names include Developer Red B, Developer Red RF, and so forth. Special combinations of naphthols and developers are recommended to produce shades with suitable light fastness on nylon, because in many instances the fastness on nylon and acetate does not equal that of similar combinations on cotton.

In the application of naphthol-developer azo-dye combinations to nylon, the required amount of naphthol is dissolved with caustic soda in the same manner as for cotton. The dyebath is heated to 160 F and 6% Naphthol Assistant GCB is added, followed by the dissolved naphthol. The assistant, because of its alkaline reaction, takes the place of caustic soda as a sharpening agent.

The nylon is treated for about 15 min, or two ends on a jig, with the naphthol and assistant. The developer color is separately dispersed through stirring in about 1 gal of water for every pound of developer color at 120 F to 130 F. The dispersed color is added to the bath and the treatment is continued at 160 F for at least 30 min longer, or about eight ends on the jig.

The treated material is rinsed well in cold water. Then the base on the fiber is diazotized in a fresh bath for 20 min, or two ends on the jig, at 90 F. This diazotizing bath contains 5% sodium nitrite and 5% sulfuric acid, 66 Bé. The temperature is then raised rapidly to 160 F and the reaction is allowed to continue for 20 min more.

The coupling is now complete and the goods are ready to be rinsed and soaped. The soaping is done with 2% nonionic detergent, 2% organic sequestering agent, and 2% soda ash, on the weight of the fabric. Soaping continues for 20 min at 190 F. A final rinse completes the dyeing. Note that soda ash should not be used in the soaping bath when this method is being applied to acetate.

Vat Dyes

43. Vat dyes can be used for dyeing nylon with satisfactory results. However, a higher dyeing temperature is required than for dyeing cotton. Vat dyes have excellent wet fastness on nylon and good light fastness in the violets, blues, greens, olives, and blacks. But they have relatively poor light fastness in the yellows, oranges, browns, and reds when applied by the usual methods. Vat dyes can also be used satisfactorily for dyeing blends of nylon and cellulosic fibers.

Much work is being done to improve the fastness properties of the vat dyes on nylon. You can keep yourself abreast of new developments by reading the trade publications.

TABLE 5

DYES FOR NYLON

Dyestuff	C. I. Name
Disperse Dyes	
	DISPERSE
Celliton Fast Yellow GA	Yellow 3
Latyl Cerise Y	Red 55
Latyl Violet 2R	Violet 18
Celanthrene Brilliant Blue FFS	Blue 3
Neutral Premetalized Dyes	
	ACID
Calcofast Neutral Yellow G	Yellow 151
Nyalan Orange R	Orange 60
Capracyl Red B	Red 182
Capracyl Blue G	Blue 165
Lanamid Brown RD	Brown 29
Acid Metalized Dyes	
	ACID
Gycolan Yellow BEL	Yellow 54
Calcofast Wool Orange RN	Orange 34
Chromacyl Pink BN	Red 186
Chromacyl Blue CG	Blue 158

Reactive Dyes on Nylon

44. The reactive dyes of the types used for dyeing the cellulosic fibers can also be applied to nylon. They are absorbed by nylon in the same manner as acid dyes. The reactive dyes, however, are of only minor importance.

The Procinyl dyes (I.C.I.) are reactive dyes which represent an important advance in dyestuff development. These are insoluble disperse dyes containing a group in the molecule which can react with the nylon molecule. The procinyls include a yellow, orange, scarlet, ruby, and blue. They are applied in a weakly acid bath at the boil. After the dye has been substantially exhausted, the bath is made slightly alkaline, which promotes the reaction of the dye molecule with the nylon molecule. There is very little unfixed dyestuff left adhering to the fiber, so that an aftersoaping is not necessary.

45. Listed in Table 5 are some of the dyes which can be used for nylon. There are many other dyes which are also suitable, of course; certain groups which have been mentioned in the text, such as vat dyes and naphthols, are not mentioned in the table.

It is well to remember in this connection that the name "nylon" is a generic name which includes many polyamide fibers which are sold under various names, such as Antron, Caprolan, Helanca, Rilsan, Taslan, and Banlon, all of which behave like nylon in their dyeing properties.

Dyeing Other Man-made Fibers

Polyester Dyeing

46. The first polyester fiber made in this country was Dacron, now known as Type 54 Dacron. It was modeled after the British fiber Terylene, and produced by condensation polymerization of terephthalic acid and ethylene glycol. The license to manufacture it was obtained by Du Pont. Since then, many fiber manufacturers have put polyesters on the market. Beaunit Company makes Vycron, Eastman makes Kodel, Chemstrand makes Blue C, Celanese makes Fortrel, and American Enka has announced its intention to market a polyester fiber.

The behavior of the various individual fibers toward dyeing can be considered similar enough to warrant giving these fibers a common designation, PE (for polyester), for discussion purposes.

Two modifications of Dacron, known as Dacron 62 and 64, possess different dyeing characteristics and so will be treated separately.

A complete range of shades is readily attainable on PE fibers with disperse dyes, including the developed disperse dyes. These dyes possess satisfactory all-around fastness properties, in many cases equalling the fastness of vat dyes on cotton. The fastness requirements of dyes for PE fibers are strict. The dyeings must be fast to hot soaping, perspiration, light, dry cleaning, and sublimation. The sublimation fastness is demanded because fabrics of PE or blends containing PE are often pleated at high temperatures. This is especially important today with so many fabrics being given "permanent press."

47. Special dyeing techniques are necessary to increase the normally low dye-absorption rate of PE to a level satisfactory for mill operation. Three methods are used to achieve this objective:

1. Dyeing in conventional equipment, using a carrier, or accelerant, to increase the rate of dye penetration into the fiber. This method can be used to dye PE in all its forms.
2. Pressure dyeing without a carrier. Yarns in package form, raw stock in pressurized machines, and piece goods in the Burlington Hy-Press beam-dyeing machine can be dyed at temperatures of 240 F to 250 F.
3. Thermosol dyeing. The Thermosol method is a patented process invented by Du Pont. Fabrics are padded with dye suspensions and dried, and then heat-set to force the dye into the fiber. Usually, temperatures of 400 F to 420 F are used in the heat-setting, for 60 to 90 sec. This method is extensively used for blends of PE with cotton, rayon, or Avril.

The dyeing of PE fibers is similar in principle to the dyeing of acetate and Arnel. Disperse dyes are used in all three instances, the dye actually dissolving into the solid fiber, then becoming anchored into available dye sites. The PE offers much greater resistance to the penetration of the dyestuff than acetate or Arnel does, but once the dyestuff has entered the fiber, it is much more difficult to remove. The energy necessary to effect this penetration is supplied by a carrier or elevated temperatures.

Use of Carrier

48. "Carrier" is a term used for any substance which, when added to the dyebath, causes a marked increase in the rate of dyeing. A wide variety of aromatic organic compounds – that is, compounds having the benzene ring in their structure – have been recommended as carriers. Some products which have been recommended include benzoic acid, salicylic acid, phenol, orthophenylphenol, paraphenylphenol, cresol, biphenyl, phenylmethylcarbinol, mono-, di-, and trichlorobenzene, butyl benzoate, and methyl salicylate. These compounds are rather difficult to handle in the mill, since they are not soluble in water. They must be either emulsified into a water-miscible liquid, or dissolved by chemical means and then reprecipitated in the bath. For this reason, carriers have been made available to the dye houses by chemical manufacturers in a readily usable form, generally as a liquid which can be poured directly into the dyebath. Some of the proprietary carriers are based on one of the chemicals mentioned, whereas others are mixtures of two of them, such as biphenyl and trichlorobenzene or orthophenylphenol, and trichlorobenzene.

49. In selecting the proper carrier for a particular job, the dyer should consider the advantages and disadvantages of the carrier, and balance the efficiency of the carrier against its cost. Some of the advantages and disadvantages of the chemicals used in preparing the carrier follow.

Orthophenylphenol is very effective. It is a solid, which means that even though it is sold as a liquid emulsion, it is absorbed by the PE fiber, where it remains as a solid after dyeing. It must be removed after the dyeing operation by a thorough scouring of the fiber or fabric; otherwise, its presence tends to reduce the light fastness of the dyeings. It is moderately priced.

Paraphenylphenol is similar to orthophenylphenol, but degrades light fastness still more, and is therefore not recommended in dyeing.

Biphenyl, also called diphenyl, is very effective, and cheaper than orthophenylphenol. It is a solid, but does not degrade the light fastness of dyeings. Biphenyl is difficult to emulsify into a liquid, and is generally found associated with trichlorobenzene in proprietary carriers.

Trichlorobenzene is a liquid which is easily emulsified, and once on the fiber, vaporizes when the fiber is dried. It is cheap and has no effect on light fastness. Although it is very effective as a carrier, its vapors are toxic.

Methyl salicylate is a liquid, easily emulsified, not expensive, but also not very effective, requiring large amounts for good color yield. Its vapors are not toxic, and it has no effect on light fastness.

Butyl benzoate is a rather inexpensive liquid with no toxicity or effect on light fastness. It is less effective than biphenyl, and finds use in dyeing Arnel.

Latyl Carrier A (Du Pont) is a mixture of methyl terephthalate and benzanilid. It is rather expensive, has no effect on light fastness, and is easily removed after dyeing. Some proprietary carriers have been especially prepared for use in particular dyehouse operations. For example, to achieve level light shades, Latyl Carrier A is recommended. For dyeing PE fibers on the jig, Carolid ELFC is recommended, as it is effective at temperatures under the boil. Sometimes a small amount of carrier is added to the bath in pressure-dyeing equipment; in such cases, Cindet Carrier 888 or Marnel 82 would be recommended.

Some PE fiber constructions have a tendency to shrink where carriers of highest effectiveness are used. This may be noticed in tricot dyeing. For such dyebaths, Cyanatex Dyeing Assistant EM or Latyl Carrier A may be preferred.

