# COATED FABRICS

A coated fabric is an engineered product derived by a combination of textile and polymer coating technology. Each type of coated fabric is designed to fulfill the requirements of a specific application. The textile substrate is chosen based on a knowledge of the strength and dimensional control requirements of the finished product. The coating, a product of polymer compounding knowledge, is chosen for its specific properties such as abrasion resistance, oil resistance, resistance to leaching, etc.

## 1. Textile Component

Industrial-grade fabrics, as opposed to apparel-grade fabrics, typically constitute the substrate classification from which the coated fabrics producer selects a construction to fulfill specific end use requirements. Because of increasing imports of apparel-grade textiles, the profitability of industrial-grade textiles has drawn resources away from other segments of the textile industry. By the mid-1980s industrial coated fabrics accounted for over 10% of all fiber consumption (1). Most textile manufacturers have divisions that specialize in the development and production of various industrial fabrics (see Geotextiles). In partnership with the coating company, the textile company can aid in the selection of the proper fabric and provide hand samples, pilot yardage, and the ultimate production quantities. A comprehensive listing of industrial fabric suppliers has been compiled (2).

### 1.1. Fibers

For many years cotton (qv) and wool (qv) were the primary textile components, contributing the properties of strength, elongation control, and aesthetics to the finished product. Although the modern coated fabrics industry began by coating wool to make boots, cotton has been used more extensively. Up until the 1980s cotton constructions, including sheetings, drills, sateens, and knits, had commanded a significant share of the market. This is because cotton is easily dyed, absorbs moisture, withstands high temperature without damage, and is stronger wet than dry. As cotton again became an important fiber for the apparel industry during the 1980s, the supply and pricing situation changed significantly and polyester–cotton blends and 100% polyesters became the fabrics of choice. Polyester is now the most widely used industrial coating and laminating fiber (3). When moisture absorbance and glueability are the most important properties, polyester–cotton blends and in some cases 100% cotton textiles still see significant use, ie, wallcovering and case goods covering.

*Polyester* has numerous advantages since its fibers are smooth, crisp, and resilient. Since moisture does not penetrate polyester, it does not affect the size and shape of the fiber. Polyester is also resistant to chemical and biological attack. Because it is thermoplastic, the heat required for good adhesion to the polyester substrate can also create a shrinkage problem during the coating process. Because of this, 100% polyester textiles are often heat set to relatively high temperatures in a post operation after weaving (see Fibers, polyester).

*Nylon* is the strongest of the commonly used fibers. Since it is both elastic and resilient, articles made with nylon will return to their original shape. Nylon has a degree of thermoplasticity so that when articles are formed and heated to a temperature above its heat set temperature, it will retain that shape. Nylon fibers are also smooth, very nonabsorbent, do not soil easily, and resist most chemical and biological action. Nylon substrates are used in applications where very high strength is required. One newly developed use for nylon that is predicted to grow to $11 - 14 \times 10^6$ m by the year 2000 is the use of Neoprene (polychloroprene) coated nylon in the production of driver's side automotive air bags. Lightweight nylon knits and taffetas that are thinly coated with polyurethane or poly(vinyl chloride) are used extensively in apparel. PVC coatings do not adhere well to nylon, so in recent years there has been an effort to develop improved adhesives and bonding agents that improve the coating adhesion to nylon textile (see Polyamides, fibers).

*Rayon* and glass fibers are the least used because of their poor qualities. Rayon's strength approaches that of cotton but its smoother fibers make adhesion more difficult (see Fibers, regenerated cellulosics). Rayon also has a tendency to shrink more than cotton which makes processing more difficult. *Glass fibers* offer very low elongation, very high strength, and have a tendency to break under compression. Because of this, glass fibers are typically used where support with low stretch is required and the product will be subject to minimal flexing or where flame retardant properties are required. These include applications such as ducting and duct tape, protective clothing, and insulation. With increasing emphasis on the fire retardant properties of upholstery constructions, the textile industry has recently developed knit constructions based on glass fibers overspun with polyester. These have acceptable flex properties and the glass fibers serve to prevent the burning upholstery covering from penetrating into the urethane foam cushioning (see Glass).

