# TECHNICAL BULLETIN


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**ISP 1012**

# FUNCTIONAL FINISHES FOR COTTON PRODUCTS

This report is sponsored by the Importer Support Program and written to address the technical needs of product sourcers.

## INTRODUCTION

One of the great attributes of cotton is its ability to impart a wide variety of functional properties to the substrate. For example, the fiber can be highly absorbent when used in towels or water repellant when used in raincoats. An untreated fiber in an open flame can be combustible; whereas, properly treated cotton can be used in fire fighter's uniforms. For some untreated cotton fabrics, wrinkling can be an inconvenience, but with a durable press finish, the same fabrics can be wrinkle free when laundered and during wear. Soiling of clothes can be reduced by using the appropriate finish application. Other finishes permit easy removal of any residual stains because of low temperature washing trends. Many other unexpected properties may also be imparted to cotton such as antimicrobial, protection from ultraviolet light, and controlled release of fragrance.

What is it about cotton that permits the finisher to impart such a wide variety of properties? Cotton and other natural cellulosic fibers are chemically reactive as are natural protein fibers such as wool. Most synthetic fibers are not very reactive, and some are considered inert. The reactive groups on the cotton molecule permit permanent attachment of these functional compounds. The surface of the fiber is polar and hydrophilic, which makes the fabric comfortable during wear and useful for absorbent applications such as towels. Furthermore, the fiber has a large surface area and is porous somewhat like a sponge. Other properties of this wonder fiber, which make these modifications possible, are the optimum degree of crystallinity and a useful range of fiber micronaire (denier) and fiber length.

In this report, an overview of some of the functional finishes for cotton is presented. For a more in-depth explanation, contact Cotton Incorporated.

## PROCESSING AIDS AND ENHANCEMENT OF PROPERTIES

During the manufacturing of cotton products, reagents are used to permit ease of processing and to improve the natural properties of cotton. At the fiber stage, natural waxes are present, which allow for the vast majority of fiber processing techniques; however, emulsifiable lubricants can be applied to permit the fibers to be processed efficiently. If the fibers are dyed and/or finished in the loose stock form, lubricants and anti-static agents must be added to process into yarn form.

Where the yarn has been bleached, dyed, or wet processed, lubricants may be used to permit ease of package transfer and knitting. If weaving is the next processing step, the warp yarns must be properly sized. The sizing composition is usually starch, but may also be polyvinyl alcohol, carboxymethylcellulose, polyacrylate, lubricants, and/or a combination of these ingredients. The purpose of the warp size is to protect the yarns during the weaving operation by imparting abrasion resistance, strength, reduced hairiness, and stabilization. The size is designed to be removed once the fabric reaches the finishing plant.

In the finishing plant, the woven fabric is desized, scoured, bleached (in most cases), and dyed, except when the cotton has been dyed in the fiber or yarn form. If the woven fabric is to be dyed, it is usually mercerized first to cover immature cotton and to improve luster. Once dyed, various functional finishes may be applied to satisfy different end-uses.

Typically, woven and knit fabrics may be sold to a specified weight per square area or to a certain number of yards per pound. When the weight of the fabric is lighter than specified, it is a common practice to add chemicals to increase the weight. These products may be required to be durable or non-durable. A non-durable finish may be urea, ethylene glycol, or glycerine. Where a durable weight is expected, a substance like methylglucoside may be fixed with a crosslinking resin.

## DURABLE PRESS

One of the most useful functional properties to be imparted to cotton products is wrinkle resistance and dimensional stability. A high level of wrinkle-resistant performance may be referred to as "durable press," "wrinkle free," or "permanent press." When reference is made to a lower degree of performance, the terms "wrinkle resistance," "easy care," and "wash and wear" are often used. However, these terms are frequently used interchangeably for marketing purposes.