Procedure for Carrier Dyeing

50. The materials must be scoured well so that it wets out uniformly and permits full penetration of the dyestuffs. Waxes and oils used in spinning PE fibers require a solvent scour for their removal. Two suggested scouring procedures are as follows:

1. I gram Igepal, 2 grams caustic soda, and 4 cc (cubic centimeters) Varsol #2 per liter of water. Scour 30 min at 190 F and rinse well.
2. Add 3 grams Amascour MS or other solvent mill scour and 1 gram caustic soda per liter of water. Scour 30 min at 190 F and rinse well.

In the case of PE-cotton blends, it is necessary to remove starches with an enzyme before proceeding with the scour.

For beck dyeing or jig dyeing of piece goods, or for yarn dyeing in hanks, open equipment can be used with a carrier to aid in the exhaust of the dyestuff. The selected disperse dyes are prepared for the dyebath by dispersing the powder into warm water (140 F to 160 F) under agitation. Many manufacturers are offering past-form dyes which require only to be diluted with water.

The dyebath is set at about 130 F and the carrier is added. The amount to use is more accurately figured as a concentration based on the volume of the bath rather than as a percentage of the material. For beck dyeing, 5 grams of carrier per liter is recommended; for skein dyeing, 5 grams per liter; for yarn dyeing in package machine, 3 grams per liter; and for jig dyeing, 12 to 14 grams per liter. The material is run for 10 min at 130 F with the carrier; then the dye dispersion is strained into the bath, the temperature is raised to 205 F to 210 F over 30 min, and dyeing is continued for 1 hr to 2 hr, or until the desired shade is reached.

After dyeing, the PE material must be scoured to remove the carrier and loosely adhering dye, and in the case of fiber blends, to clear the other fiber. For this purpose, a good synthetic detergent with soda ash added is used, with temperatures up to 200 F for 15 min.

High-Temperature Dyeing

51. It is well known that temperature is a very important factor in increasing

the rate of diffusion of dye into a fiber. Dyeing occurs in three stages, which may be considered in equilibrium with each other as follows:

$$\text{Dye in solution} \rightleftarrows \text{dye on fiber surface} \rightleftarrows \text{dye in fiber}$$

The higher the temperature, the greater the tendency to shift the equilibrium to the right, with resultant exhaustion of the dyebath and more rapid dyeing of the fiber. At elevated temperatures, the dyeing is made somewhat easier because the fiber then offers a more open structure through which the dyes can more readily diffuse.

Dyeing at temperatures above the boil has become an established commercial operation. Dyeings of better color yield and fastness properties, savings in time and chemicals, and better lot-to-lot reproducibility in comparison with carrier dyeings can be realized.

A typical procedure for high-temperature, or pressure, dyeing with disperse dyes would be as follows:

Set the bath at 130 F with

0.25 gram per liter Alkanol HCS and

x% disperse dyes previously pasted with Avitone T.

Raise the temperature to the boil in 20 to 30 min.

Add acetic acid slowly to lower the *p*H to about 4.0.

Close the machine and raise the temperature to 250 F in about 30 min.

Dye from 1 hr to 2 hr, depending on the depth of shade desired.

Cool and rinse by overflowing.

Scour for 15 min at 180 F with Duponol RA surface-active agent.

In this procedure, the scouring can be done with sodium hydroxide and hydrosulfite to obtain maximum fastness on dark shades.

Proper dye selection for pressure dyeing is very important, because such factors as stability, tarring properties, exhaust rates, and transfer properties must be considered.

The Thermosol Process

52. The Thermosol Process, developed by Du Pont, presents another example of the use of elevated temperatures to promote rapid diffusion of dye into the fiber. In this process the dye is placed mechanically on the surface of the fiber by padding and drying. A brief exposure of the dye-coated fiber to rather high temperatures (about 400 F) effects diffusion of the dye into the fiber. The process, which is applicable to many of the newer fibers as well as to PE, offers numerous advantages: The process is continuous, it requires no carrier, it handles fabrics in open width, it shows excellent dye-fixation efficiency (75% to 90%), it permits dyeing and heat-setting to be done at the same time, and it gives results which are independent of previous heat-setting experience of the fabric. The

Thermosol dyeing process is an important factor in the development of the popular blends of cotton and PE.

For Thermosol dyeing, the pad bath is prepared by pasting the required amount of dye with about 7.5 grams per liter Compound No. 8-S or Avitone T softener with hot water, and then dispersing with about half the desired volume of water to be used. To avoid specking, this dispersion is then screened or passed through a colloid mill. A thickner – Keltex, Superclear Gum, Du Pont Sodium CMC, or the like – is added as a solution to improve the smoothness of paddings and to control migration in drying. A surface-active agent, such as Alkanol WXN, at about 2 to 2.5 grams per liter, is then added and the liquor is made to final volume with water. The fabric is padded at 120 F to 130 F and dried at about 275 F. Because migration can occur in drying, the heat must be applied uniformly to both sides of the fabric. The Thermosol treatment, or heat-fixation step, is accomplished in 90 sec (seconds) at 390 F to 410 F in a roller-type oven, or it may be done more rapidly at higher temperatures in radiant-heat units. In the heat-fixation step, the goods must be framed to about one inch more than the desired finished width.

Dye selection is important. The dye must be chosen for its color yield, fastness properties, and ability to withstand heat. It is apparent that, for best shade control and to prevent equipment contamination during the Thermosol step, only dyes having the minimum vaporization tendency be used.

53. It might be well at this point to define vaporization and sublimation. Both terms describe the same physical action, but at different stages in the dyestuff application.

Vaporization is the tendency of unfixed dyestuff, especially disperse dyes applied to a fabric before fixation, to vaporize, or pass into the vapor phase, on drying or heat curing. Any such vaporized dye will condense on cooler portions of the equipment or goods.

Sublimation is the tendency of dyes, especially disperse dyes, to pass into the vapor phase on any treatment subsequent to their fixation on the fiber. This phenomenon gives rise to staining of any fiber or cloth in contact with the dyed fiber on pleating, ironing, or even on storage.

Developed Dyes

54. Developed dyes, often referred to as azoic dyes or insoluble azo dyes, are often used to produce good blacks, navy blues, and other shades on PE. Dyes of this type are so described because they are actually manufactured, or developed, in the fiber by chemical reactions (diazotization and coupling) involving the dye components which have been applied to the fiber. The insoluble pigments formed in the fiber produce shades that have generally good fastness properties. Developed dyes are also cheaper to use than the direct dyes.

Of particular interest is the developed black shade which is most commonly used on PE. Two steps are involved in its application: 1) the exhaustion of the two components – that is, the base and the developer – onto the fiber either at the same time or separately, depending on the developer and the dyeing temperatures; and 2) the diazotization and the coupling, in which the two components are chemically united to form the insoluble black pigment within the fiber.

Dyeing may be carried out with a carrier, or in the preferred technique, in high-temperature equipment. The two components are Latyl Diazo Black B (C.I. Disperse Black 1) and Naphthol AS-D. They are dispersed in water and added to the bath together.

Because the Naphthol AS-D is so difficult to disperse properly for use in pressure equipment, the two components are marketed together in a convenient paste form, under such names as Amacron Developed Black JB paste or Latyl Black ND paste.

The procedure for dyeing a black on PE fiber is as follows:

Set the bath at 100 F.

Add
3.0% Latyl Diazo Black B
3.0% Naphthol AS-D
or
12.0% Amacron Developed Black JB paste.

Add acetic acid to bring the pH to 6.0, which should be less than 1.0% on the weight of the material.

Raise the temperature to 235 F to 250 F.

Dye for 60 to 90 min.

Rinse well.

Set the bath at 130 F.

Add
4.0% sodium nitrate
4.0% sulfuric acid

Raise the temperature to 190 F, and hold for 30 min.

Rinse.

Scour for 15 min with
0.5 gram per liter caustic soda
0.5 gram per liter sodium hydrosulfite and a detergent.

Rinse.

55. In Table 6 are listed some characteristic dyes for PE fibers. The listing is broken down into two categories, acid dyes and chrome dyes. The acid dyes have good fastness to sublimation, but may stain wool in PE-wool blends; the chrome dyes stain wool only lightly, but may not possess good fastness to sublimation.

TABLE 6

DYES FOR POLYESTER FIBERS

Dyestuff	C. I. Name
Good Fastness to Sublimation	
	DISPERSE
Latyl Yellow YLW	Yellow 42
Amacron Orange LS	Orange 5
Amacron Orange SF	Orange 29
Latyl Scarlet FSW	Red 56
Eastman Fast Blue B-GLF	Blue 27
Latyl Brilliant Blue BG	Blue 60
Amacron Blue RLS	Blue 70
Eastman Polyester Red B	. . .
Eastman Polyester Brilliant Pink B-LSW	. . .
Eastman Polyester Brilliant Red 2B-LSW	. . .
Eastman Polyester Brilliant Rubine R-LSW	. . .
Eastman Polyester Blue 2G-LSW	. . .
Latyl Yellow GFS	. . .
Low Stain on Wool	
	DISPERSE
Latyl Yellow 3G	Yellow 54
Cibacete Brilliant Pink FG	Red 55
Amacron Red BM	Red 60
Eastman Polyester Blue 3RL	Blue 64
Genacron Violet BN	Violet 27
Polydye Burnt Orange O	

PE-Cellulosic Blends

56. Polyesters are often blended with cotton, rayon, or Avril, the most common percentages being 50/50 or 65/35. These blends lend themselves to dyeing by the three methods previously outlined, that is, carrier dyeing, pressure dyeing, and Thermosol dyeing.

The PE portion is dyed with disperse dyes, while the cellulosic portion may be dyed with direct, vat, sulfur, or fiber-reactive dyes, or with naphthol combinations.