### 1.2. Textile Construction

There are many choices in textile construction. The original and still the most commonly used is the woven fabric. Woven fabrics have four basic constructions: the plain weave, the drill weave, the satin weave, and the twill weave. The plain and the drill weave are the strongest constructions because they have the tightest interlacing of fibers. Twill weaving produces distinct surface appearances and is used for styling effects. Satin weave is used primarily for high style applications because it is the weakest of the wovens. Woven nylon and polyester have displaced heavy cotton in most tarpaulin applications. Also, as the technology for producing weft inserted fabrics improves, wefts are also finding increasing use in the production of tarpaulins. For shoe uppers and other applications where strength is important, woven cotton fabrics are used.

Knitted fabrics are used where moderate strength and considerable elongation are required. Whereas cotton yarns formerly dominated the knit market, they were first displaced by polyester–cotton knits and later by 100% polyester knits because the polyester knits have a higher strength to weight ratio; therefore, lighter weight backings can be used to achieve similar properties. When a polymeric coating is applied to a knit fabric, the stretch properties are somewhat reduced from those of the fabric. The stretch and set properties of the final construction are important for upholstering and forming. The main use of knit fabrics is in apparel, heavyweight transportation and furniture upholstery, shoe liners, boot shanks, and any product where elongation is required.

Many types of nonwoven fabrics (qv) are utilized as substrates for coated fabrics, including products made by the wet web method, saturated nonwovens, spunbonded nonwovens, and needled nonwovens. Today's nonwovens are engineered fabrics designed for specific end uses. The wet web process gives a nonwoven fabric with paperlike properties and poor drape. Most often wet web nonwovens are used in the production of coated fabrics such as wallcoverings. These webs are often treated with latex polymers to improve the strength and stripability properties of the finished wallcovering. Saturated nonwovens are prepared by laying dry webs, tightly compressing by needle punching, and then impregnating them with 50–100% by weight with a soft latex. The finished product often resembles a split leather; in fact, it is often split on a leather skiving machine to produce thinner substrates. Most often these impregnated nonwoven fabrics are used for shoe liners. It is difficult to achieve uniformity of stretch and strength in two directions as well as a smooth surface; therefore a high quality nonwoven of this type is very expensive. Spunbonded nonwovens are available in both polyester and nylon in a wide range of weights. They are often lower priced than other nonwovens. Their strength properties are very high and elongation is low. Since they are quite stiff, these materials are used where strength and price are the primary considerations.

The most common nonwovens used for coated fabric substrates are the lightly needled, low density nonwovens which are typically prepared with either polypropylene or polyester fibers. Specialty fibers such as Kevlar or Nomex are also used when high strength or fire retardant properties are desired (see High performance fibers). By varying the amount of needling combined with careful orientation of the fibers and selection of the fiber length, the nonwoven manufacturer can obtain very good strength and balanced stretch. Optionally, a very thin layer of polyester-based polyurethane foam can be needled into the nonwoven to improve the drape and surface coating process. Upholstery produced on polyester and polypropylene substrates has now replaced most expanded PVC on knit fabric constructions in automotive, furniture, and marine upholstery applications. This is because a product that has many of the properties of the expanded products, such as plushness, tailorability, and stretch can be produced at a much lower cost.

### 1.3. Post Finishes of the Textile Component

The construction that results from either weaving or knitting is called greige good. In many cases, other steps are required before the fabric can be coated. This often includes scouring to remove surface impurities and finishes added to the yarns to improve weaving, and heat setting to correct the width, stabilize the textile, and minimize shrinkage during coating. Optional treatments include: dyeing if a colored substrate is required; napping of cotton and polyester–cotton blends to add bulk, impart a softer hand, or increase adhesion; and mildew and/or antiwicking treatments for textiles that will be used to produce products for outdoor applications.