The chemistry used to achieve durable press has evolved over the last 75 years. Some of the disadvantages of the earlier compounds used were large excess free formaldehyde, poor durability, discoloration, poor hand, excess strength loss, and lack of ability to be post-cured for permanent creases. Today, the capped dimethyloldihydroxyethylene urea (DMDHEU) has successfully reduced and/or eliminated these disadvantages. This compound functions by crosslinking the reactive hydroxyl groups on the cotton. In most instances, this reagent is applied by padding, spraying, or foaming. After drying, the finish is cured at elevated temperatures. If the garments made from such fabric are to have permanent creases, the curing is delayed until after the garments are pressed.

A finish containing DMDHEU has a number of other necessary components. There is the wetting agent that permits the rapid penetration of the chemistry into the fabric. An appropriate catalyst is required to bring about crosslinking of the compound with the cotton. Other ingredients are included to impart the necessary handle (level of softness), sewability, and abrasion resistance. At this time, reagents may also be added to impart a variety of other functional properties to the fabric.

A special method of applying DMDHEU is the moist-curing system, which is practiced exclusively outside the U.S. This technique minimizes the loss of strength and improves abrasion resistance while maintaining good durable press. It is used primarily for lightweight fabrics such as shirting. In this case, the DMDHEU and low pH catalyst is padded, dried to about 10% moisture, and batched for several hours. The low pH (i.e., high acidity) combined with moisture allows the DMDHEU to gradually cure while it is batched. Finally, the fabric is after washed and top softened. Note that care must be taken to control all parameters (moisture, acidity, time) carefully, or this process could lead to poor quality due to over- or under-curing.

Another procedure, which permits a better balance of physical properties when durable press processed, is the pretreatment of the fabric with anhydrous liquid ammonia. Even without the durable press finish, the anhydrous liquid ammonia softens the hand, improves the surface appearance, and imparts significant dimensional stabilization.

In addition to DMDHEU, a couple of other resin types are used but to a lesser extent. Dimethylureaglyoxal (DMUG) has been found useful because of its very low free formaldehyde; however, it is expensive and not as efficient as the DMDHEU. Selected polycarboxylic acids are available and are totally formaldehyde free. However, these products are also expensive and are not quite as efficient as DMDHEU.

Instead of applying the crosslinking finish to the cotton fabric before cut-and-sew, the garments may be treated. This procedure is an advantage particularly if the garments are to be dyed or stoned washed before the crosslinking finish is applied. A convenient way to administer the finish is by metered addition. In this case, only enough finish to be absorbed by the garments is applied by spraying or foaming. After the finish is applied, a tumbling sequence is used to achieve uniformity. The garments are then dried, pressed, and cured. For more on finishing cotton with crosslinking agents, see Cotton Incorporated's technical bulletins TRI 3013-Wrinkle-Resistant Finishing of Cotton Fabrics and Garments and TRI 3014-Wrinkle-Resistant Finishing of Garments with Controlled Metering of Chemicals.

Attention must be given to the durable press finish to achieve an acceptable balance of properties on the cotton fabric. If the level of durable press finish is too low, the surface smoothness and dimensional stabilization will not be adequate. On the other hand, if the level of durable press finish is too high or if the curing conditions are too severe, strength and abrasion resistance may not meet performance standards. In addition to these parameters, care must be taken to use the appropriate type and level of auxiliary finishing agents for improved strength and abrasion resistance. The colorfastness of the product may also be affected by improper selection or application of chemistry.

## WATER REPELLENCY

Water repellants for raincoats have been available for many years. At first, the finishes exhibited poor breathability and inadequate durability to washing and dry cleaning. In recent years, there has been dramatic improvement in the chemistry of reactive aliphatic water repellants, silicones, and fluorochemicals. Moreover, the construction of the cotton fabric is a key to good performance when applying these repellant finishes. For all-weather coats, silicones are commonly used in Europe; whereas, for the United States, a combination of reactive aliphatic water repellants (also known as extenders) and fluorochemicals are commonly used. The silicones tend to give a better hand, and the fluorochemicals exhibit better repellency. Although these repellant finishes add significantly to cost, the consumer is often willing to pay the difference for the improvement.