In the carrier method, the disperse dyes show little cross staining of the cellulose. Any staining that does occur can be cleared, if necessary, after the dyeing of the disperse color. Similarly, in dyeing under pressure, whatever stain accrues to the cellulosic portion may be cleared before the cotton dye is applied. In fact, in dyeing with vat and sulfur dyes, the action of the sodium hydrosulfite which is used to reduce the vat or sulfur color will destroy any stain on the cotton.

57. Generally, PE-cellulosic blend yarn is dyed in pressure equipment. It has been noticed that some protective colloids reduce agglomeration, that is, precipitation of disperse dyes under pressure. However, it is generally agreed that a small addition (1% to 2%) of a mild carrier is most effective in preserving the

brightness of the dyes and assuring maximum color yield. Carriers based on butyl benzoate or methyl salicylate are preferred.

When the cellulosic portion of the blend is to be dyed with direct dyes, these dyes may be applied in the same bath as the disperse dyes. About 10% salt is added at the beginning of the dye cycle, but complete exhaustion of the direct dye at the high temperature of the pressure equipment is impossible. Thus, when pressure is reduced toward the end of the dye cycle, more pickup of the direct color may be anticipated. The most serious disadvantage of applying direct color under pressure is the degrading effect of pressure on the direct color, necessitating a careful choice of dyes which are stable.

58. Another widely used method of dyeing PE-cellulosic blends is with disperse and vat colors. Here again the bath conditions are not favorable for applying both disperse and vat colors at the same time, particularly in heavy shades. In dyeing under pressure, vat colors are apt to agglomerate, and tend to filter out on portions of the package. It is, therefore, preferable to dye the PE portion first with the disperse color under pressure, and then to reduce the temperature and dye with the vat color. Many of the lighter shades, however, have been successfully dyed by applying the disperse dye and the vat color at the same time, particularly if precautions are taken to add an anionic surfactant to the dyebath, a surfactant which will not subsequently act as a retarder in reduction of the vat color. Addition of a small amount of such a dispersing agent will be found helpful in preventing agglomeration of the vat color under pressure; the dispersing agent will act as a leveling agent rather than as a retarding agent when the vat color is brought under reduction. Some manufacturers have marketed for such purposes proprietary mixtures of vat and disperse colors, such as Kaline (American Aniline), Dekatyl (Du Pont), and Astracel (General Dyestuff).

59. Disperse-sulfur color combinations are applied in two baths. Similarly, when naphthols are used to color the cellulosic portion, they are applied after the disperse colors are fixed. Naturally, not all such blends are dyed in pressure equipment. Package dyeing is effectively carried out when the PE portion is dyed with disperse color, using a carrier. In such cases, all of the problems resulting from the effect of pressure on the direct and vat colors are absent. However, there remains the problem of removing the carrier, which in the case of disperse-direct color mixtures is difficult after the direct color has been applied. It is, therefore, preferable to dye the PE first, scour well to remove the carrier, and then apply the direct color.

Dyeing PE-Cotton Blends by Pad-Thermosol Method

60. At the present time, the majority of PE-cellulosic blend fabrics are dyed by the pad-Thermosol method. In this method the cellulosic portion is stained considerably more than in the carrier or pressure-dyeing methods. If the fabric is to be dyed with the cellulosic portion reserved white, it is necessary to clear

the bath. To do this, a hot scouring is necessary, and it is advisable in many cases to give a treatment with 1% soda ash and 1% sodium hydrosulfite at 160 F to destroy any dye which stains the cotton.

Dyestuffs used for solid shades are disperse colors for the PE portion, and vat or fiber-reactive dyes for the cellulosic portion. Temperatures used in the curing are in the range of 400 F to 430 F, and curing time is from 60 to 90 sec. At this high temperature the fixation of the disperse dye on the PE occurs almost instantaneously. Because of this, many dye houses are using contact heat-setting equipment instead of the cure ovens. Exposure time on the heating elements is only 10 to 15 sec, and faster speeds can be maintained. For most disperse dyes, such a short time is sufficient to fix the dye which is directly attached to the PE fiber, but does not allow for the migration of the disperse dye absorbed by the cellulosic fiber. When a padding is made of PE-cotton with a mixture of disperse and vat dyes and dried, the cotton portion absorbs more than 65% of the available dye used. After Thermosoling, however, 90% of the disperse dye is fixed on the PE portion. This means that a considerable amount of the disperse dye which is on the cellulosic portion is able to migrate over to the PE during Thermosoling. Since this migration takes some seconds and is clearly a function of the time in Thermosoling, the best results are obtained by using a cure oven with a duration time of 60 to 90 sec. The phenomenon is recognized, and some mills are using a combination of the contact heat-setting roller with a cure oven.

61. In dyeing PE-cellulosic blend fabrics with disperse and vat dyes, the procedure is as follows: The disperse dye is mixed with the vat dye paste, a small amount of Keltex gum being used as thickener, and the mixture is then padded on the fabric and dried. The exact amount of each dye to obtain the desired shade and a good union on the two fibers is determined by trial. In making these trials it should be remembered that it is not possible to take a formula for shade on 100% PE and a similar formula for shade on 100% cotton and combine them. The reason for this is that the vat dyes also have a definite affinity for the PE portion and will stain it considerably during Thermosoling. Since the shade obtained on the PE is very often different from that which is produced on the cotton, it is necessary to conduct these trials and examine each portion of the blend to see that a union is being produced. After the fabric has been padded and dried, it is passed through the Thermosol unit, during which time the PE portion is dyed. Now the goods must be treated to fix the vat dyestuff on the cellulosic portion. This is generally accomplished by the pad-steam method, which has been described under cotton dyeing. The fabric is padded with a solution of caustic soda and sodium hydrosulfite, consisting of about 6 oz each per gallon, and is immediately aged in an air-free ager for 30 to 45 sec. The cloth is then treated with an oxidizing agent, such as a weak solution of sodium bichromate or sodium perborate, rinsed, soaped hot, and rinsed again. This combination procedure is not possible for disperse and sulfur color dyeing. In

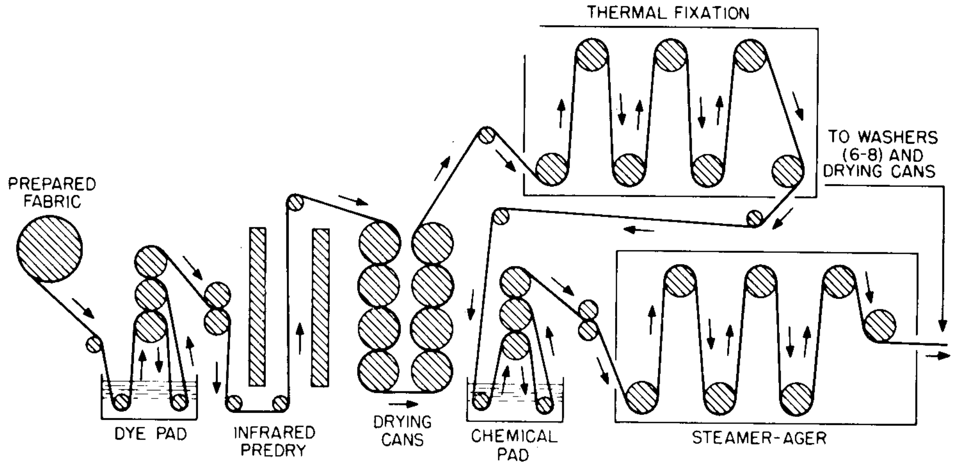


FIG. 4. DISPERSE-VAT DYE APPLICATION TO PE-COTTON BLENDS

such cases, the PE portion is dyed first by the usual Thermosol method and the cloth is again padded with the sulfur dyestuff, suitably reduced, and finally washed.

The arrangement for a disperse–vat-dye application to PE-cotton blends is shown schematically in Fig. 4.

62. PE-cotton blends may also be dyed with disperse and fiber-reactive dyes. Since both types of dyes lend themselves to continuous dyeing techniques on their appropriate fibers, simultoneous application of the two classes of dyes is made on the blend. The disperse dye is suitably dispersed into a pad liquor and the fiber-reactive dye is dissolved and added to the liquor. A mild alkali, such as sodium bicarbonate, is added to fix the fiber-reactive color. After the cloth has been padded and dried, the goods are Thermosoled, to fix both the disperse and fiber-reactive colors. It is a well-known fact that the presence of a strong alkali in the pad liquor will seriously dull and weaken the shade of a disperse dye on the PE. Therefore, it is advisable to choose the type of fiber-reactive dye which can be effectively fixed with a mild alkali.

Orlon Dyeing

63. Since the introduction in 1948 of Orlon, Du Pont's acrylic staple fiber, tremendous improvements have been made both in the fiber itself and in the methods by which it may be dyed. This fiber became fully commercial in 1950 as Type 41 in staple form and Type 81 in filament form. Both types were very hard to dye with acid-type dyes applied by the cuprous ion method. Today there are many types of Orlon which, because of intensive fiber research, are relatively easy to dye with several classes of dyestuffs.

Important physical properties of Orlon include very good weatherability, chemical inertness, resistance to moths and mildew, good, durable whiteness, moderate tensile strength, and a soft, luxurious hand.

Orlon is currently available in Types 42, 72, and 75, all of which are dyeable with cationic and basic dyes in a full range of bright shades, and with disperse dyes in light and medium shades. Types 28, 29, and 44 are dyeable with acid dyes, disperse dyes, and, to some extent, basic and cationic dyes. The development of processes for making high-bulk yarns of Orlon, for dyeing tow to obtain colored yarn which can be bulked by a steaming operation, and for dyeing skeins to obtain colored high-bulk yarns has contributed much to the success of Orlon in the knitwear field.