## 2. Polymeric Coating Component

### 2.1. Rubber and Synthetic Elastomers

For many years nondecorative coated fabrics consisted of natural rubber on cotton cloth. Natural rubber is possibly the best all-purpose rubber but some characteristics, such as poor resistance to oxygen and ozone attack, reversion and poor weathering, and low oil and heat resistance, limit its use to special application areas (see Elastomers, synthetic; Rubber, natural).

Polychloroprene (Neoprene), introduced in 1933, rapidly gained prominence as a general purpose synthetic elastomer having oil, weather, and flame resistance. The introduction of new elastomers in solid or latex form was accelerated by World War II. In addition to natural rubber and polychloroprene, other rubbery polymers in use include: styrene–butadiene (SBR), polyisoprene, polyisobutylene (Vistanex), isobutylene–isoprene copolymer (Butyl), polysulfides (Thiokol), polyacrylonitrile (Paracril), silicones, chlorosulfonated polyethylene (Hypalon), poly(vinyl butyral), acrylic polymers, ethylene–propylene–diene monomer (EPDM), fluorocarbons (Viton), polybutadiene, polyolefins, and many more. Copolymerization makes the number of variations available staggering (see Acrylic ester polymers; Acrylonitrile polymers; Copolymers; Fluorine compounds organic; Olefin polymers; Polymers containing sulfur; Silicon Compounds; Urethane polymers). The number of commercially available elastomers is large with many producers of those polymers offering several variations that provide a wide range of properties.

Most elastomers are vulcanizable; they are processed in a plastic state and later cross-linked in a heating process to provide elasticity in their final form. With the number of elastomeric coatings available, almost any use requirement can be met. Also, by compounding these various elastomers, it is possible to develop products that meet particular area requirements and specific environmental conditions. Additional information about compounding and processing of elastomeric coatings is available (4). The only limitations to possible

**Table 1. Natural Rubber Formulation**

| Component | Parts |
|---|---|
| smoked sheet | 100.00 |
| stearic acid | 1.00 |
| ZnO | 3.00 |
| Vanplast R | 3.00 |
| Agerite White | 0.50 |
| SRF Black (N774) | 4.00 |
| calcium carbonate | 75.00 |
| clay | 50.00 |
| sulfur | 0.75 |
| miscellaneous accelerators | 1.35 |
| *Total* | *238.60* |

**Table 2. SBR Compounding**

| Component | Parts |
|---|---|
| SBR | 100.00 |
| stearic acid | 2.50 |
| ZnO | 3.00 |
| Vanplast R | 7.00 |
| Agerite White | 0.50 |
| SRF Black (N774) | 4.00 |
| Cumar MH | 20.00 |
| calcium carbonate | 75.00 |
| clay | 75.00 |
| sulfur | 2.50 |
| miscellaneous accelerators | 2.35 |
| *Total* | *291.85* |

constructions that can be developed are in the areas of processability and cost. These elastomers are applied to the textile by either calender or solution coating. Thin coatings are typically applied from solution and thicker coatings by direct calendering to the textile. A typical natural rubber-based formulation is shown in Table 1.

SBR (styrene–butadiene rubber) has replaced natural rubber in many applications because of price and availability. It has good aging properties, abrasion resistance, and flexibility at low temperatures. A typical SBR-based formulation is shown in Table 2.

Neoprene offers resistance to oil, weathering, is inherently nonflammable, and is processable on either coaters or calenders. Other elastomers such as EPDM can often be formulated for equivalent performance and unlike Neoprene, they do not discolor and can be formulated into light-colored products. EPDM is most often used to produce roofing membranes because of its excellent outdoor aging. Some Neoprene is also used in the uncured state for forming flashings on single-ply rubber roofing systems. A typical Neoprene based formulation is shown in Table 3. This mixture can be calendered or dissolved in toluene to 25–60% solids for application as a thin coating.

Isobutylene–isoprene elastomer (Butyl) has high resistance to oxidation, resists chemical attack, and is the elastomer most impervious to air. Because of these properties it is often used for protective garments, inflated air structures, cold air balloons, and fumigation covers.