## STAIN RESISTANCE

Stain repellants are used on a variety of cotton fabrics from apparel to home furnishings. The main advantage is that the fabrics resist soiling during use. When a spill occurs, it can usually be spot cleaned easily, since the stain is confined to the surface rather than penetrating deep into the fabric. Such finishes normally employ the use of a fluorochemical, either alone or in conjunction with an extender. These products may be marketed as "repellent"; however, when they are used on loosely constructed fabrics (knits for example), they actually are "resistant" (the wearer would

become wet in a rainstorm). As with the water repellent finishes, the stain resistant products are also expensive, but the consumer is willing to pay for them.

## SOIL RELEASE

Removal of soil during low temperature washing is a property desired by most consumers. The stain resistant finishes mentioned above are effective in resisting soil; however, if soil does penetrate the finish, it is quite difficult to remove. To counteract this, there is available a fluorochemical finish that not only repels stains, but also promotes release of that stain during washing. The repellency of this soil releasing fluorochemical is not as good as the highly water and oil repellant type. Soil release finishes are normally applied with the durable press finish; however, care must be taken in the selection of softeners and other auxiliaries so as not to interfere with the soil repellant/soil release properties.

Another approach to soil release is the use of selected acrylic polymers. Unlike the soil release fluorochemical finish, the acrylic soil release agents give no soil repellency. However, good soil release properties are obtained. To achieve outstanding soil release and some repellency, a blend of the fluorochemical and the acrylic soil release chemistries are often blended together. When acrylic soil release finishes are used, it is frequently necessary to afterwash the fabrics due to the harsh hand that is imparted. After one wash, the hand is soft. The cost of the acrylic soil release chemical is significantly lower than the fluorochemical product.

## COMBINED STAIN RESISTANCE AND SOIL RELEASE ("DUAL ACTION")

Recently, products have been introduced that combine stain resistant and soil release properties in the same finish. The finish may incorporate a single product designed to give dual action properties, or a stain resistant product and soil release product may be combined in the same finish. These finishes provide more stain resistance than the traditional soil release finishes, yet if the stain does penetrate the finish, it is more easily removed. Fluorochemical products are normally used in these finishes, but the acrylic soil release products may also be incorporated. Dual action finishes may be somewhat expensive depending on the degree of durability desired. For more information, see Cotton Incorporated's technical bulletin ISP 1007-Water and Stain Repellant Finishing of Cotton Fabrics.

## FIRE RETARDANCY

Fire retartancy is a concern for many cotton fabrics in end-uses. Federal and state mandates require that plain surface cotton fabrics less than 2.6 ounces per square yard and all-cotton containing raised-surfaced fabrics must be tested and pass the hazardous fabric flammability test as outlined in Title 16 *Code of Federal Regulations*, part 1610. Fabrics going into home furnishings, commerce, and public use – such as floor coverings, draperies, and upholstery – have their own state and federal flammability regulations to observe. In a like manner, special end-uses, such as fire fighter's and foundry worker's apparel, must meet certain flammability tests that reflect their safety needs. Each of these has specific FR testing methods and may require different types or levels of chemistry. For more information, see Cotton Incorporated's

technical bulletins TRI 4003-Flame Resistant Cotton Fabrics/Answers to Most Frequently Asked User Questions and TRI 4004-Flammability Testing-A Review by Cotton Incorporated.

There are several approaches to permit cotton to pass these flammability requirements. As suggested above, one method is to have the proper construction. With other factors being equal, the more dense the cotton fabric the less the flammability. Where possible and acceptable, a tighter constructed fabric can be used. Increased surface hairiness makes the fabric more flammable. Minimizing this exposed fiber generated in manufacturing will help.

Another aid in making the cotton more flame resistance is blending with other selected fibers. For fleece, blending the cotton with polyester in the yarn portion to be napped has been demonstrated to be successful where the nap height is not excessive. Other fiber types that can be blended with cotton to reduce flammability include nylon, wool, acrylic, and aramid.

A more difficult approach to control flammability is chemical finishing with flame retardants. The agents that have shown to be effective contain one or more of the following elements: phosphorus, chlorine, bromine, boron, antimony, sulfur, and nitrogen. Flame retardants may be classified as durable and non-durable. Some of the non-durable types include diammonium phosphate, ammonium sulfamate, boric acid, and ammonium bromide.