Orlon in the form of raw stock, tow, top, yarn, skeins, and piece goods can be satisfactorily dyed to a full range of shades. Blends of Orlon with wool, with the cellulosic fibers, or with other man-made fibers in the form of yarn and woven or knit fabrics, can be dyed in solid or contrasting shades.

Cationic and Basic Dyes

64. Cationic and selected basic dyes are by far the most popular dyes for Orlon Types 42, 72, and 75, because of their brilliance and fastness properties, ease of application, and completeness of range of shades. Disperse dyes are often used for pastel colors.

The dyeing of Orlon with cationic dyes proceeds in three stages: 1) absorption of dye on the fabric surface, 2) diffusion into the fiber, and 3) anchoring the dye by formation of the dye-fiber bond. A high dyebath temperature is required to force the dyestuff through the fiber to the dye sites to which it must be bonded. At temperatures up to about 180 F there is little penetration of the dye through the fiber, but at 190 F the penetration is rapid, and if retarders were not used to slow the abrupt action, uneven dyeings would be apt to result. The acid condition present in the dyebath promotes the fixation of the dye after it has penetrated the fiber.

Acrylic fibers become slightly plastic at the temperature of the dyebath. After any acrylic fiber has been dyed, whether it be raw stock, yarn, knitwear, or piece goods, the dyebath temperature must be lowered slowly, first to 180 F by natural cooling, then to 160 F by running in fresh water gradually. Only by following these precautions, which apply to all wet treatments above 180 F, can soft fabrics free from cracks and creases be obtained.

Use of Retarders

65. Because of Orlon's affinity for cationic dyes, a retarding agent, such as Du Pont Retarder LAN, should be used to slow the rate of dyeing to assure level and uniform application, especially in the light and medium shades. The lighter the shade desired, the more retarder is needed. Pastel shades, that is, shades requiring less than 0.1% of dye, require 5% retarder; light shades, up to 1% of dye, require 3% to 4% retarder; and medium shades, up to 3% of dye, require 2% retarder.

When Orlon is dyed in packages, high temperatures and pressures can be used without a retarder. Temperatures can be raised to 220 F to 230 F. Deep shades

TABLE 7

CATIONIC DYES FOR ACRYLIC FIBERS

Dyestuff	C. I. Name
	BASIC
Genacryl Yellow 4G	Yellow 11
Maxilon Orange GA	Orange 21
Genacryl Pink G	Red 13
Sevron Brilliant Red 4G	Red 14
Sevron Red GL	Red 18
Sevron Blue B	Blue 21
Sevron Brilliant Red 3B	Violet 15

can thus be dyed on yarns or raw stock. When high temperatures are used, a relatively high rate of flow of the dye liquor through the material is required.

Cationic dyes require care in dissolving. They are best dissolved with the aid of a small amount of acetic acid. Since they will be used in an acid bath, the acid used in bringing them into solution poses no problem. Table 7 lists some typical cationic dyes used for Orlon and other similar acrylic fibers.

Importance of Temperature

66. Temperature plays an important part in the rate of exhaustion of cationic dyes on Orlon. This is clearly shown in Fig. 5. After a 20-min dyeing time in the application of Sevron Blue B, a 6-deg (degree) temperature rise – from 200 F to

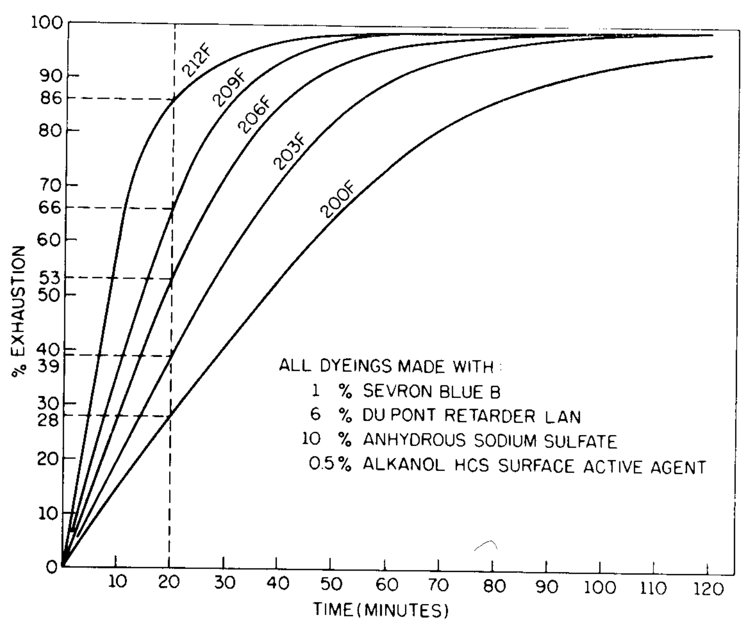


FIG. 5. EFFECT OF TEMPERATURE ON RATE OF EXHAUSTION OF CATIONIC DYES ON ORLON

206 F – almost doubles the rate of exhaustion – from 28% to 53% – whereas at 212 F, in the same period of time, the rate of exhaustion is more than tripled, increasing from 28% to 86%.

Increasing the amount of retarder used at any given temperature has an effect on the rate of exhaustion similar to that obtained by lowering the dyeing temperature. Therefore, the dyer should carefully consider the temperature and the dyes to be used before deciding how much retarder he will need to use to obtain the best results. When retarder is used, the dyebaths can be heated rapidly to 180 F to 190 F, because little exhaustion occurs at this temperature. However, from 190 F to the boil, a slow rate of rise in the temperature is desirable to assure maximum levelness. Some mills having good temperature control obtain good levelness by using considerably less retarding agent and slowly raising the temperature to 205 F to 208 F over a period of 45 to 60 min. A final boiling for 15 to 30 min is then necessary to develop the true shade and the fastness properties of the cationic dyes. A *p*H of 4.5 to 5.5 is also required in order to reproduce true shades, because some dyes may show a change in shade below *p*H 4.0, while others are not stable at or above *p*H 7.0.

67. A recommended dyeing procedure for Orlon on a package machine without a retarder is as follows:

Run inside out all the way.

Add, as machine fills at 160 F,
  0.5% Igepal

Start pump and add
  1.0% acetic acid 56%
  5.0% Glauber's salt

Run 5 min. Add cationic dye properly dissolved over 5 min.

Run 10 min. Raise to 195 F at 1.5 deg per min.

Run 10 min. Raise to 205 F at 1 deg per min. Run 30 min.

Put under pressure and raise to 225 F. Run 20 min.

Cool slowly to 180 F. Unseal. Sample. Continue cooling to 160 F. Do not drop. Running wash to 100 F.

Drop and soften.

In this case the Glauber's salt is acting as a retarder.

Disperse Dyes

68. Good fastness and ready application properties make selected disperse dyes very useful for dyeing Orlon. Limited build-up properties, however, limit the use of these dyes to light shades.

Disperse dyes, which show excellent leveling and transfer properties, are applied to Orlon from a bath containing about 0.5% of a detergent, such as

TABLE 8

DISPERSE DYES FOR ACRYLIC FIBERS

Dyestuff	C. I. Name
	DISPERSE
Artisil Yellow G	Yellow 3
Eastman Orange GRN Conc.	Orange 3
Celliton Fast Pink RF	Red 4
Amacel Cerise B Ex.	Red 11
Amacel Fast Pink G	Red 66
Hisperse Violet RRH	Violet 1
Amacel Pure Blue B Ex.	Blue 1
Celliton Fast Blue Green BA	Blue 7
Celliton Fast Black BTNA	. . .

Duponol RA surface-active agent. The dyes are first pasted with a suitable wetting agent, stirred into hot water, and then added to the dyebath. Dyeing is carried out at the boil for 1 to 2 hr. Commercial dyeings with these dyes are usually trouble free. Some typical disperse dyes suitable for dyeing Orlon and other acrylic fibers are listed in Table 8.

Creslan Dyeing

69. Creslan is an acrylic fiber manufactured by American Cyanamid Company. The original type, Creslan 58, is dyeable with disperse, cationic, and acid dyes. Disperse dyes have only fair buildup and moderate fastness properties. Cationic dyes have fair buildup and light fastness and good wash fastness. Neutral premetalized, acid premetalized, and chrome dyes have good buildup and good fastness to light.

A new type, Creslan 61, is manufactured particularly for the knitwear trade. It is a good white fiber with dyeing characteristics similar to those of Orlon 42 or 75. The most important dyes for this fiber are the cationics, that is, the basic dyes recommended for Orlon, which are listed in Table 7. Again, as with Orlon, disperse dyes can be used for pastel colors.

Acrilan Dyeing

70. Acrilan is an acrylic fiber manufacturer by Chemstrand Corporation. This solvent-spun acrylon nitrile polymer exhibits interesting versatility, both in end uses and in the number of dye classes for which it has affinity. It is a woollike fiber having good bulking power, wrinkle recovery, warmth, and fullness of hand, and finds a wide range of applications from suitings and shirt fabrics to carpets.

The first type to be marketed was Acrilan 1656, sometimes called Acrilan regular. This type is dyeable with disperse, acid, neutral, acid-prementalized, and chrome dyes, and, to some extent, with cationic dyes. Acrilan 41 is manufactured especially for carpets, whether tufted, woven, or knitted. Its dyeing characteristics are similar to those of Acrilan 1656. Acrilan 16 is designed for dyeing with cationic dyes, and thus more closely approaches Orlon 42 in its dyeability. It has no affinity for acid dyes.

Dyeing Acrilan 1656 or 41

71. Cationic and other basic dyes are usually selected when brightness of shade is of primary importance. These dyes exhaust more slowly on Acrilan than on Orlon, and therefore retarding agents are not required.

Set the bath with
- 0.5% Igepal
- 3.0% urea
- 5.0% Glauber's salt

Dissolve the dye with the aid of a little methyl alcohol or acetic acid, and add to the bath.

Heat to 210 F for 15 to 20 min.