**Table 3. Neoprene Compounding**

| Component | Parts |
|---|---|
| Neoprene W | 100.00 |
| magnesium oxide | 4.00 |
| Agerite Stalite S | 2.00 |
| Vanwax H | 3.00 |
| Thermax (N990) | 60.00 |
| Vanplast PL | 5.00 |
| sulfur | 0.50 |
| miscellaneous accelerators | 2.00 |
| *Total* | *176.50* |

Chlorsulfonated polyethylene (Hypalon) resists ozone, oxygen, and oxidizing agents, and is the coating of choice for roofing applications where oil resistance is needed, ie, fast food restaurants, etc. In addition, it has nonchalking weathering properties and does not discolor, permitting pigmentation for decorative effects.

### 2.2. Polyurethane

Urethanes have a number of important applications in coated fabrics. The most important is the production of fabrics for apparel, tenting, life vests, evacuation slides, flexible fuel storage tanks, and other industrial-grade coated fabrics. This is because polyurethanes are lighter weight than vinyl polymers and have better abrasion resistance and strength. Polyurethane fabrics can also be easily decorated to look like leather. Many urethane-coated fabrics are used in women's footwear and apparel where styling is important and light weight is desirable. These products usually consist of 0.05 mm of polyurethane on a napped woven cotton fabric. The result is a lightweight product that has good abrasion and scuff resistance. Urethane coated fabrics have not been successful in high quality shoes for either men or children because they do not have the long-term durability of a natural leather shoe.

Low weight coatings of polyurethane on 22, 44, and 89 tex (200, 400, and 800 den) woven nylon fabrics produce products that are suitable for apparel, luggage, and athletic bags. The lightest weight products are used for windbreakers and industrial clothing whereas the heavier weight fabrics are used for luggage and athletic bags. The coatings that are typically on the back side of the textile provide water repellency to the product and help prevent fraying when the fabrics are die cut when manufacturing the finished products. Polyurethanes have found only limited application in the upholstery market because they are often subject to hydrolysis with long-term exposure to body oils. Also because of their light weight, they do not offer the plushness and stretch that is normally required for upholstery applications.

### 2.3. Poly(vinyl chloride)

By far the most important polymer used in coated fabrics is poly(vinyl chloride). This relatively inexpensive polymer resists aging processes readily, resists burning, and is durable. It can be compounded readily to improve processing, aging, burning properties, softness, etc. In addition, it can be decorated to fit nearly any required use including leather prints, textile looks, or detailed patterns. PVC-coated fabrics are used for furniture, marine and automotive upholstery, window shades, automotive trim, wallcoverings, book covers, convertible topping, shoe uppers and liners, and many other uses. Two of the largest uses of PVC-coated fabrics are in vinyl wallcoverings and upholstery. Fabric backed wallcoverings range from very lightweight products with 0.08 mm of PVC on lightweight nonwoven backings for residential use to heavyweight expanded wallcovering for commercial applications with up to 0.50 mm of PVC that is later expanded to approximately 1.00 mm. Vinyl

**Table 4. Formulation of Calendering PVC**

| Component | Parts |
|---|---|
| poly(vinyl chloride) resin (calender-grade) | 98.50 |
| acrylic processing aid | 1.50 |
| epoxy plasticizer | 5.00 |
| phthalate plasticizer | 65.00 |
| BaZn stabilizer | 3.00 |
| $TiO_2$ (and other pigments) | 15.00 |
| calcium carbonate (filler) | 25.00 |
| stearic acid (lubricant) | 0.25 |
| *Total* | *213.25* |