Several durable types are presently being used or have shown some promise. One of the most effective treatments for apparel is impregnation with a tetrakishydroxymethylphosphonium hydroxide, partially drying, exposure to ammonia gas for the development of an insoluble polymer, and finally oxidation with hydrogen peroxide to convert all the phosphorus to the penta valent state. Another process that is used to a much lesser extent involves the binding of decabromodiphenyl oxide and antimony oxide onto the fabric with a polymer such as an acrylic or polyurethane. A more recent technology is the binding of a hydroxy containing phosphorus compound with a crosslinking resin to the cotton. Selected polycarboxylic acids have shown some promise in applications where the degree of flame retardancy is not too stringent. These durable flame retardants are quite expensive, and some applications require non-conventional equipment. Special methods are often required to soften the hand. In some instances, the strength and abrasion resistance of the treated fabrics may be adversely affected. For more information, see Cotton Incorporated's technical bulletin TRI 4002-Fabric Flame Retardant Treatment "Precondensate"/NH3 Process.

## ULTRAVIOLET LIGHT PROTECTION

With a decrease in the coverage of the earth's atmosphere with ozone, humans are increasingly exposed to the detrimental effects of ultraviolet radiation from the sun. This problem is particularly acute in Australia. Even in other parts of the world, this exposure can be a problem during excessive exposure to the sun. Some of the health problems due to excess exposure to bright sunlight are skin cancer, accelerated ageing, and cataracts. Fair skin people are more prone to these problems than others.

Scoured and bleached cotton fabrics offer little protection to ultraviolet radiation. However, there are options that can be exercised to improve this protection by cotton garments. The first

choice is to modify the construction to increase the cover factor. Second, the fabric can be treated with agents that will absorb the ultraviolet radiation and prevent most of it from reaching the skin of the wearer. Fortunately, direct and reactive dyes commonly used for cotton fabrics are efficient absorbers when applied at a level to give at least a medium depth of shade. For lighter colors and for white fabrics, selective optical brighteners may be used at sufficient concentration levels to give adequate protection.

## ANTIMICROBIAL FINISHES

These finishes have increased in importance in recent years for several reasons. They serve the consumer by offering some protection from the harmful effects (such as infectious diseases) of certain microbes. More commonly, the finish is designed to inhibit odors that may have been generated by the body, soils, contaminants, or personal care products. Some of these finishes are designed to reduce the deterioration of the fabric from biological activity.

There are two basic types of microbes. One is bacteria such as staphylococci, coryne, and escherichia coli. The other type is fungi, which includes mold and mildew as well as microbes that cause athlete's foot and ringworms on the body. The antimicrobial agent works either by the slow release of the active ingredient or by surface contact with the microbes. The antimicrobial agent inhibits the activity of microbes by interfering with the necessary mechanism of the microbe's cell.

The selection of the appropriate antimicrobial system used will depend on a number of considerations. The first determination is the type of antimicrobial activity desired. Second is the way the system is applied (by padding, exhausting, or incorporating a synthetic fiber containing the antimicrobial agent). Other important considerations include skin sensitivity of the agent to the consumer, environmental impact of any effluent and the discarded textile, effect on other desirable properties of the fabric, durability, and cost. Since most manufacturers are not set up to do antimicrobial testing, independent and expensive laboratory services may be required.

Several durable antimicrobial agents show some promise for selected end-uses. Below is a brief description of some of these products.

- Polyhexamethylene biquanide hydrochloride (PHMB) has a broad spectrum of activity against bacteria and fungi with a long history of safe use. Application may be by pad, spray, foam, or exhaust methods. Upon drying, it becomes quite durable; however, researchers have reported good and bad results.

- Metallic silver combined with zeolite and dispersed in the polymer before extrusion spinning provides a polyester fiber that can be intimately blended with cotton to produce a durable antimicrobial composite. The blend is reported to have excellent anti-bacterial and anti-fungal properties. It has been reported in patents where these antimicrobial agents have been fixed on cotton fabrics with a binder such as an acrylic or polyurethane.