Run 1 hr to 1½ hr at 210 F, and sample.

Cool slowly to 160 F.

Rinse.

Scour at 140 F with
- 1.0% Igepal
- 0.5% tetrasodium pyrophosphate

Rinse.

Acid dyes will build to deep shades, and so are preferred for navy, black, deep reds, and browns.

Set the bath with
- 1.0% Palatine Fast Salt O
- 6.0% sulfuric acid
- 10.0% Glauber's salt

Add previously dissolved dye.

Run 10 min at 180 F.

Heat to 210 F for 30 min, and run 90 min at 210 F.

Cool slowly to 160 F.

Rinse.

Scour as previously explained.

72. Acid premetalized dyes are suitable for dyeing Acrilan in medium and dark shades. Dyeing is carried out in a strongly acid bath.

Prepare the bath with
- 2.0% Cibalan Salt S
- 8.0% sulfuric acid
- 10.0% Glauber's salt

Start dyeing at 120 F.

Raise temperature to the boil in 40 min, and keep at the boil for 1 hr to 1½ hr.

TABLE 9

DYES FOR ACRILAN 41 AND 1656

Dyestuff	C. I. Name
Cationic Dyes	
	BASIC
Sevron Yellow 3RL	Yellow 15
Sevron Red GL	Red 18
Genacryl Blue RGL	. . .
Acid Dyes	
	ACID
Xylene Light Yellow 2G	Yellow 17
Neolan Orange GRE	Orange 62
Calcofast Orange YF	Orange 69
Neolan Red GRE Conc.	Red 183
Chromolan Red 3RB	Red 207
Anthraquinone Blue SWF	Blue 25
Alizarine Light Blue B	Blue 45

Cool gradually and rinse well.

Soap off with Igepal or other nonionic detergent.

Neutral premetalized dyes have a low saturation value on Acrilan. The color yield can be improved by dyeing under pressure.

Dyes suitable for dyeing Acrilan 1656 and 41 are listed in Table 9.

Disperse Dyes on Acrilan

73. Selected disperse dyes are used on Acrilan for all shades ranging from pastels to black. Although not sufficiently fast to light to be used for carpet yarn or stock, disperse dyes find application for apparel, especially black. The black is developed on the fiber by simultaneous dyeing of the base, such as Amacel Black 4S Extra, and a naphthol, usually Naphthol AS-D, then diazotizing and coupling in a bath with sodium nitrite and hydrochloric acid.

Set the bath at 90 F to 100 F with a 0.5% anionic surfactant.

Add 3.0% Amacel Black 4S Extra.

Add 3.0% Naphthol AS-D dispersed in water.

Circulate 10 min.

Add 2.0% acetic acid.

Raise temperature to 205 F to 210 F, and dye for 60 to 90 min.

If pressure equipment is available, dye under pressure at 235 F to 240 F.

Cool gradually to 140 F.

Rinse well.

Diazotize for 30 min at 190 F with

4.0% sodium nitrite

8.0% formic acid

TABLE 10

DYES FOR CROSS-DYE EFFECTS ON ACRILAN 16 AND 41

Dyestuff	C. I. Name
Cationic Dyes	
	BASIC
Sevron Brilliant Red 4G	Red 14
Sevron Red GL	Red 18
Acid Dyes	
	ACID
Calcofast Orange YF	Orange 69
Alizarine Light Blue B	Blue 45
Chromolan Red 3RB	Red 207

Cool gradually, and then rinse.

Scour with

0.5% soda ash

1.0% sodium hydrosulfite

Rinse well.

Acrilan 41–Acrilan 16 Mixtures

74. When Acrilan 41 and Acrilan 16 yarns are plied together, interesting color effects can be created.

In a bath set with 3% formic acid, Type 16 yarn can be dyed with selected cationic dyes, and Type 41 left undyed. The dyes selected must be insensitive to acid and must leave the Type 41 yarn unstained. Suitable dyes are listed in Table 10.

To obtain two-color cross-dyes, cationic dyes are selected for Type 16 yarn and acid dyes for Type 41 yarn. The dyebath is set with 4% to 6% sulfuric acid. Acid dyes are selected on the basis of high light fastness. Dyes suitable for this method are listed in Table 10.

Tone-on-tone effects are also possible. If the two types of yarns are dyed with cationic dyes with 3% urea in the bath, Type 16 will absorb 75% of the dye and Type 41 only 25%. Most cationic dyes are suitable for this tone-on-tone method.

Modacrylic Dyeing

75. "Modacrylic" means modified acrylic. Verel is a modacrylic fiber. Dynel is a copolymer of 60% vinyl chloride and 40% acrylonitrile. Zefran is an acrylonitrile-vinylidene chloride fiber.

Dynel, manufactured by Union Carbide, comes in three types: Type 60, or normal; Type 63, or high-bulk; and Type 97 for the carpet industry. In the production of this fiber, the copolymer is dissolved in acetone and spun in much the same way as acetate in tow form; it is then cut into staple as desired. This fiber exhibits a high degree of chemical inertness, dimensional stability, nonflammability, and moth resistance. Dynel also shows good wet and dry strength, resiliency, softness and warmth of hand, and drapeability. The uses for Dynel are many and varied: blankets, draperies, industrial fabrics, protective and work clothing, and high-pile fabrics for coatings and trim (synthetic fur coats and collars, for example, either as 100% Dynel or blended with Orlon acrylic fibe-` Novel uses include doll wigs, paint-roller covers, and synthetic-straw hats.

Dynel can be dyed with disperse dyes, neutral-dyeing metalized dyes, selected neutral acid dyes, and certain cationic dyes. Dyeing temperatures at or near the boil are generally required in order to make practical use of the dyes. Delustering of the fiber takes place in dyeing; thus all dyeings on Dynel must be relustered afterward to provide best appearance and fastness characteristics. Relustering is accomplished by any one of three methods: 1) dry heat, 5 to 10 min at 240 F; 2) steaming, 2 to 5 min at 40 to 60 lb pressure; and 3) boiling about 15 min in a 25% Glauber's salt solution. The third method is useful mainly with yarn and raw stock. Dynel is a thermoplastic fiber, and after hot, wet processing must be carefully cooled to avoid setting creases and wrinkles.

76. Dynel shows good affinity for practically all disperse dyes, but only selected members of this class have good fastness properties on the fiber. The dyes should be well dispersed, but a minimum of dispersing agent should be used in order to avoid reducing the affinity of the dye. The dispersed dye is then added to the dyebath and the temperature is gradually brought to the boil. Dyeing temperatures as low as 190 F can be used, but better tinctorial value is generally obtained at or near the boil.

Selected neutral-dyeing premetalized dyes are readily applicable to Dynel to produce light-to-medium shades. Although the affinity of the fiber for these dyes is strong, dyeing temperatures near the boil are required for best results. Deeper shades can be made, using 3 to 5 grams per liter Latyl Carrier A or 2% to 3% on fiber weight of DSP-112, a recently introduced dyeing assistant which functions as a carrier, or swelling agent, for Dynel.

Although many cationic dyes can be applied to Dynel by the same methods used for applying them to Orlon, the light-fastness properties of these dyes are generally on the poor side. To increase the tinctorial value of cationic dyes on Dynel, 1% to 2% of an anionic agent, such as Duponol D paste surface-active agent, and 1% to 2% of a nonionic surface-active agent, such as Alkanol HCS, should be added slowly after the bath has been at the boil for 30 to 60 min. The use of 5 grams per liter Latyl Carrier A also achieves the same results.

77. Light-to-medium shades are readily available on Dynel with selected neutral-dyeing acid dyes applied with the assistance of DSP-112. Heavy shades, however, require the use of the cuprous ion technique which was developed for this fiber.

In this technique, the bath is set with the required dye and about 0.1% sulfuric acid to give a pH of 6.5, and the temperature is raised to the boil. Dyeing

TABLE 11

DYES FOR DYNEL AND VEREL

Dyestuff	C. I. Name
Disperse Dyes	
	DISPERSE
Setacyl Yellow G	Yellow 3
Latyl Yellow 4RL	Yellow 23
Amacel Orange GR	Orange 3
Acetamine Rubine B	Red 13
Celliton Fast Brown 5RA	Red 32
Celanthrene Pure Blue BRS	Blue 1
Neutral Premetalized Dyes	
	ACID
Calcofast Neutral Yellow G	Yellow 151
Nyalan Orange R	Orange 60
Capracyl Red BB	Red 178
Capracyl Blue G	Blue 165
Cationic Dyes	
	BASIC
Genacryl Yellow 5GF	Yellow 13
Astrazon Brilliant Red 4G	Red 14
Maxilon Blue 2GB	Blue 22
Acid Dyes	
	ACID
Supramine Yellow RA	Yellow 25
Milling Yellow H5GA	Yellow 44
Supranol Red PBX	Red 114
Pontacyl Fast Black N2B	Black 26A
Alizarine Sky Blue B	Blue 78
Wool Fast Blue GL	Blue 102

is then effected by slowly adding a reduced copper solution over a 20-min period. The reduced copper solution is prepared by mixing, just prior to use, 1% copper sulfate, on the weight of the fabric, dissolved in a small amount of warm water, and 0.4% zinc formaldehyde sulfoxylate, on the weight of the fabric, dissolved separately in a small volume of lukewarm water.

Dyes for Dynel and Verel

78. Some characteristic dyes used to dye Dynel and Verel are listed in Table 11. There are, of course, many other dyes available which can be used to dye these fibers.

Zefran Dyeing

79. Zefran, a nitrile alloy fiber manufactured by Dow Chemical Company, is probably the most dyeable synthetic fiber. It has an affinity for virtually all common types of dyes; this affinity is due in part to its high moisture-regain property. Based on light- and wash-fastness performance, however, it is likely that neutral-

dyeing and acid-dyeing metalized, direct (copper-aftertreated), vat and azoic dyes will find greatest use on this fiber. Other types of dyes may be used when such factors as shade brightness are the primary consideration. Continuous dyeing of Zefran with vat dyes by pad-steam procedures is feasible.