**Table 5. Plastisol PVC Formulation**

| Component | Parts |
|---|---|
| poly(vinyl chloride) resin (dispersion-grade) | 100.00 |
| epoxy plasticizer | 4.00 |
| phthalate plasticizer | 70.00 |
| BaZn stabilizer | 2.50 |
| $TiO_2$ (and other pigments) | 10.00 |
| calcium carbonate (filler) | 25.00 |
| dispersant (wetting agent) | 1.00 |
| *Total* | *212.50* |

upholstery is most popular in commercial applications where durability and cleanability are important. Even the recent trend of increasing use of natural leather in upscale residential upholstery and automotive end uses has created a market for matching PVC-coated fabrics that are used for trim and backs and other nonseating surfaces. Every year millions of meters of PVC-coated fabrics are produced for these uses. Tables 4 and 5 show typical PVC formulations (see Vinyl chloride; Vinyl polymers, Vinyl chloride Polymers).

## 3. Processing

Coated fabrics can be prepared by lamination, direct calendering, direct coating, or transfer coating (see Coating processes). The basic problem is to bring the polymer and the textile together without altering undesirably the properties of the textile. Almost all of the coating processes require that the polymer be in a fluid or semifluid condition during lamination and often heat is required to obtain adhesion between the polymer and the textile. Because of this, it is important that the heat during lamination not damage sensitive synthetic or thermoplastic fabrics.

### 3.1. Calendering

The base polymer must first be mixed with other compounding ingredients such as stabilizers, extenders, fillers, plasticizers, colorants, lubricants, etc, before it can be transferred to the calender (see Plastics processing). With PVC compounds, the first step is to prepare a dry blend and then transfer it to a Banbury mixer for fluxing. With other elastomeric polymers, the ingredients are typically added directly to the Banbury. During fluxing the temperature of the polymer compound is raised to 150–170°C through the internal heat of mixing. This fluxed mixture is then transferred to a series of mills where it is further mixed before transfer to a calender.

On the calender it passes through a series of heated rolls where the smoothness and gauge is adjusted to the desired conditions before being married directly to the preheated textile fabric on the bottom roll. The object is to get the required amount of adhesion without driving the compound into the fabric excessively, which would cause a clothy appearance and lower the stretch and tear properties of the finished coated fabric.

### 3.2. Coating

Coating operations require a more fluid compound. Rubbers and other elastomers are often dissolved in solvents before being coated on textiles. In the case of PVC, fluidity is achieved by dispersing the resin system in plasticizers and making a plastisol. If lower viscosity is required, an organosol can be made by adding solvent to the plastisol. This plastisol or organosol can be applied to the textile by various methods. In the past the most common coating method was to use a knife over roll or reverse roll coater. The knife over roll or knife over plate is most common in the production of polyurethane-coated fabrics. It usually has significant speed limitations and is best suited for applying thin coatings. The reverse roll coater is probably the most versatile coating technique. It is not without limitations, but it can typically handle the widest variety of coating viscosities, speeds, and application rates (5). Today, a rotary screen coater is often used to apply coatings to the textile. Unless the fabric is very dense, knife over roll or reverse roll coaters often give too much penetration of the coating. An advantage of a rotary screen coater is that it can be used to apply a metered thickness of coating to a textile with minimum penetration. There is even technology available that allows the fabric to pass between two rotary screen heads so that different compounds or colors can be applied to both sides of a textile at the same time (see Coating processes).

Another common coating method is a transfer coating method. A release paper, most often with an inverse leatherlike grain, is coated by either a knife over roll coater or a reverse roll coater. Many polyurethane coated fabrics and most expanded PVC-coated fabrics are transfer coated. The expanded products consist of a wear layer, an expanded layer, and the textile substrate. The wear layer is coated on release paper and gelled. Then a layer of vinyl-based compound containing a chemical blowing agent such as azodicarbonamide is applied. The fabric is placed on top of the second layer and sufficient heat is applied to decompose the blowing agent causing the expansion.

### 3.3. Lamination

In lamination a film is prepared by calendering or extrusion (see Laminated materials, plastic). It is then adhered to a textile at a laminator by either an adhesive or sufficient heat which partially melts the film to obtain a mechanical bond. There are a variety of adhesives available for lamination, including solvent systems, water-base latex systems, and various forms of hot melt adhesives (qv).