- Quaternary silicones like 3-trimethoxy-silylpropyldimethyloctadecyl ammonium chloride have been used for a number of years as a durable odor preventive on socks. However, it is reported to be less than 90% effective on bacteria and to have limited activity against fungi.

- A renewable antimicrobial agent is based on the reaction of monomethylol-5,5-dimethylhydantoin (MDMH) with cotton and subsequent reaction with hypochlorite bleach. The activity is derived from the slow release of chlorine that can be renewed when subjected to hypochlorite bleach again. This application requires that the fabric be white or dyed with pigments or vat dyes due to the reduction of most dyes by chlorine.

- Trichloro-orthophenylphenol (Triclosan) can be added to the spinning solution of acrylic or acetate fibers for blending with cotton. Triclosan may also be exhausted or thermofixed to cotton blends containing polyester to impart antimicrobial properties. Some reports indicate good results and others show inferior performance.

- Chitosan made insoluble by crosslinking is effective in neutralizing some odors. Although it is environmentally friendly, the level of the finish required to be effective imparts excessive stiffness to the fabric.

- Magnesium hydroperoxy acetate, another environmentally friendly compound, can be fixed to cotton to impart some antimicrobial properties. Few industrial evaluations have been reported.

## SLOW RELEASE OF FRAGRANCE AND ODOR ABSORPTION

Recent years have seen the development of some unique chemistries, which are finding a place in the market. Beta-cyclodextrin is a compound that has a cage-like structure, where other compounds may be entrapped for a period of time. This special chemical or a more soluble derivative can be fixed permanently to cotton by conventional crosslinking resins.

One use of this technology is the slow release of a desired fragrance. The perfume when applied to the fabric finished with the beta-cyclodextrin is entrapped in the caged structure, where it is slowly released over a much longer period of time than without the beta-cyclodextrin. In a similar fashion, the finish can be used to absorb foul odors while the garment is being worn. These foul odors may derive from cigarette smoke, cooking, and body scents. During the washing of the garment, these offensive odors are removed from the caged structure of the cyclodextrin.

## MOISTURE MANAGEMENT IN APPAREL FABRICS

For some markets, there is a need to improve the comfort of selected apparel fabrics. One way to achieve this objective is to promote better moisture transmission. Both fabric construction and finishing can play a significant role in improving this property.

The fabric structure should be as porous as permitted by other desired fabric properties. This porosity permits easier escape of the moisture and heat from the body. Some of the construction

features of the fabric to consider are more floats, fewer ends and picks, fewer stitches per inch for knits, and lighter weights.

The finish also plays an important role in the comfort of the fabric. The wicking rate of the fabric should be adequate to rapidly transport liquid moisture away from the body. When the perspiration spreads by the wicking fabric over a large area, the rate of evaporation to the atmosphere is greatly increased with a corresponding cooling effect. Unfortunately, most softeners used in the finish impart poor wicking properties to the fabric. Thus, an effort must be made to select hydrophilic softeners, although these products usually do not give the softest hand. Other hydrophilic additives may be used with these softeners. Reducing the amount of softener used may help. In some cases, crosslinking resins improve the wicking rate by decreasing the water holding capacity of the cotton.

## THE FUTURE

Other functional chemistries are being applied and perfected such as insect resistance, thermal protection, thermal management, medicine, and others. Durability will remain an important consideration as will cost. Due to the very high level of reactivity of cotton fibers and the wide range of knitted and woven products that can be constructed, cotton will remain a significant part of these finishes.

# Importer Support Program

The Cotton Board and Cotton Incorporated are funded by U.S. upland cotton growers and importers of cotton and cotton products (this includes raw cotton, piece goods, and finished apparel). A percentage of the importer funds are devoted for importer specific programs organized under the Importer Support Program. Examples of projects funded from this fund include training schools, educational programs, focus groups, economic meetings, and research initiatives.

Selected technical issues have been identified by importer members as relevant to their business. This report is a condensed, less technical report of those issues intended to provide the reader with basic, yet useful information on the topic.

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