Metalized dyes provide good-to-excellent light fastness and good wash fastness. The acid-dyeing metalized types are applied at the boil with 8% sulfuric acid. The neutral-dyeing types require 5% ammonium acetate and 2% acetic acid (56% concentration).

Direct dyes are best applied with 15% common salt; the dyeings are then aftertreated with 2% of a coppered fixing agent. Selected direct dyes have good light and wash fastness.

80. Vat dyes can be applied by either of two conventional procedures: the reduced method and the pigment pad-chemical pad-steam method. When vat dyes are applied by the reduced method, the usual procedures for cotton are followed, but the bath should not contain more than 5 grams per liter sodium hydroxide. Yellowing of the fiber, which is not fast to light, is caused by excessive caustic.

Good results have been obtained by applying vat dyes continuously by the pigment pad-chemical pad-steam method. Blends of Zefran with cotton or with rayon are also dyed satisfactorily by this procedure.

Azoic dyes are applied from a bath containing a suitable naphthol preparation and not more than 0.25 oz per gallon of sodium hydroxide. The temperature is raised to 160 F, 30% common salt is added, and dyeing is continued for 45 min. After rinsing, the goods are entered into a fresh bath at 80 F, which contains the appropriate fast-color salt or diazotized base. The temperature is then raised to 140 F and dyeing is continued for 30 min. The dyeing is then finished by rinsing, and a 30-min scouring at 170 F with 2% Duponol RA surface-active agent.

Characteristic dyes used to dye Zefran are listed in Table 12.

Dacron 62 and 64

81. Dacrons of the sixties series are polyester fibers which have been modified to accept cationic dyes as well as disperse dyes. Dacron 62 is a filament fiber which lends itself admirably to the fabrication of silklike crepes and taffetas. It may be dyed with disperse dyes, as described for other PE fibers, or with cationic dyes, as described under Orlon. The cloth constructions of Dacron 62 are much more often printed than dyed. Dacron 64 is a staple PE fiber which finds its principal use in PE-wool blends. The dyeing of such blends will be described later.

Rhovyl (Vinyon)

82. Rhovyl is a polyvinylchloride (PVC) fiber made in France by Rhodiaceta. Another PVC fiber is PeCe made in Germany by several manufacturers. The first PVC fiber in this country was called Vinyon.

TABLE 12

DYES FOR ZEFRAN

Dyestuff	C. I. Name
Neutral Premetalized Dyes	
	ACID
Lanamid Yellow GA	Yellow 124
Capracyl Orange R	Orange 60
Supralan Bordeaux NB	Red 182
Capracyl Blue G	Blue 165
Acid Premetalized Dyes	
	ACID
Gycolan Yellow BEL	Yellow 54
Chromacyl Orange GR	Orange 34
Neolan Pink BA Conc.	Red 186
Pharmalan Blue 2G	Blue 158
Palatine Fast Black WANA Conc.	Black 52
Direct Dyes	
	DIRECT
Direct Fast Yellow RL	Yellow 50
Pontamine Fast Red 3BLN	Red 83
Calcodur Blue 2RFL Conc.	Blue 80
Direct Fast Brown BRL	Brown 95
Vat Dyes	
	VAT
Ponsol Brilliant Red Bd Paste	Red 16
Calcoloid Blue GCD Double Paste	Blue 14
Algol Yellow GC Infra Paste	Yellow 2
Indanthrene Brilliant Green B Infra Double Paste	Green 1

PVC fibers are characterized by their resistance to acids, alkalis, oxidizing agents, bacterial degradation, and burning. They have a low melting point, starting to soften at 175 F. Rhovyl 55 and Rhovyl 30 shrink considerably in boiling water. Rhovyl T does not.

Rhovyl can be dyed with disperse colors. The temperature of the bath should not exceed 170 F, although when Rhovyl is blended with other fibers, such as viscose, Avril or cotton, somewhat higher temperatures may be tolerated. Carriers, such as Cindet Carrier AC-9 or Marnel 82, may be necessary to obtain deep shades.

The following is a typical formula for a red shade on a 50/50 Rhovyl-viscose blend of yarn on a package-dyeing machine. The percentages are based on the weight of the yarn.

Scour with 0.5% detergent. Set dyebath with 2% monosodium phosphate and 5% Cindet Carrier AC-9. Run liquor 10 min at 100 F. Add 1.5% Lenra Brilliant Scarlet RF (for the Rhovyl), heat slowly to 170 F, and run 45 min.

Drain, refill at 120 F, and run 10 min.

Drain, refill at 90 F, add 0.5% Avitex AD, 1.5 Procion Scarlet GS, and 1.3%

Procion Red GS (fiber-reactive dyes for the viscose). Run 10 min. Add 50% salt over 20 min, run 20 min, add 10% soda ash over 10 min, and run 30 min. Maintain the temperature at 90 F.

Sample, and when on shade, wash clean.

Saran Dyeing

83. Saran is a copolymer of vinylidene chloride manufactured by The National Plastic Products Company, Lus-Trus Extruded Plastics, Incorporated, the Sunlight Manufacturing Company, and the Saran Yarns Company. The Firestone Industrial Products Company also manufactures this copolymer of vinylidene chloride under the trade name *Velon*. Saran has found extensive use for automobile and outdoor upholstering fabrics. This plastic product has fair resistance to concentrated sulfuric acid and good resistance to all other acids; it is unaffected by most alkalis, with limited resistance to ammonium hydroxide. Saran has generally good resistance to most other chemicals and is insoluble in most organic solvents, but is swelled or softened by oxygen-bearing solvents such as dioxan and cyclohexanone at elevated temperatures. Saran does not support combustion but will melt.

Because of the high resistance of Saran to chemicals and most solvents, it was found that the coloring of Saran was best done, by means of both inorganic and organic pigments, by means of extrusion. Recently, the Saran Yarns Company introduced a fine, crimped Saran staple, which has a limited affinity for disperse dyes. The thoroughly scoured yarn is dyed in a 1-to-20 bath at 200 F for 1 hr, with 0.25% of concentrated nonionic detergent as a dyeing assistant. The finished dyeings are not very fast to light and washing; consequently, the manufacturer is considering pigmentation before extrusion of this type also. This fine staple is being used in combination with wool for carpets. It imparts to the finished carpet a pleasing iridescence, longer life, and a pronounced ease of cleaning.

Olefin Fibers

84. Polyethylene and polypropylene are two fibers being produced commercially by polymerization of olefins. Polyethylene has a low melting point, which precludes its use as a textile fiber. The best method of coloring this fiber is bv adding inorganic or organic pigments to the mass before extrusion.

The melting point of polypropylene, however, is just within the range of usefulness as a textile fiber. Thus polypropylene is finding use in carpeting, draperies, hosiery, and knitwear. Polypropylene fabrics should not be ironed.

85. The dyeing of polypropylene posed a serious problem when the fiber was first introduced. Only oil-soluble dyes were found to penetrate the fiber, and these dyes exhibited poor fastness to washing and dry cleaning because there were no dye sites in the fiber to give them anchorage. It was only when the fiber manufacturers added organic metal salts to the fiber to stabilize it against heat and light degradation that dye sites could be found.

Disperse dyes are oil-soluble dyes which are dispersed in water. The disperse dyes, available for dyeing acetate and polyesters, were tested on polypropylene, but few produced suitable colors. Now research has created new dyes which produce attractive shades having satisfactory fastness properties, with the various metal salts used as fiber stabilizers. This is a new concept in dyeing. Generally, in the dyeing of mordant colors on cotton, the metal mordant is first formed in the fiber; then water-soluble mordant dyestuffs are applied to form a chemical combination with it. The dyes used for metalized polypropylene, however, are not water soluble, but are constructed in such a way that they will react with the metal salt in a mildly acid bath.

The dyes so constructed are known as Koprolene dyes (American Aniline), Olefin dyes (Verona), and Polypropylene dyes (National and Sandoz). They are applied like acetate dyes, that is, in water dispersion in a bath at 180 F to 190 F with 1% acetic acid (50%). After 30 min another 1% acetic acid is added. Dyeing time is generally 1 hr, after which the polypropylene is rinsed.

Most commercial polypropylene is supplied today in spun-dyed colors. Recently, a dyeable polypropylene fiber has been marketed by Union Carbide. The new fiber has affinity for acid dyes and neutral premetalized dyes. Only the neutral premetalized dyes exhibit any degree of wash or light fastness.

Spandex

86. Spandex is the generic name for various stretch fibers. Chemically, spandex is a long-chain polymer of at least 85% polyurethane. The bare fiber, which has high elasticity, is used for nets. It has low tensile strength, so that it is generally spirally wound with a protective covering fiber, such as nylon, cotton, acetate, or rayon. Such fibers are called core spun, and are marketed under such names as Lycra, Vyrene, and Spandelle.

Most dyestuff classes will color the spandex core. Dyeings, however, have poor fastness, especially to dry cleaning, so that in dyeing deep shades on fabrics containing spandex, difficulty may be encountered in customer usage. The dyestuffs having best fastness on the polyurethane filament are the neutral premetalized dyes.

Optical Brighteners

87. Optical brighteners are true dyestuffs. They impart a whitening effect to fibers by reflecting white light in the ultraviolet portion of the spectrum.