### 3.4. Post Treatment

Coated fabrics can be decorated and protected by applying inks and coatings to the surface. Often the finished product is an attempt to simulate the look of leather. This is most common in upholstery, luggage, and athletic bag constructions where natural leather is the main competitor, although any number of decorative effects can be created and are used in producing products such as wallcovering.

The typical method for applying these print inks is a rotogravure method. In the past these inks were usually made up of vinyl copolymer resins and pigments dissolved in ketones and other solvents. These print inks are usually applied to a flat surface and often multiple print patterns are applied to obtain a highly decorative effect. There has been a gradual movement to the use of water-base inks since the 1980s and the passage of the Clean Air Act of 1990 has targeted a reduction of air toxics emissions by 75% through the year 2000 (6). This target is to be met by applying MACT (maximum achievable control technology) standards.

**Table 6. Vinyl-Based Topfinish for PVC Coated Fabrics**

| Component | Parts |
|---|---|
| vinyl chloride–vinyl acetate copolymer | 85.50 |
| polymethacrylate resin | 14.50 |
| BaZn vinyl stabilizer | 1.75 |
| silica gel | 14.00 |
| methyl ethyl ketone | 950.00 |
| toluene | 50.00 |
| *Total* | *1115.75* |

Although this reduction can be achieved by emissions control devices, most manufacturers still using solvent-based inks and coatings will choose to accelerate their conversion from solvent to water-base inks rather than purchase and operate control devices.

Most decorative coated fabrics, especially those used in upholstery, apparel, or luggage applications, also have a clear final finish. Again this can be either a solvent or water-based system and typically is based on a hard vinyl or vinyl acrylic polymer or a urethane. This finish usually serves several purposes. Because most coated fabrics, particularly vinyl-coated fabrics, are slightly tacky, the coating serves to dry the surface and provide slip. Also the finished luster of the coating can be adjusted with ultrafine silica to anything from very dull to full bright. Finally, the coating often imparts improved stain resistance to the product. This is particularly true of some of the special stain resistant coatings being offered by several manufacturers of PVC upholstery and wallcovering.

If a textured surface is desired, the coated fabric is heated to soften it and pressure is applied by an engraved embossing roll. Most often embossing is the final step and comes after the printing and finishing operations are complete; however, sometimes the coated fabric is embossed first and then printed or given a wash coat of ink (spanishing) to achieve a unique decorative effect.

A typical solvent-based finish coating for PVC is shown in Table 6.

## 4. Economic Aspects

In the total market for coated fabrics, the first consideration is the required performance of the finished product, followed by cost considerations. Because of their higher cost, the rubber and specialty elastomers are only used for producing coated fabrics that require oil or chemical resistance, low air permeability, or other unique properties. Likewise, urethane-coated fabrics are often used for the production of style and design oriented coated fabrics for the apparel, shoe, and handbag market because it is easy to produce small run sizes using transfer coating methods. In addition, the finished products have light weight and good abrasion and scuff resistance and are significantly less expensive than the natural leather hides that they replace.

Because of performance and cost considerations, PVC-coated fabrics are the workhorse coated fabrics. They are easily processed by either calender coating or transfer coating, are easily decorated by a combination of printing and embossing, and depending on the choice of compound formulation and textile backing can be designed for many different uses. The largest uses of PVC coated fabrics are in upholstery applications for marine, contract, and automotive applications, and for the production of fabric backed vinyl wallcovering. These products offer the combination of high style decorative effects with the benefits of performance and long-term durability.

## 5. Testing

Depending on the application for a coated fabric there are many different specifications that the products must meet. These specifications refer to specific tensile and tear values for the construction, abrasion specifications, chemical resistance, air permeability, fire resistance, and toxicity, and many other properties. Most often the specifications are set by the individual customers of these products, however, there are also various industry and trade groups and the federal government that set specifications for families of products. Several of these are published by the Chemical Fabrics & Film Association, Inc. (CFFA), and the federal government, such as the Federal Specification—Wallcovering, Vinyl Coated CCC-W-408C. Most of the test methods used for measuring these properties are standard ASTM methods or methods suggested by the customer or industry trade groups.

## 6. Health and Safety Factors

Some materials used in coating operations have been identified by the federal government as being hazardous to workers' health. Because of this, manufacturers of coated fabrics are subject to OSHA standards relating to acceptable exposure to these chemicals. In most cases, depending on the individual chemical, this required engineering changes to the process, protective equipment, personnel monitoring, and extensive record keeping. One change that many manufacturers have made or are presently working on is the development of formulations for coatings, inks, and finishes that do not contain heavy metals. This is particularly true in the vinyl industry where there is a movement away from stabilizer systems containing cadmium, mildewcides that contain arsenic, and pigment systems containing lead chromates and lead molybdates.

Most exposure problems are related to solvents and dusts, so particular attention should be given to raw material mixing areas and solvent exposure during coating and post-printing and finishing operations. In particular, emptying bags and bulk transfer of raw materials should be monitored. Even when calender coating textiles, consideration should be given to exposure to the gases that are given off during heating. Under federal "Right to Know" laws, training is required for all employees exposed to these chemicals and the MSDS for these chemicals must be readily available in the workplace. No coating operation should be initiated without making a full review of applicable federal and state OSHA standards for the raw materials that will be used in the processes.

The actual coated fabrics themselves are not subject to these federal regulations. They are classified as "Articles of Commerce." However, in recent years most manufacturers have, for the convenience of their customers, generated an MSDS for their products. Their customers, the manufacturers, and contractors using these coated fabrics have requested this information because they are also covered under federal and state "Right to Know" laws and want to ensure the safety of their employees.

## BIBLIOGRAPHY

"Coated Fabrics" in *ECT* 1st ed., Vol. 4, pp. 134–144, H. B. Gausebeck, Armour Research Foundation of Illinois Institute of Technology; in *ECT* 2nd ed., Vol. 5, pp. 679–690, by D. G. Higgins, Waldron-Hartig Division of Midland-Ross Corp., in *ECT* 3rd ed., Vol. 6, pp. 377–386, by F. N. Teumac, Uniroyal, Inc.

### Cited Publications

1. R. P. Antoshak, *J. Coated Fabrics* **15**, 239 (Apr. 1986).
2. *Industrial Fabric Products Review, 1990 Buyer's Guide*, Industrial Fabrics Association International, St. Paul, Minn., 1990.

3. W. C. Smith, *J. Coated Fabrics* **15**, 180 (Jan. 1986).
4. *The Vanderbuilt Rubber Handbook*, R. T. Vanderbuilt Co., Inc., Norwalk, Conn., 1990.
5. J. A. Pasquale, III, *J. Coated Fabrics* **15**, 271 (Apr. 1986).
6. *Clean Air Act Law and Explanation*, Commerce Clearing House, Chicago, Ill, 1991.

#### General References

7. R. M. Murray and D. C. Thompson, *The Neoprenes*, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del., 1963.
8. H. L. Weiss, *Coating and Laminating Machines*, Converting Technology Co., Milwaukee, Wis., 1977.
9. *1990 Rubber Red Book*, Communication Channels, Inc., Atlanta, Ga., 1990.
10. *Modern Plastics Encyclopedia 1990*, McGraw-Hill Inc., New York, 1990.
11. *1990 Plastics Directory*, The Cahners Publishing Co., Newton, Mass., 1990.
12. *ASTM Annual Book of Standards*, American Society of Testing and Materials, Philadelphia, Pa., 1990.
13. *CFFA Standard Test Methods*, Chemical Films & Fabrics Association, Inc. (CFFA), Cleveland, Ohio, 1984.
14. *CFFA-W-101-A*, CFFA, Cleveland, Ohio, 1984.
15. *CFFA-M-101A*, CFFA, Cleveland, Ohio, 1991.
16. *CFFA-U-101A*, Cleveland, Ohio, 1984.

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