The particular optical brightener selected depends upon the fiber to be dyed. Numerous optical brighteners are available for synthetic fibers, as well as for cotton and wool. They are applied to the white fiber after scouring and bleaching. The method of application is generally the same as for a direct-dyeing dyestuff, which means that for cotton the brighteners should be applied with salt, for nylon with a little acid, for PE with a carrier, and for acrylics, acetate, and Arnel, simply by dyeing in a neutral bath. Tables are available from the dyestuff manufacturers recommending the best product to be used for each particular fiber. These brighteners vary considerably in their resistance to light and to bleaching agents, and also in their resistance to high temperatures. A few of the available brighteners are suitable for more than one fiber. For example, Tinopal AN is suitable for nylon and acrylics, while Uvitex EBF is suitable for PE and Arnel.

Dyeing Blends

Fiber Mixtures

88. Because of the development of the man-made fibers, the problem of dyeing mixtures of different fibers has become increasingly difficult. Fabrics containing more than one fiber may be constructed in different ways. A fabric may be woven with one yarn as the warp and a different yarn as the filling. Or yarns made from different fibers may be plied together to form one yarn. In such yarns, the two fibers are distinct enough to be easily recognized as two different fibers, especially when the yarns are dyed different shades. Blended yarns, however, are produced by intimate mixing of the staple fibers together into a yarn in such a close state that it is difficult to distinguish one fiber from the other when they are dyed into shades which are not too dissimilar.

Blends are created to improve the strength of a weaker fiber, to improve other physical properties of the fiber, or to extend an expensive fiber with a cheaper one. Plied yarns and patterned weaves are generally produced to show novelty effects, in which case the two yarns are usually dyed two different shades or colors.

The possible combinations are endless. A yarn blended of two fibers may be woven into a fabric with a yarn made from a third fiber, or from one of the two fibers used in the blend. Fabrics containing three or more different types of fiber are common. In most cases, however, only two fibers are used, and these appear in blended yarns rather than in plied yarns. The successful dyeing of blends is a challenge to the dyer, a challenge requiring a knowledge of the actions of the various groups of dyestuff on each of the fibers present, as well as of their interaction. The dyer may be asked to dye one fiber, leaving the other white, or he may be asked to dye the two fibers in a union. He may even be asked to dye the two fibers in contrasting colors.

Acetate Blends with Cotton, Rayon, or Avril

89. In regard to acetate blends with cotton, rayon, or Avril, the dyer has a simple problem, since the basic fibers have affinities for entirely different classes of dyestuffs. Disperse dyes are used for the acetate portion, while the cellulosic portion is dyed with direct colors, fiber-reactives, sulfurs, naphthols, or vats. In handling acetate blends with cellulosics, it should be borne in mind that acetate is saponified with alkalis at temperatures over 130 F. The amount of alkali used in dyeing sulfur or vat colors is sufficient to saponify acetate to only a slight degree. Actually, a relatively large amount of alkali is required to completely

saponify the acetate. However, if it is desired to keep the acetate white, and an alkali is used in dyeing the cellulosic portion, the temperature must be kep below 130 F.

Nylon and Cellulosic Fibers

90. Dyeing solid shades on nylon-cellulosic blends is relatively easy. Dyein the cellulosic fiber and resisting the nylon is difficult, but dyeing the nylon an resisting the cellulosic is relatively simple. The nylon fiber can be dyed wit neutral premetalized dyes, leaving the cellulosic portion unstained. Also, th nylon may be dyed with disperse dyes, as in the acetate-cellulosic blends.

If it is necessary to dye the cellulosic portion and leave the nylon white, th nylon should be resisted, using a nylon resist agent. Most resist agents are colo less compounds which compete with the dye for the active sites in the nylo fiber, thus in effect dyeing the nylon with a colorless dye. There are many of these products available, and they are similar chemically to synthetic tanning materials. In some cases they are organic compounds used for mothproofing. In the first category are Albatex WS and Mesitol WL. In the second category are Erional NW and Mitin FF. The amount used may vary between 1 to 10 grams per liter, depending upon the degree of resist effect desired.

When nylon-cellulosic blends are dyed with direct colors, both fibers will be dyed, but not necessarily to the same depth. Vat dyes will dye the cellulosic portion and stain the nylon deeply. Naphthols applied according to the method for cotton will not dye the nylon; similarly, naphthols applied according to the method for acetate fibers will not dye the cellulosic portion.

Nylon with Wool

91. Exhaustion of suitable wool dyes on a mixture of nylon and wool would give different distributions, depending upon the origin of the wool, the structure of the nylon, the liquor ratio, the temperature, the *p*H, and the time. Thus the dyeing of such a mixture is a complicated problem, and each particular blend will have to be tested.

The neutral-dyeing acid dyes are normally used to dye nylon-wool blends. These dyes build up well and produce satisfactory unions in light to heavy shades. They have fair to good light fastness and good wet fastness. A typical dyeing procedure would be as follows:

Adjust the *p*H of the bath to 7.5.

Add (based on the weight of the goods)

- 10% Glauber's salt
- 5% to 10% ammonium acetate or ammonium sulfate
- 1% Duponol D paste

Raise to the boil in 1 hr and boil for 1 hr.

Exhaust with 5% to 20% glacial acetic acid.

Many level-dyeing acid dyes are used to dye nylon-wool blends, and they produce a good union in the light to medium shades. Here again the dyer should experiment to determine which dyes will give the desired results. Chrome dyes, as a type, have only fair light fastness. In many cases, blends of nylon and wool are hard to chrome because the wool absorbs too much of the chrome from the bath and thus does not leave enough for the nylon.

Nylon-Orlon Blends

92. Cross-dyed or union effects can be obtained on blends of nylon and Type 42 Orlon. In this case, the nylon is dyed with selected acid or disperse dyes and the Orlon with cationic dyes. A one-bath two-step procedure is used. Du Pont's new Sevron dyes are particularly suitable for this blend because they show very little, if any, stain on the nylon.

For dark shades, the one-bath two-step procedure is as follows:

The bath is set up with a 40-to-1 liquor-to-fabric ratio.

Wet out the fabric.

Add the selected acid dyes and 5% to 10% acetic acid (28% concentration), the amount of acid depending upon the depth of the shade desired.

Raise the temperature to the boil and hold for 45 min.

Cool the bath to 190 F.

Add to the bath
- 0.5% Capracyl leveling salt
- 2% acetic acid (28% concentration)
- 0.3% sodium acetate
- x% cationic dyes

Raise the temperature to the boil and hold for 2½ hr.

Scour with 2% Capracyl leveling salt for 10 min at 140 F.

Rinse the fabric.

For light shades, a one-bath one-step procedure is used. The liquor-to-fabric ratio is again 40 to 1 and the procedure is as follows:

Wet out the fabric.

Add the selected cationic disperse dyes and
- 1% Duponol RA surface-active agent
- 2% acetic acid (28% concentration)
- 0.3% sodium acetate
- 1% to 4% Du Pont Retarder LAN surface-active agent, depending on the depth of shade

Raise the temperature to the boil and dye for 1 hr.

Rinse the fabric.

Nylon-PE Blends

93. Nylon-PE blends present no dyeing problems when the nylon is dyed and the PE is left white. However, to get union shades and cross-dye effects, the dyes must be selected with great care. As a rule, disperse dyes do not produce union shades on 50/50 blends of these two fibers. The choice of carrier can also have a bearing on the results obtained. Some disperse dyes stain the PE heavier than the nylon, while others have the reverse effect. For cross-dye effects or tone-on-tone shades, it is better to dye the nylon more heavily than the PE.

The one-bath dyeing method limits the depth of the shade on the PE because of the staining effect the disperse dyes have on the nylon. Excessive staining of the nylon reduces the fastness properties of the blend and interferes with cross-dyeing. Therefore, it is recommended that the two-bath method be used to dye the PE to medium and heavy shades. For light union dyeing and for cross-dye effects, particularly if the PE is dyed to a pastel shade, the one-bath method is quite satisfactory. In this case, selected disperse dyes are used for the PE, while selected acid dyes are used for the nylon. The one-bath method can also be used in high-temperature equipment, since there is less tendency for the nylon to be stained by the disperse dyes at 235 F to 250 F.

A typical one-bath method is as follows (The percentages recommended are based on the weight of the goods):

Wet out the fabric at 110 F with 0.5% Duponol RA surface-active agent.

Add 5 grams per liter Latyl Carrier A.

Add the disperse and acid dyes.

Raise the temperature to the boil and hold for at least 90 min.

Scour at 140 F with 1% Duponol RA surface-active agent.

A typical two-bath method is as follows:

Dye the PE in the first bath with a suitable carrier.

Scour for 30 min at 180 F with
- 1 gram per liter caustic soda
- 1 gram per liter sodium hydrosulfite
- 1 gram per liter Product BCO textile-processing agent

Dye the nylon to shade in the second bath.

Nylon with Acetate

94. Most disperse dyes color nylon to a shade and strength different from that obtained on acetate. For this reason, only a limited number of selected disperse dyes are used. Those which show the closest balance between nylon and acetate are Acetamine Yellow CG, Amacel Fast Pink G, and Celanthrene Fast Blue 2G.

Orlon in Blends

95. Type 42 Orlon has become increasingly popular as a blend component

with virtually all of the principal natural and synthetic fibers. In such blends the Orlon may be used for its properties or for the pleasing results it produces, or for both reasons. Improvements in fiber, dye, and application technology have made available to fabric designers an almost unlimited choice in styling effects. The most important blends will be considered here in a very general manner to give an idea of the possibilities available.

Blends of Orlon and wool can be union-dyed or cross-dyed, or either fiber may be dyed while the other is left white. Popular blends are 50/50 and 80/20 blends of Orlon and wool. Cationic dyes are applied to the Orlon and acid dyes to the wool. A full range of shades is possible. Dyeing is carried out at temperatures as close to the boil as possible to minimize staining of the wool by the cationic dyes. Most older basic dyes stain excessively. Single-bath procedures are operable in which, depending on shade and acid dye selection, the wool may be dyed first and then the Orlon, or both may be dyed at the same time. Since many fabrics of such blends are designed to be washable, only wool dyes of superior fastness should be used. These include the neutral-dyeing acid dyes, milling dyes, chrome dyes, and premetalized neutral-dyeing dyes.

96. Blends of Orlon and silk can be union-dyed, or cross-dyed in tone-on-tone effects, or the silk can be dyed and the Orlon left white. Selected cationic dyes are applied to the Orlon and acid or direct dyes to the silk.

A full range of styling choices is available in dyeing blends of Orlon and the cellulosic fibers. Orlon, in this case, is dyed with disperse dyes for light shades and with cationic dyes for medium and heavy shades, while the cellulosic fiber can be dyed with direct or vat dyes. Conventional resin aftertreatments are needed to give good wash fastness to the direct dyes without significant effect on the shade of the cationic dyes. For maximum washability, however, vat dyes must be used on the cellulosic fiber.

Blends of Orlon and nylon offer the full range of dyeing possibilities. Cationic dyes are used for the Orlon, while disperse, acid, or direct dyes are applied to the nylon. Application can be made in separate baths, or the one-bath two-step method can be used.

Orlon and Dacron in blends offer a choice of solid shades, tone-on-tone effects, or heathers, in which the Dacron is left white. Since a carrier must be used for dyeing the Dacron portion of the blend, some staining of the Orlon is encountered. Also, if Dowicide A is used as the carrier, a soda ash scour must be used to remove any residual carrier.

PE-Wool Blends

97. The very popular PE-wool blends are in great demand for lightweight men's suitings and women's skirt material. The PE most often used is Dacron 64. This is chosen because it is crimped and therefore has a minimum tendency to pill out of the blend. Furthermore, it is easier to dye than the Dacron fifties series,

it dyes deeper and brighter than Dacron 54, and it accepts cationic dyes, which are often employed for dark shades.

Most blends are in the ratio of 65/35 or 55/45 Dacron 64 and wool. The process consists in dyeing the PE with disperse dyes, using a carrier which will not harm the wool and which will leave the wool with the least stain. The orthophenylphenol carriers are not recommended for this purpose for two reasons: first, because they advance the staining of the wool, and second, because they are difficult to remove and adversely affect light fastness. Carriers based on biphenyl, methyl salicylate, or butyl benzoate, however, can be used. The wool is dyed with acid, premetalized-acid, or premetalized-neutral dyes, or with chrome colors. Both the one-bath and the two-bath methods are used in the trade. In the one-bath method, the PE is dyed first and the blend is given an intermediate scouring to remove as much of the carrier and stain on the wool as possible. Dyes which stain wool the least are listed in Table 6.

In the two-bath method the dyes are all applied at the same time as the carrier, and given as good a scour as the wool dyes will stand.

Arnel-PE Blends

98. With suitable disperse dyes and a small amount of biphenyl carrier, solid dyeings on Arnel-PE blends can be produced. If the PE portion takes up too little dye, the amount of carrier may be increased; if it takes up too much dye, the amount of carrier may be reduced. Only dyes fast to sublimation can be used, as the fabric must be heat-set after dyeing because of the Arnel.

Arnel-Acetate Blends

99. Disperse dyes can be used for both fibers in Arnel-acetate blends. These blends are hardly a commercial success, because the fastness properties of the dyes on the acetate portion are not high enough to satisfy the requirements of the Arnel-tagged cloth. The difference in the dyeing rate of disperse dyes on the Arnel and acetate gives a distribution favorable to the acetate and a tone-on-tone effect.

Arnel-Nylon Blends

100. Disperse dyes used for Arnel do not have good fastness on the nylon in Arnel-nylon blends, so that the problem of union dyeing is complicated by the requirements of good wet fastness. If, however, disperse dyes are used from the group having good wash fastness on Arnel, the nylon may first be stripped by scouring at a high temperature and then filled in with the fastest neutral premetalized dyes.

Arnel-Orlon Blends

101. To reserve the Arnel in Arnel-Orlon blends, cationic dyes may be applied to the Orlon. To dye the Arnel, disperse dyes are used. While the disperse dyes have some affinity for the Orlon, they will not build up on it beyond a light or

medium shade. Therefore, the distribution of the disperse dyes favors the Arnel to a high degree.

Dyeing for union is possible with a combination of disperse and cationic dyes. Although a two-bath system is more successful than a one-bath system, it requires a lengthy procedure, and so a one-bath process is employed, but is limited to light shades.

Acrilan-Wool Blends

102. When Acrilan is to be blended with wool, it is best dyed in the form of raw stock or tops. Acid dyes will give a fairly good union, as will the acid premetalized and neutral premetalized dyes. The top chrome dyeing procedure, as explained in Part 2 of *Textile Dyeing*, yields fast dyeings. Blends of different types of Acrilan have already been described.

Acrilan and Cellulosic Fibers

103. There are various ways in which a blend of Acrilan and cellulosic fibers can be dyed. The Acrilan may be dyed with disperse, basic, neutral premetalized, acid premetalized, chrome, and acid dyes. The cellulosic fibers may be dyed with direct, fiber-reactive, or vat dyes. The following is a process for disperse and direct dyes in a one-bath method:

Prepare the bath with dyestuffs and 2% of a suitable dispersing agent, such as Igepon.

Start dyeing at 120 F.

Raise the temperature to the boil within 30 min.

Add 2% Glauber's salt and continue at the boil for another 30 min.

Cool back to 170 F and run 20 min.

This completes the exhaust of the direct dyes. Rinse well.

The direct dyeings may be aftertreated to improve wash fastness.

An example of acid and direct dyes in a two-bath method is as follows:

Prepare the first bath with suitable acid wool dyes and 8% sulfuric acid based upon the weight of the Acrilan only.

Dye at the boil and rinse well after shade is reached.

Neutralize with a little soda ash.

Second bath: Dye with direct dyes, as usual for cotton, but do not raise temperature over 170 F.

Exhaust dye with 20% Glauber's salt. Rinse well after shade is reached.

104. The text descriptions of the dyeing methods for various blends give a general idea of the problems confronting the dyer. Fiber blends other than those described here may be encountered. However, if the principles laid down in this text are followed, any given combination of fibers can be successfully dyed.

Naturally, many more combinations are possible than the ones enumerated, Orlon and acetate or Acrilan and Orlon, for instance. However, any mixture must have a reason for being, and many of these combinations are impractical because one fiber does not augment the other either in strength or wearing qualities, or because the mixture does not find consumer acceptance. Many blends are attempted which never reach the market. Those which have been given in this text are practical and acceptable fabrics.

Little has been said of the use of silk in blends. Silk is a protein fiber which reacts very much like wool to dyestuffs. However, it is more easily dyed than wool and accepts practically every known type of dyestuff with good affinity. Therefore, if silk appears as a component of a two-, three-, or four-fiber blend, it can be dyed with any of the dyes used in dyeing the other fibers, with one exception: direct dyestuffs applied in a slightly alkaline bath will dye cellulosic portions of a mixture and leave the silk undyed.

Sources of Information

105. Many interesting dyeing patterns may be obtained through the use of blends. New dyestuffs and new fibers constantly add new possibilities. Complete and accurate descriptions of new combinations can often be found in the textile trade publications. As the investigations of all fibers continue, the fiber manufacturers and the dyestuff manufacturers will supply to the trade the latest information that has been obtained. Dyers who are dealing with blends are well advised to keep a file handy in which all available data can be put for ready reference.

If the dyeing establishment forms part of a mill, the contents of the blends are usually known. However, for commission dyers and converters, a fiber identification chart is very helpful. One such chart is compiled annually by the editors of the *Textile World*, and reprints can be obtained from the publishers at 330 West 42nd Street, New York, N. Y. 10036. The chart lists the most important chemical properties of the fibers. It also shows microscopic photographs for fiber identification.

Textile Dyeing

5508C PART 3 Edition 1

Examination Questions

Notice to Students.—Study this instruction text thoroughly before you answer the following questions. Read each question carefully and be sure you understand it. Show enough of your work to indicate how your answers were obtained. We will not accept answers alone. When you complete your work, examine it closely, correct all the errors you can find, and see that every question is answered; then mail your work to us. DO NOT HOLD IT until another examination is ready.

1. A fabric is composed of a blend of 50% nylon and 50% Type 42 Orlon. There are 400 lb of the fabric, which is to be dyed dark blue with 4% Pontacyl Fast Blue 5R, C. I. Acid Blue 113, and 4% Sevron Blue B, C. I. Basic Blue 21. List the types and amounts of dyes and dyeing assistants you will use. Outline the entire procedure. (25%)

2. You want to dye 200 lb of rayon with 2% Benzo Fast Blue R, a direct dye. List the types and amounts of dye and assistants you will use in both the scouring bath and the dyebath. Outline your procedure. (15%)

3. You are given an order that calls for the dyeing of 300 lb of nylon. The goods are to be dyed dark blue on a jig with 2% Pontacyl Fast Blue, 5R, C. I. Acid Blue 113. List the types and amounts of dye and dyeing assistants you will use. Outline your procedure. (15%)

4. A lot of 400 lb of Orlon yarn is to be dyed on a package machine with 1.5% Sevron Yellow 2R, C. I. Basic Yellow 30, and without a retarder. List the types and amounts of dye and dyeing assistants you would use in the dyebath. Outline your procedure. (15%)

5. A lot of 300 lb of rayon is to be dyed with 2.5% Victoria Pure Blue BO, C. I. Basic Blue 7. Tell what you must do to the rayon, and then list the types and amounts of dye and dyeing assistants you will use to take the lot through the dyeing process. Outline your procedure. (15%)

6. A dye order calls for 500 lb of Acrilan 41 to be dyed with 3.5% Sevron Yellow 3RL, C. I. Basic Yellow 15. How would you dye the Acrilan? List the types and amounts of dye and dyeing assistants you would use. Outline your procedure. (15%)